

**INGERSOLL**

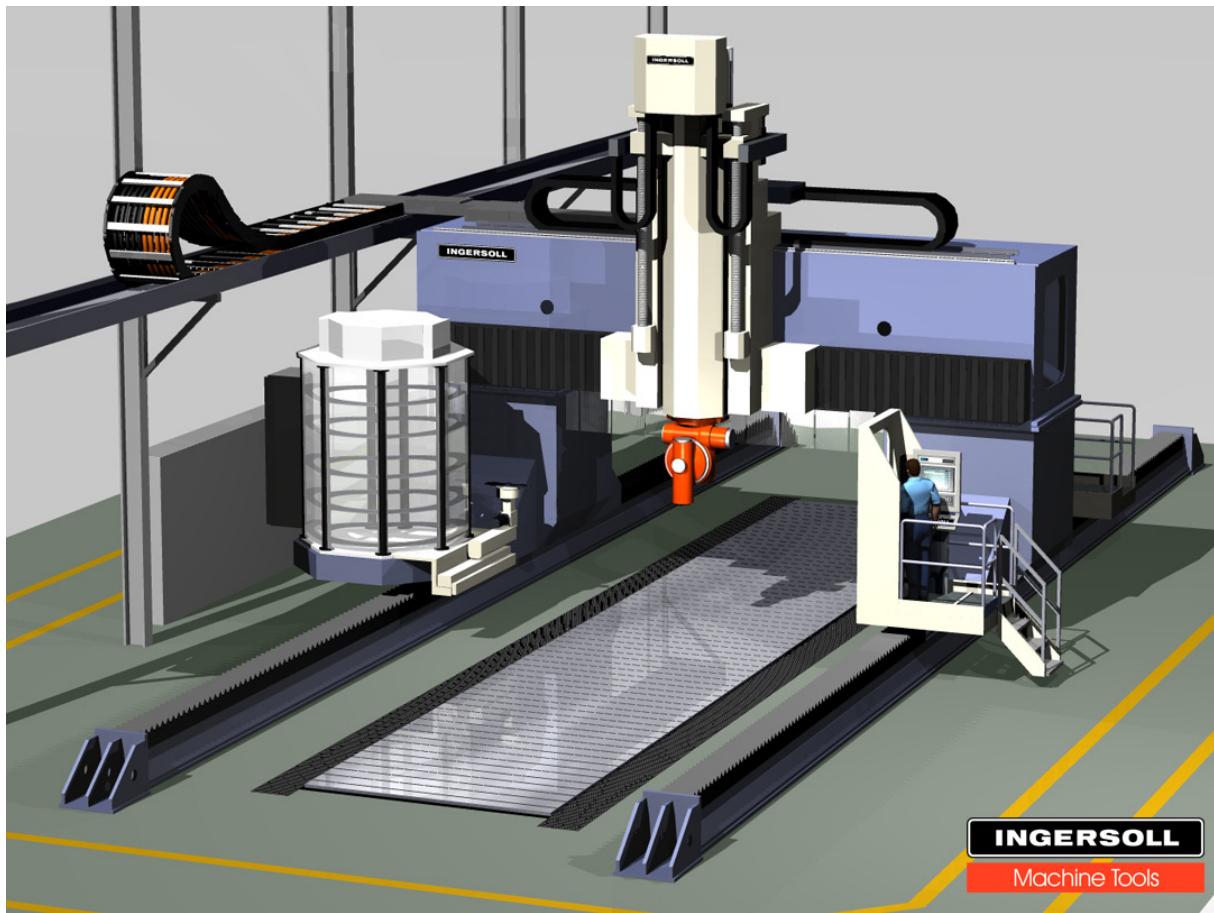
Machine Tools

## MasterMill Gantry

designed and built for

# THE BOEING COMPANY

located in Portland, Oregon



# MAINTENANCE MANUAL

Shop Order 2N00073



## REVISION HISTORY

DATE	SECTION	CHANGE DESCRIPTION
21-Dec-09	All	Updated after Proj. Engineer review.
17-Mar-10	All	Preliminary release to customer.
31-Mar-10	Ch. 10	Corrected zone 1 and 2 X-axis travel limits.
10-May-10	Ch. 2 & Ch. 9	Added light tower.
1-Jun-10	Ch. 16	Added oil weep hole to OH150 Spindle Unit.
7-Jun-10	Ch. 4	Revised description of spindle lube pushbutton.
29-Jun-10	Ch. 10	Updated gate locations and added tool platform door.
2-Aug-10	Ch.2, 8, 16,19	Added information on tool changer pocket configuration and maintenance.
24-Aug-10	Ch. 11 & App. B	Added flow switch for internal coolant on OH150 unit.
31-Aug-10	Ch. 2, 6 and 7	Updated spindle and spindle unit max speed and torque.
	Ch. 9 & App. B	Added magnetic chucks.
	Ch. 13	Made G70 and G700 the reset codes.
3-Sep-10	Ch. 19	Added spare parts for tool changer door, mist enclosure, operator cabin, and tool load platform.
20-Sep-10	Ch. 10 & App. B	Modified I/O addresses for tool load platform.
23-Sep-10	Ch. 13	Updated list of subroutines.



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**The Boeing Company MasterMill Gantry**  
**2N00073**

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# **CHAPTER 1 - INTRODUCTION AND SAFETY**



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## **1.1 INTRODUCTION**

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This manual has been prepared to aid you in the operation of your custom built **INGERSOLL** machine.

This machine embodies a combination of modern engineering skills and experience gained from over 100 years of building quality machine tools. Ingersoll believes this machine to be the finest of its kind whose life and performance depend on proper use, care, and maintenance.

All operating and maintenance personnel should read this manual carefully before operation and maintenance of this machine. This information will help achieve optimum machine performance and reliability.

Ingersoll Machine Tools, Inc. makes no representation or warranty, expressed, implied, or statutory with respect to, and assumes no responsibility for the accuracy, completeness, sufficiency, or usefulness of the information contained herein. No warranties of merchantability or fitness for purpose shall apply.

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## **1.2 PROPRIETARY AGREEMENT**

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This manual discloses certain information which Ingersoll Machine Tools holds as proprietary and confidential business information. The purchaser/holder of the machine subject to this manual is granted a limited, non-exclusive, royalty-free license for the life of the machine, to those proprietary or confidential portions of the information Ingersoll, in its sole discretion, deems confidential or proprietary. This limited license allows for the use, reproduction and disclosure of such confidential or proprietary information by the purchaser to its employees for the purpose of operating and maintaining the Ingersoll machine and for no other purpose.

The information contained in this manual and conveyed by the instructor in a training session is believed to be accurate. In spite of continuous review, there is always a possibility of error, misapplication of content, or individual misunderstanding. Ingersoll assumes no liability for unsatisfactory safety or machine performance that might result from such error, misapplication or misunderstanding.

All verbal information is intended to help students understand and troubleshoot within their areas of expertise using the knowledge obtained from Ingersoll.

## 1.3 OCCUPATIONAL SAFETY AND HEALTH ACT

This machine complies with the Occupational Safety and Health Act of 1970 standards where the requirements are specific. The balance of the standards is complied with as interpreted by Ingersoll. Since these standards are continually evolving, and since they are subject to considerable interpretation by a third party, Ingersoll cannot guarantee or warrant compliance with the provisions or standards of O.S.H.A. or any regulations issued under that statute.

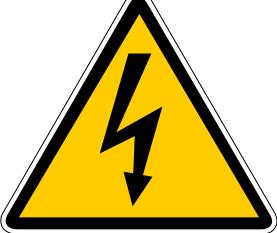
## 1.4 SAFETY AND WARNING INDICATORS

This precision machine tool has been designed to ensure the maximum safety. Only qualified technicians should work on this equipment. Alignment, operation, and maintenance of this machine tool with all its attached power operated devices are potentially hazardous if safety precautions are not followed.

Throughout this manual you will be reminded of safety factors:

- WARNING
- CAUTION
- CAUTION STORED ENERGY
- CAUTION DANGER HOT

<b>WARNING</b> 	WARNING SIGN DANGER TO PERSONNEL. BE VERY CAREFUL!
<b>CAUTION</b> 	CAUTION SIGN CARE MUST BE TAKEN OR EQUIPMENT MAY BE DAMAGED.

<b>CAUTION</b>  <b>STORED ENERGY</b>	<p>THIS SIGN IS USED WHEN DANGEROUS STORED ENERGY MAY BE PRESENT. THIS WILL REQUIRE ADDED CAUTION AND A WELL THOUGHT OUT PLAN BEFORE REPAIR BEGINS. BE PREPARED TO CHECK OR HAVE CHECKED ANY PRESSURIZED LINES, OR ELECTRICAL CIRCUITRY. BE PREPARED TO BLOCK / SUPPORT ANY NECESSARY COMPONENTS BEFORE DISASSEMBLY BEGINS.</p>
<b>CAUTION</b>  <b>DANGER</b> <b>“HOT”</b>	<p>WHENEVER THE MAIN DISCONNECT (LOCATED IN THE ELECTRICAL CABINET) IS TURNED OFF, IT IS EXPECTED THAT THIS ACTION WILL REMOVE ALL POWER FROM THE MACHINE.</p> <p>THE ELECTRICAL CIRCUITS THAT HAVE VOLTAGE (<b>“HOT”</b>) WHEN THE MAIN BREAKER IS DE-ENERGIZED IS IDENTIFIED BY HAVING ORANGE WIRES OR BLACK WIRES WRAPPED WITH ORANGE TAPE.</p> <p>IT IS <u>ALWAYS</u> GOOD PRACTICE TO MEASURE THE VOLTAGE ON THE CIRCUITRY YOU ARE WORKING ON TO PREVENT ANY ELECTRICAL RELATED INJURY. BE PREPARED TO OPEN THE APPROPRIATE ELECTRICAL CABINET TO OPEN THE CIRCUIT BREAKER WIRED TO THE HOT CIRCUITRY.</p>

## 1.5 POWER DISTRIBUTION

When the main disconnect handle, located in an electrical box to the right of electrical cabinet door #1, is pulled downward it removes power from all devices on the machine. Refer to the electrical schematics for the main disconnect circuitry. The “HOT” circuits are the ones that have power whenever the main circuit breaker is pulled. They can be identified as having black wires wrapped with orange tape or simply orange wires.

<b>CAUTION</b> 	<p><b>ALL MACHINE MAINTENANCE SHOULD BE PERFORMED WITH THE MAIN POWER BREAKER IN THE OFF AND LOCKED POSITION.</b></p>
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## 1.6 MACHINE GUARDING/SHIELDING

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The machine is provided with close perimeter guarding to provide protection from moving parts, pinch points, flying particles and similar hazards. Expanded metal is used in the areas where visibility is important. Sheet metal guarding is provided for belt drives and couplings.

Non-interlocked, sliding guards are provided at points requiring frequent access. Fixed guards are used in areas not requiring access by a production operator and requiring only non-routine access. **However, all maintenance should be performed with the main power breaker off and locked.** Personnel should be aware of the danger of opening gates while the machine is operating.

## 1.7 EMERGENCY STOP CONTROLS

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All machine control hand held devices and operator panels have a RED EMERGENCY STOP button that immediately stops all machine motion. Resetting from an emergency stop can only occur from the location where the stop was initiated. All electrical safety devices and circuits are hard wired.

## 1.8 ADDITIONAL SAFETY FEATURES

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### 1.8.1 WARNING SIGNS

Warning signs are attached at each hinged or sliding guard, advising persons of the danger of opening the gate while the machine is in operation. However, these safeguards cannot be expected to protect persons who deliberately abuse or misuse the safety facilities provided. The safeguards do not protect persons who ignore the correct machine operating procedures.

### 1.8.2 COLOR CODING OF EQUIPMENT

Specific components and controls on the equipment will be color coded for designating emergency controls or dangerous apparatus.

**RED**

**RED:** All fire protection equipment and apparatus signifying danger or stop are red in color. Emergency stop bars, stop buttons, and emergency electrical stop switches on the equipment are red in color.

**ORANGE**

**ORANGE:** Orange designates dangerous parts of the machine or energized equipment, which may cut, crush, shock, or otherwise cause bodily harm or injury.

Orange emphasizes these hazards when enclosure doors are opened, or gear, belt or other guards around moving equipment are opened or removed.

Open or removed guarding exposes unguarded hazards. Orange indicates the insides of transmission guards for gears, pulleys or chains, movable guards and edges of pulleys, gears, rollers, cutting devices and power jaws.

**YELLOW**

**YELLOW:** Yellow designates caution. Also, it is used to mark physical hazards, such as areas that a person may strike against, stumble, fall, trip or get caught in between.

All machine guards, guardrails, and other areas for potentially striking against, stumbling, falling, tripping and being caught in between are painted yellow.

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## 1.9 BUILD SPECIFICATIONS

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The Ingersoll equipment is built in compliance to latest revision (as of the time of shipment) of the following standards and codes:

- National Fire Protection Association (NFPA) Electrical Standards for Industrial Machinery, NFPA-79, 2007.
- National Fire Protection Association (NFPA) National Electrical Code, NFPA 70, 2005.
- Occupational Safety and Health Standards (OSHA), Part 1910 of Chapter XVII of Title 29 of the Code of Federal Regulations.

### 1.9.1 SAFETY FEATURES

In compliance with North American standards for machine tool manufacturing, the following safeties have been applied:

- Software travel limits
- Electrical limit switches
- Mechanical stops
- E-Stop pushbuttons on the Main Controller and Auxiliary pendants
- Operator protection via interlocked doors/gates
- Machine protection via Main Controller warnings/alarms

### 1.9.2 ENVIRONMENTAL REQUIREMENTS

The machine was manufactured and assembled in an environmentally monitored facility. In order to maintain geometric tolerances and accuracies, facility temperature variation must be limited.

## 1.10 TAGS AND LOCKOUTS

There are five (5) hazardous energy sources associated with machinery. The following table lists how devices can be used to lockout and tag these five energy sources.

LOCKOUT, TAG, TRYOUT OVERVIEW	
ITEM	DESCRIPTION
ELECTRICAL	<ol style="list-style-type: none"><li>1. Use an electrical lockout or throw a disconnect switch, and then apply a customer-approved padlock, lockout device and tag.</li><li>2. Ensure that all power sources are locked and tagged.</li><li>3. Release stored electrical energy to obtain "Zero energy state".</li><li>4. Ensure that all circuits are dead and that a zero energy state has been achieved.</li></ol>
PNEUMATIC	<ol style="list-style-type: none"><li>1. Release pressure to reach a zero energy state.</li><li>2. Use adapters when needed, to isolate air valves with stored energy; shut off valves; and padlock, lockout device, and tag to lockout the energy source.</li></ol>
FLUID AND GASES	<ol style="list-style-type: none"><li>1. Identify and recognize all hazards.</li><li>2. Insert a blank or blind in the line.</li><li>3. Use a lockout valve, adapters if necessary, and a padlock, lockout device and tag at the energy source.</li></ol>
MECHANICAL	<ol style="list-style-type: none"><li>1. Release or block all stored mechanical energy (e.g. spring-load or gravity).</li><li>2. Use a padlock, lockout device, and tag to obtain a zero energy state.</li></ol>
FOR MORE INFORMATION	For specific information on lockout, tag, and tryout procedures, refer to: Federal OSHA, Code of Federal Regulations, title 29, part 1910, section 147.

## 1.11 SAFETY RECOMMENDATIONS

For your safety and to prevent equipment damage, thoroughly study this manual and use this section of recommendations. **The format of the table below** does not assign importance to any one item over another. They are all equally vital for safe interaction with the machine operating area. Row items are numbered only for reference.

1.	<b>MAINTAIN MACHINE</b>	Keep the machine properly maintained. Perform all maintenance in accordance with the manuals provided and follow the checklists and recommendations.  Never operate the machine unless maintenance routines have been regularly performed and the machine is known to be in good working order. Be aware of scheduled maintenance and the last maintenance performed.
2.	<b>KNOW MACHINE</b>	Understand how the machine operates prior to use. Never operate the machine if you have any questions such as but not limited to, procedures, power, tools, maintenance and cleaning.
3.	<b>RESTRICT PERSONNEL</b>	Never allow untrained personnel to operate the machine, conduct tests or be present where machine movement and debris can interact with them.
4.	<b>DISCONNECT POWER</b>	Never attempt to repair or perform maintenance on the machine until all main electrical power has been disconnected. Only authorized electrical maintenance personnel should have access to these areas of the machine.
5.	<b>VERIFY CONSOLE</b>	Always check indicators, warning lights, dials and screens on the Operator's Console and control stations before operating this machine. Consult the industrial or manufacturing engineering department for proper feeds and speeds.
6.	<b>GUARDS LOCKS GATES</b>	Ensure that all guarding, interlocks and safety equipment are in good condition and in place during the operation of the machine.

7.	<b>TOOLS SPEEDS LOADS</b>	<p>Be certain tools are properly mounted and locked, and the work piece is securely positioned before starting the machine.</p> <p>Never operate any machine beyond its rated speed or capacity.</p> <p>Never overload the machine. This is potentially dangerous to both the operator and the machine.</p>
8.	<b>NEVER BYPASS</b>	<p>Never wire, fasten, bypass or otherwise lock out any interlocks, overloads (circuit breakers), over-travels (limit switches) or disconnects, to void their assigned function. These are provided for safety and for proper machine operation.</p>
9.	<b>NEVER REACH</b>	<p>Never reach across or under any moving machine part.</p>
10.	<b>IF YOU LIFT...</b>	<p>Always use lifting equipment on heavy or awkward work pieces and components.</p>
11.	<b>AFTER ABSENCE</b>	<p>Never assume you were the last user of the machine and that no one else has touched it since you left it.</p> <p>When returning to the machine after an absence, always check the setup. The equipment may have been used and not replaced correctly.</p>
12.	<b>CLOTHING JEWELRY HAND TOOLS</b>	<p>Do not wear loose clothing or jewelry that could become entangled in the moving parts of the machine.</p> <p>Always wear properly designed impact resistant safety glasses and safety shoes.</p> <p>Never lay tools or tooling on the machine where it might interfere with the operation of the machine.</p>
13.	<b>VERIFY PARTS</b>	<p>Be alert for loose, worn or broken parts. When suspected, do not operate the machine. Report these items and any unusual noise or action of the machine to the proper authority.</p>

14.	<p><b>WELDING WARNING</b></p> 	<p>Machine and control elements can be damaged by the electrical currents and noise generated by welding. For this reason Ingersoll recommends that on-machine welding not be done.</p> <p>If on-machine welding is performed, the following practices should be followed in order to minimize the likelihood of machine or control damage.</p> <p>A. Connect the welder ground securely to the part being welded as close as possible to the point of the weld.</p> <p><b>FAILURE TO FOLLOW WELDING WARNINGS IS THE PRIMARY CAUSE OF MACHINE / CONTROL DAMAGE WHILE WELDING.</b></p> <p>B. Turn off all machine and control power including the machine controller "hot box" while welding.</p> <p>C. Keep the welder at least 25 feet away from any machine control enclosures including the operator station, CNC/PLC, drives, and machine-mounted electronics such as feedback amplifiers.</p>
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## 1.12 BLOCK AND LOCK COUNTERBALANCE STRUCTURES

It is extremely important that all maintenance personnel be informed of machine components that can move when power, hydraulics, pneumatics or otherwise normally secure holding systems fail, such as rams or crossrails that are counterbalanced or components that otherwise can move involuntarily as a result of gravity.

When conducting any machine maintenance, extreme care and lockout procedures must be followed to block, inhibit or otherwise de-mobilize any structure that can move due to gravity.

Company-approved lock-out/tag-out procedures must also be followed during maintenance to lock and tag electrical circuits prior to working on a circuit or the mechanical equipment supplied by the circuit.

In light of these risks, maintenance personnel are required to BLOCK AND LOCK all machine components such as counterbalanced rams and crossrails so their movement downward cannot occur. Blocking should only be conducted with approved devices. Refer to the Preventive Maintenance Chapter in the Maintenance Manual for additional details.

**WARNING**

The Z-axis (ram) on this machine carries a large amount of weight and is a counterbalanced axis. It is essential that the counterbalance systems are functioning at all times to prevent an axis from inadvertently falling, which could result in severe machine damage or injury. Prior to any maintenance work on the ram, the axis must be driven to its lower limit and physically blocked to prevent motion.

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### 1.13 INGERSOLL CONTACTS

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For service or sales needs, please contact the appropriate Ingersoll department below. When it is necessary to order parts, request a service person, or call for assistance, have the following information available and refer to the Ingersoll Job Number as it appears at the top of this page.

DEPARTMENT	E-MAIL	TELEPHONE
Service	<a href="mailto:service@ingersoll.com">service@ingersoll.com</a>	815-987-6017
Technical Support	<a href="mailto:smgtechsupport@ingersoll.com">smgtechsupport@ingersoll.com</a>	815-987-6017
Spare Parts	<a href="mailto:parts@ingersoll.com">parts@ingersoll.com</a>	815-987-6148
Retrofits and Rebuilds	<a href="mailto:rebuilds@ingersoll.com">rebuilds@ingersoll.com</a>	815-987-6000

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## **CHAPTER 2 - MACHINE OVERVIEW**



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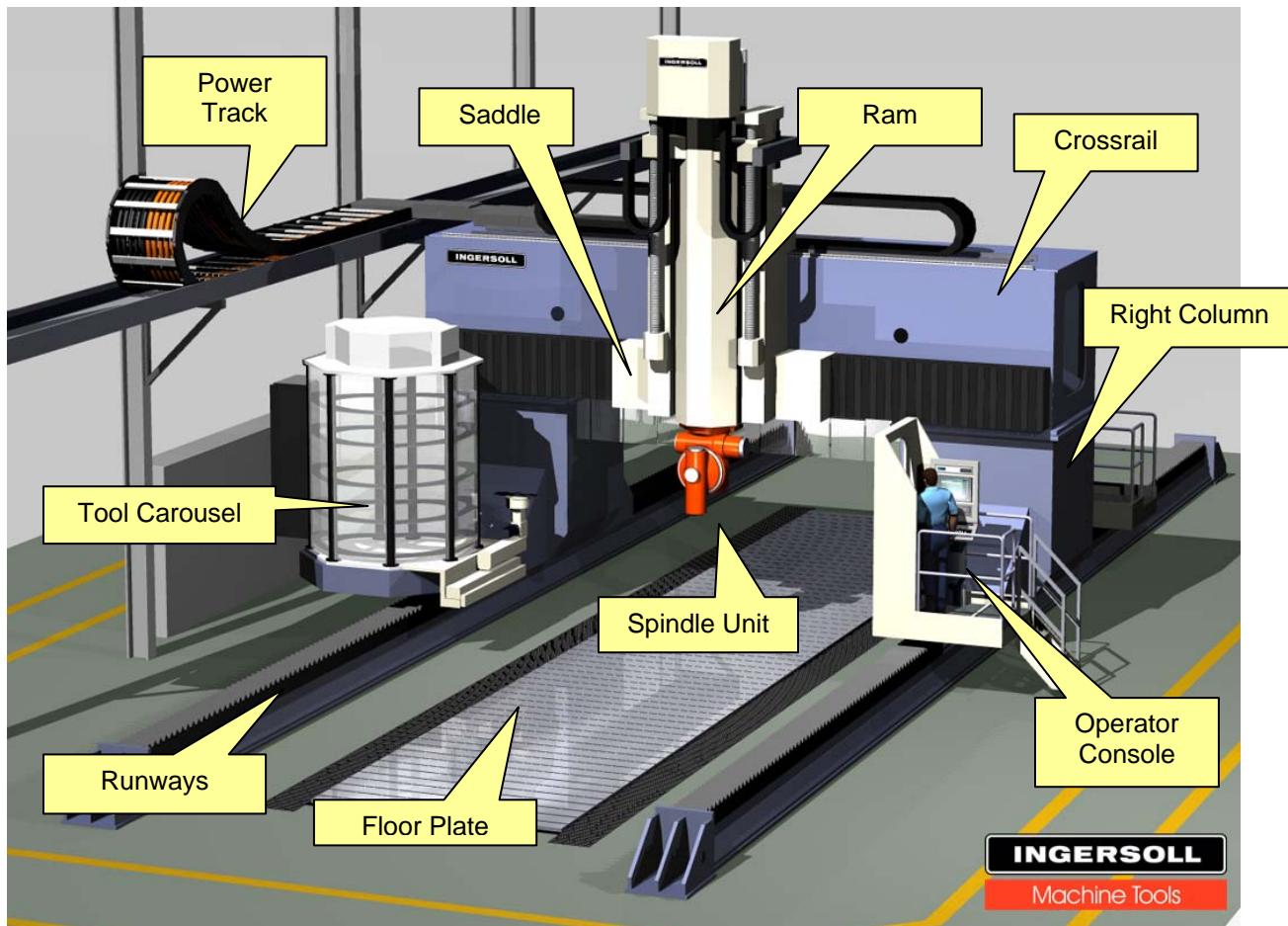
## 2.1 MACHINE COMPONENTS

The Ingersoll MasterMill Gantry machine has a ram (Z-Axis) attached to a crossrail with support columns. The basic machine structure is comprised of a bed, table, columns, crossrail, and ram. All axes have digital drives for maximum performance.

Axes comprise 4 contouring axes (X, Y, Z, C) and 1 additional contouring axis (A) with some spindle unit attachments. This machine currently has one permanently attached spindle unit.

Tools can be automatically loaded into the spindle unit from a carousel-type tool storage system located on the left machine column.

The machine is controlled by a Siemens 840D CNC. The main operator console is attached to, and moves with, the right column of the machine.



INGERSOLL MASTERMILL GANTRY

### **2.1.1 RUNWAYS**

The machine runs on two parallel linear rail runways. X-axis is the longitudinal travel of the machine's columns along the runways, driven in gantry mode by two racks and double-preloaded pinions.

### **2.1.2 FLOOR PLATE**

A cast iron floor plate is located between the two columns. T-slots in the table allows for precision mounting of fixtures and parts.

The machining area can be divided in two different work zones using a movable/removable mechanical barrier that is placed between the zones. Zone 1 is towards the front of the machine (towards X-axis minus travel) and Zone 2 is at the rear of the machine (towards X-axis plus travel).

### **2.1.3 COLUMNS**

Two column structures of welded steel plate and tubing form the sides of the work zone and provide the vertical rail system for Crossrail movement. The gantry columns travel along X-axis driven by two racks and double preloaded pinions.

### **2.1.4 CROSSRAIL**

The Crossrail is supported by the two columns and forms the upper structure of the work zone.

### **2.1.5 SADDLE**

The Saddle is constructed of welded steel plate and travels horizontally along the crossrail. The saddle is driven by double-preloaded pinions.

### **2.1.6 RAM**

The Ram is carried on the saddle and provides vertical motion by a pair of precision ball screws and preloaded nuts. The weight of the ram is assisted by a hydraulic counterbalance on the ballscrew with two hydraulic cylinders.

The ram contains the spindle motor, C-axis, and the spindle unit gripper fingers (these secure an attachment to the ram face). Spindle units are attached to the ram to provide greater machining capabilities.

### 2.1.7 SPINDLE

The MasterMill ram contains a dual winding torque motor that drives the spindle and tool.

**NOTE:** The values shown below are for the spindle motor only. Power and speed limits for the spindle unit are shown in the spindle unit section.

Spindle Motor Type: Phase TK-340-540-010 dual winding

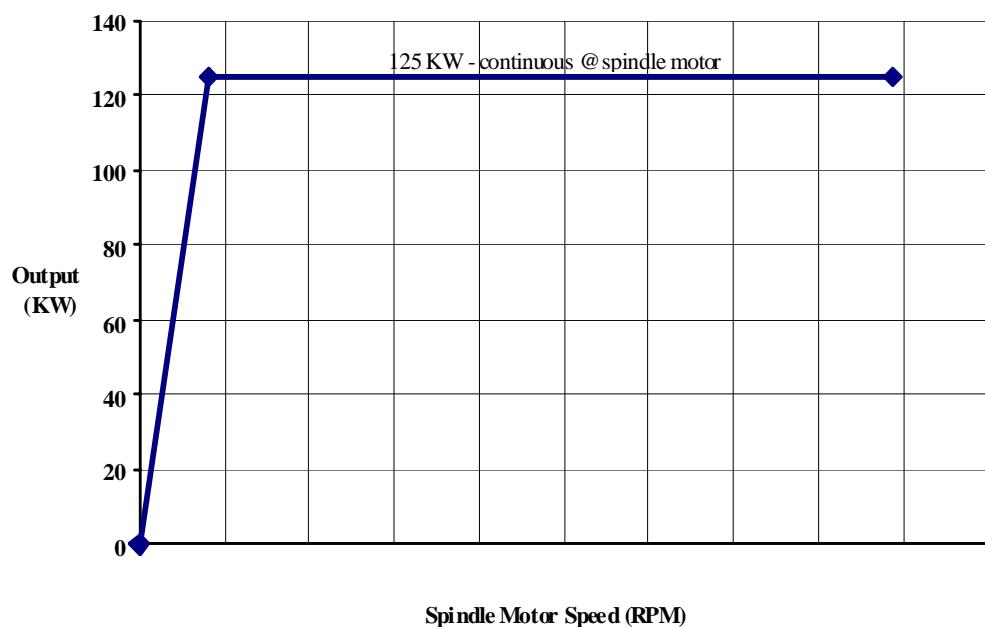
Spindle Motor Max Power: 125.2 KW (167.9 HP)

Max Spindle Motor Torque: 2965 NM (2187 ft lb)

Spindle Motor Max Speed: limited to 4437 rpm

Spindle Motor Base Speed: 405 rpm @ motor

**Spindle Motor Speed & Power**



## 2.2 SPINDLE UNITS AND TOOLS

### 2.2.1 SPINDLE UNITS

This machine supports one spindle unit (SU) that is permanently mounted to the ram.

Spindle units supplied with this machine are shown below:

<b>SU Number</b>	#14
<b>Type</b>	Offset Swivel
<b>Power</b>	125.2 kW (167.9HP) @ 288 to 3169 rpm
<b>Torque</b>	4151 NM (3062 ft lb) @ 0 to 288 rpm
<b>RPM Max</b>	3169 rpm
<b>Gear Ratio</b>	1.4 : 1
<b>Spindle Unit Load/Unload</b>	Future option
<b>Tool Load / Unload</b>	Automatic
<b>Coolant</b>	Internal & External
<b>Spindle Taper</b>	CAT 60 simultaneous fit
<b>C-Axis Range</b>	$\pm 200^\circ$ @ 10 rpm
<b>A-axis Swivel Angle</b>	$\pm 110^\circ$ @ 5 rpm

### 2.2.2 TOOLS

#### 2.2.2.1 STORAGE

A tool storage carousel comprised of 112 pockets is mounted on the opposite side of the machine from the operator position. A robotic manipulator is used to exchange CAT 60 taper, simultaneous fit tools with the spindle unit. A tool check in terminal is provided next to the carousel for ease in entering tool data.

#### 2.2.2.2 TOOL CHIPS

Tool data can be stored on chips mounted on the tools. A Balluff tool chip reader is mounted in the tool carousel check-in pocket to automatically read the chip data as tools are loaded into the carousel.

#### 2.2.2.3 TOOL MEASUREMENT LASER

A Renishaw tool laser allows the measuring of length and radius of tools.

#### 2.2.2.4 PART PROBE

One Renishaw RMP60 RF Probe Unit is provided for use. The Renishaw probe acts as an omni-directional switch and is effective in the X+, X-, Y+, Y- and Z- directions. The radio signal is transmitted to an interface module situated in the electrical cabinet. The probe can be stored in the tool carousel for automatic loading into the spindle units.

The following user-friendly support functions are included:

- Load zero offsets and tool compensations
  - calculation of circle center point from three or four measuring points
  - calculation of average value
  - calculation of empirical values
  - collision monitoring
  - plausibility check of defining parameters and output of message texts and alarm messages.
- 
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### 2.3 CONTROLS AND OPERATOR CONSOLE

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#### 2.3.1 MACHINE CONTROL

The machine and its peripheral equipment are controlled by a Siemens 840D CNC. The Siemens 840D includes a PLC and a front-end computer to provide a powerful and adaptable control system.

#### 2.3.2 MAIN CONTROL PANEL

The Main Control Panel is used to operate the machine from a single position, which consists of a color graphic display, keyboard, indicator lights, selector switches, pushbuttons, and potentiometers for machine operation. The operator console is mounted in an enclosure attached to, and traveling with, the right column of the machine.

#### 2.3.3 AUXILIARY PENDANT

A small hand-held auxiliary pendant can be plugged into a box on the left column near the tool changer and into a location on the tool carousel cabinet.

#### 2.3.4 VIDEO SYSTEM

Due to the large size of the work area, two (2) color cameras are provided to allow the operator more visibility of the work area. The camera output is displayed on a 19", flat panel, color, LCD monitor located near the operator console that has split-screen capability so the output of the cameras can be viewed simultaneously.

#### 2.3.5 VISIPORT

A Visiport (a 10 inch spinning window) on the operator console enclosure allows the operator better visibility to the machining process when coolant and mist may be present.

### 2.3.6 LIGHT TOWER

A light tower (stack light) is mounted on top of the electrical cabinets on the left hand side when facing the front of the cabinets. The machine logic will turn on the appropriate light to indicate the status of the machine.

LIGHT COLOR	MACHINE STATUS
Green	The machine is operating with no alarms.
Yellow	The machine is operating with a warning alarm (minor fault).
Red	The machine has a critical fault condition.

## 2.4 ELECTRICAL CABINETS

The electrical cabinets are located on the floor to the left of the machine, one continuous bank of cabinets. The main Electrical Cabinets are air-conditioned and house the following:

- Servo-drives for axes servomotors
- Spindle drive
- CNC/Machine Interface
- Power Modules

### 2.4.1 POWER REQUIREMENTS

The electrical system meets the requirements of UL regulations. All components are rated for the application and environment.

A constant, non-fluctuating, clean power drop is required for proper operation of the machine. To help achieve optimum performance of this equipment, it is important that the main power supply you provide meets the following conditions:

Voltage: Symmetrical 3-Phase, 480 VAC, -10% to +6%, 60 Hz  $\pm$  5%.  
The electrical power supply to the machine must be type TN  
(the supply transformer must have a "wye" secondary with a  
grounded star point wired to the machine controller PE  
terminal).  
Power: 575 kVA  
Current: 695 Amps peak (full load)  
Main Breaker: 800 Amps

**NOTE:** Full power (estimated at 575 kVA) is ONLY required when machine is working its hardest. This is during a full HP cut with spindle motor, and all axes moving or maintaining servo positions.

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## **2.5 FLUIDS**

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### **2.5.1 POWER UNIT PLATFORM**

This machine is supplied with a power unit platform that consists of the hydraulic power unit, chiller and the lubrication service panel. Also on the power unit platform is the pneumatics service panel that includes the pneumatic lockout and distribution and some of the pneumatic services for the machine. The location of the power unit platform is provided on the machine plan view layout.

The fluids systems on the Ingersoll machine consist of various subsystems that provide hydraulics, lubrication, pneumatics, and heat removal.

### **2.5.2 HYDRAULICS**

The hydraulic power unit is located on the power unit platform. This hydraulic system is used for the following machine functions:

- Z-Axis Counterbalance
- Spindle Tool Gripper
- Unclamp Corner SU Grippers
- C and A-axis Clamps
- Spindle Unit Recirculating Lubrication

### **2.5.3 LUBRICATION**

Lubrication of the Ingersoll machine is achieved both automatically through separate subsystems and manually. The reservoirs and pumps of the lubrication subsystems are located on the Lubrication Service Panel located on the Power Unit Platform.

The automatic lubrication subsystems include:

- X, Y, and Z axis pinions, bearing trucks, ballscrew nuts

### **2.5.4 COOLANT SYSTEM**

Pressurized internal coolant is pumped from a clean tank and pressurized external coolant is pumped from the main coolant tank, routed through the machine sections and power tracks, coupled through the spindle units, and delivered to work piece with integral coolant nozzles in the spindle units.

- Internal (through the spindle) coolant = 19 L/min @ 25 bar (5 GPM @ 363 PSI)
- External coolant = 38 L/min @ 3.8 bar (10 GPM @ 55 PSI)

External coolant is also piped to a hand held wash hose with a manual on/off valve in each work zone.

Used coolant is recovered as it flows into the chip conveyors. The coolant is routed to the filter system.

The filter system is designed to automatically clean and remove chips from dirty machine tool coolant. Dirty coolant and chips enter the coolant system, where a steel belt conveyor moves the large chips and swarf up the filter's incline, and dumps them into a chip tote. The coolant and fine particles fall through the steel belt conveyor, into the main coolant tank.

A "no media" backwash system is used to separate the fine particles from the coolant. The fines are transported up the filter's incline with the backwash conveyor, and dumped into the chip tote. The clean coolant is contained in a separate tank from the main tank and is used for internal coolant.

A disc-type oil skimmer is provided with the filtration system.

#### 2.5.4.1 CHIP CONVEYOR

Two chip conveyors run parallel to the X-axis of the machine, one on each side of the floor plate. A third, cross chip conveyor connects the two parallel conveyors to the coolant filtration system. These conveyors deliver the chips and used coolant to the coolant filtration system.

#### 2.5.4.2 MIST COLLECTOR & COOLANT CONTAINMENT ENCLOSURE

A Mist collection system is provided to remove mist during machining operations. A curtain is connected to the front of the crossrail to help contain coolant and a mist collection shroud is installed near the spindle on the ram to collect mist during machining. The mist collection system pulls air from the work area through ductwork located in the crossrail and into the mist collection unit mounted on the right column of the machine.



#### 2.5.5 CHILLER

Heat removal for the spindle motor and X, Y, A, and C axes motors is supplied by a refrigerated Koolant Kooler chiller unit with air-cooled condenser. The chiller is located on the left machine column chiller platform. The chiller contains a reservoir and a pump that supplies water-glycol to the various areas on the machine.

## **2.5.6 PNEUMATICS**

There is a solenoid valve on the Lubrication Service Panel that turns on the main air to the machine. This solenoid is hard-wired controlled and is energized when power is applied to the machine. A lockout valve on the Lubrication Service Panel overrides the Air On solenoid allowing the pneumatic system to be disabled for maintenance.

The following machine functions require air:

- X, Y, and Z-axes Heidenhain air pressurization
- Air supply to Trabon lubrication sub-systems
- Spindle seal pressurization
- Ram face blow off
- Spindle tool taper blow off
- Spindle unit air
- C-axis bearing lubrication (future use)
- Tool probe air purge

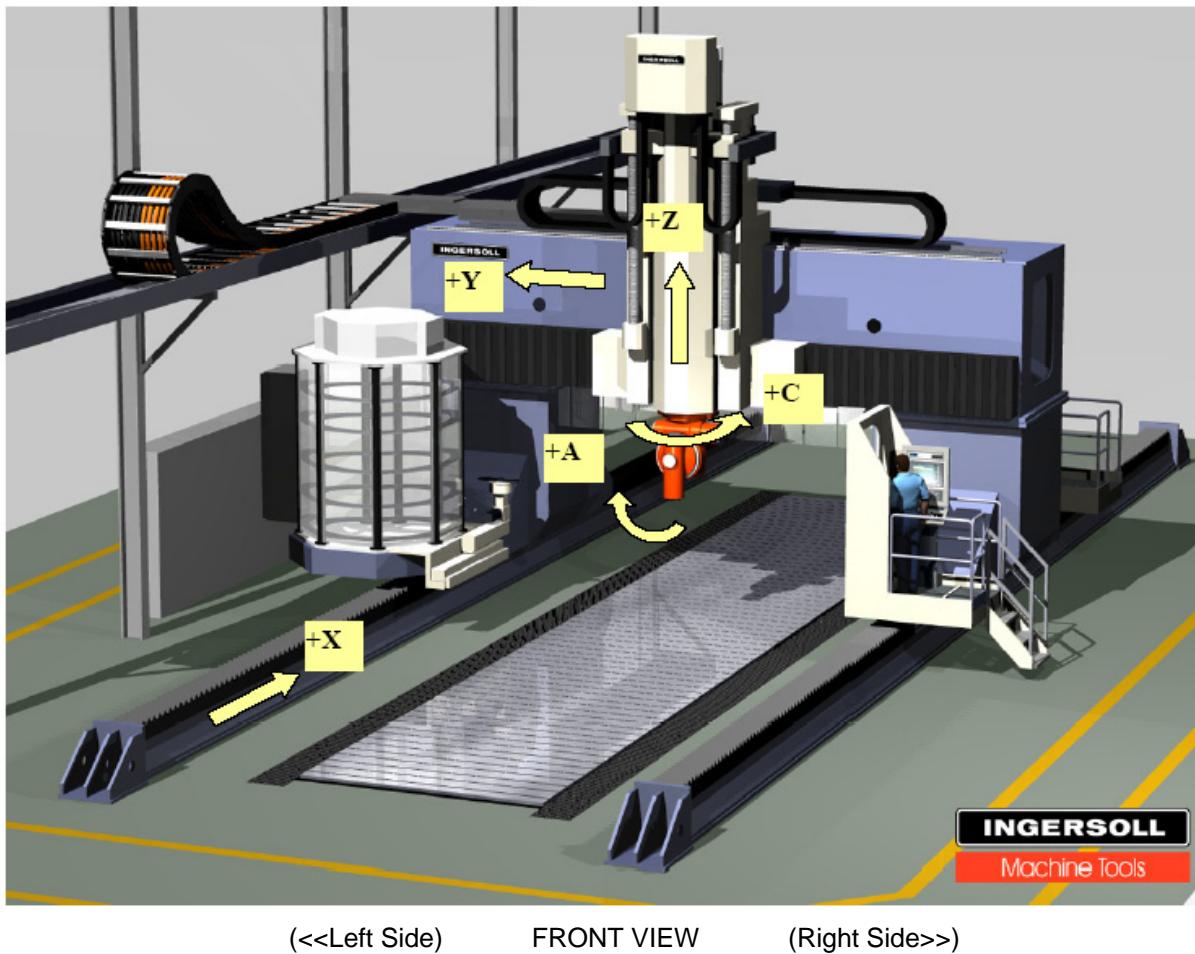
### **2.5.6.1 AIR REQUIREMENTS**

A supply of clean, dry, pressurized air is necessary for proper operation of the machine. To help achieve optimum performance of this equipment, it is important that the air supply provided by the customer meets the following conditions:

Pressure: 1416 NL/M at 6.2 bar (50 SCFM at 90 PSI) +/- 10%  
Filtration: 40 microns maximum and oil-free  
Dew point: -40°C +/- 1°C at 6.9 bar (-40°F +/- 2°F at 100 PSI)

## 2.6 MACHINE AXES

X-axis motion is achieved via the Gantry columns moving along the length of the floor plate. Y-axis motion is achieved via the Saddle moving across the crossrail. Z-axis motion is achieved via the ram moving up and down on the Saddle. C-axis rotation is achieved as the spindle units rotate about the Z-axis direction. A-axis is the tilt motion provided with some of the spindle units that can be attached to the ram.



Axis	Axis Direction	
X	Plus (+)	Towards Rear of Machine
Y	Plus (+)	Towards Left (Away from Op Console)
Z	Plus (+)	Ram Up, Retracted away from work piece
C	Plus (+)	Counterclockwise viewed from top of ram
A	Plus (+)	Upwards toward tool changer with C at 0°
SP	Plus (+)	Counterclockwise viewed from back of Spindle

**2.6.1 MOTORS, BRAKES AND FEEDBACK**

Axes and Motors are listed in the table below:

<b>Axis</b>	<b>Description</b>	<b>Axis Type</b>	<b>Axis Motor</b>
X	Gantry	4 motor master/slave and gantry drive coupling	(4) Phase TK-450-300-33
Y	Head Saddle	2 motor master/slave drive coupling	(2) Phase TK-450-300-33
Z	Ram	2 motor master/slave drive coupling	(2) Siemens 1FT6 134-6SF71-1AB0
C	Head Rotation	1 motor	(1) Phase TK-570-300-55
A	Tilt / Swivel Axis	1 motor	(1) Phase TK-240-160-050
SP	Spindle	2 winding motor	(1) Phase TK-340-540-010

Axis Brakes and Axis Feedback Scales are listed in the table below:

<b>Axis</b>	<b>Brake</b>	<b>Feedback</b>
X	Dynamic braking (electronic)	(4) Heidenhain ECN 113 rotary absolute for velocity feedback (2) Heidenhain LB382C Distance coded scale for position feedback
Y	Dynamic braking (electronic)	(2) Heidenhain ECN 113 rotary absolute for velocity feedback (1) Heidenhain LB382C Distance coded scale for position feedback
Z	Mechanical brake (2) + Motor brake (2)	(1) Heidenhain LB382C Distance coded scale
C	Hydraulic clamp	(1) Renishaw Angle Encoder RESM 550
A	None	(1) Heidenhain RCN226 rotary encoder + (1) Renishaw RESM A 417 angle encoder for position feedback
SP	None	(1) L & B GEL 244 512 line incremental

## 2.6.2 AXIS TRAVEL, FEEDRATES AND HOMING

Axis Names, Axis Travel Limits and Axis Feedrates are listed in the table below:

Axis Letter	Axis Description	Travel	Travel Limits		Feedrate
			Minus	Plus	
X	Gantry	16,500 mm (649.6 in)	-8250 mm (324.8 in.)	+8250 mm (324.8 in.)	30,000 mm/min (1181 in/min)
Y	Head Saddle	4000 mm (157.4 in)	-2000 mm -78.74 in.)	+2000 mm (+78.74 in.)	30,000 mm/min (1181 in/min)
Z	Ram	1900 mm (74.8 in)	+915 mm (+36.02 in.)	+2815 mm (+110.83 in.)	30,000 mm/min (1181 in/min)
C	Head Rotation	+/- 200 °	- 200 °	+ 200 °	10 rpm
A	Spindle Unit Tilt / Swivel	+/- 110 °	- 110 °	+ 110 °	5 rpm
SP	Spindle	360 ° rollover	n/a	n/a	3,300 rpm

Axis Home Positions are listed in the table below:

Axis	Home Direction	Home Position	Home Sequence
X	Plus	Varies	Short move with distance coded scale
Y	Plus	Varies	Short move with distance coded scale
Z	Plus	Varies	Short move with distance coded scale
C	Plus	+ 0 °	Standard incremental sequence
A	Plus	+ 90 °	Standarded incremental sequence after spindle unit is attached
SP	n/a	n/a	n/a

## **CHAPTER 3 - CONTROL DESCRIPTION**



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## CHAPTER 3 - CONTROL DESCRIPTION

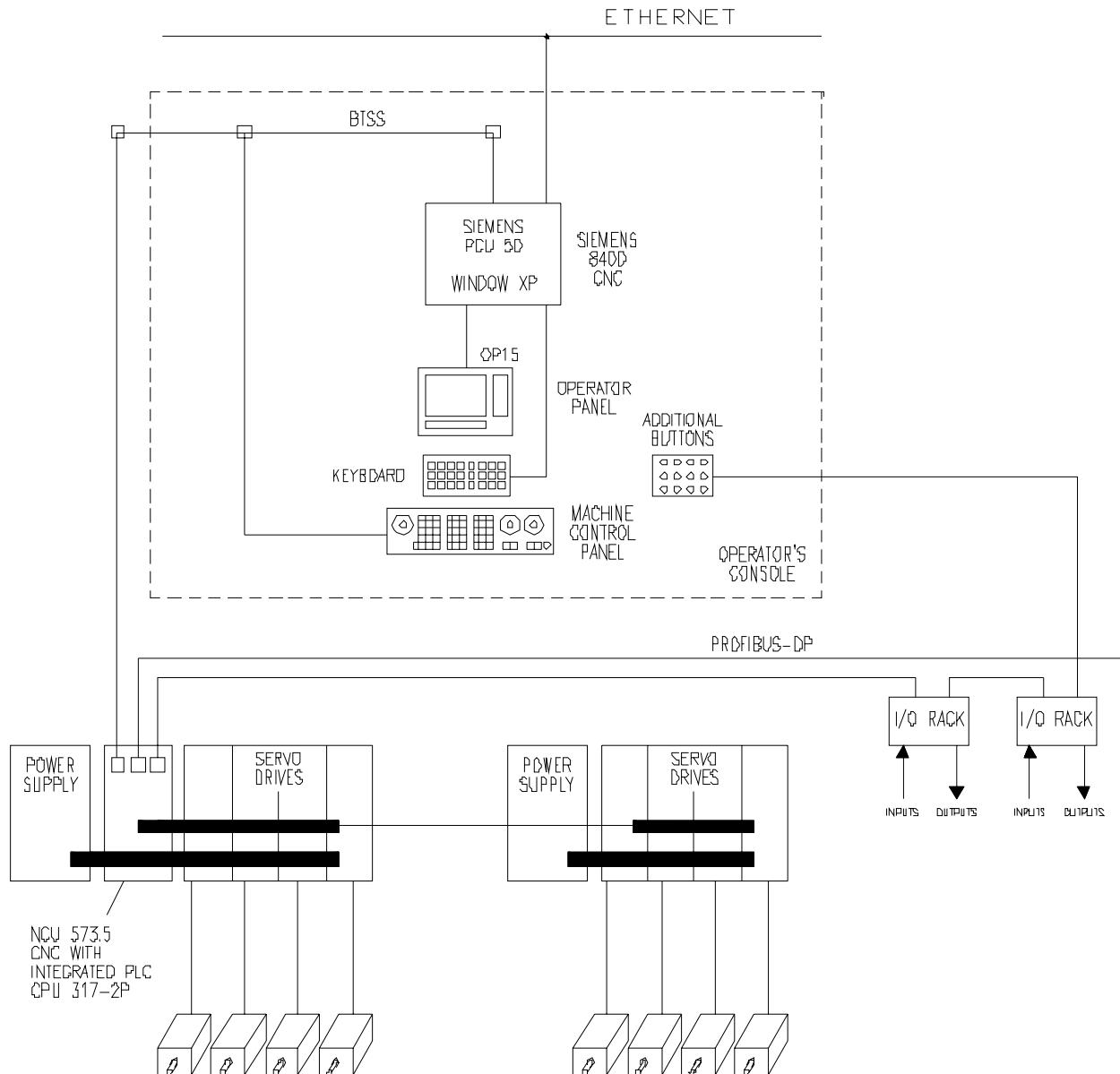
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### 3.1 INTRODUCTION

The Ingersoll Machine Control consists of a Siemens 840D CNC control system. This controller is designed to store and execute part programs, coordinate axis motions, and control the spindle, and is comprised of three modules: the Numerical Control Unit (NCU); the Programmable Logic Controller (PLC); and the Panel Control Unit (PCU).

The Ingersoll Machine Control architecture is shown below.



### **3.2 CNC (COMPUTERIZED NUMERICAL CONTROL)**

The numerical controller is a Siemens 840D CNC control system. This controller is designed to execute part program and axis motion commands. The Siemens CNC controller is comprised of three modules; the Numerical Control Unit (NCU), the Programmable Logic Controller (PLC), and the Panel Control Unit (PCU).

The CNC also monitors and controls all of the machine's auxiliary systems and devices through machine-specific logic programs.

Hardware housed in the control cabinet for the CNC includes:

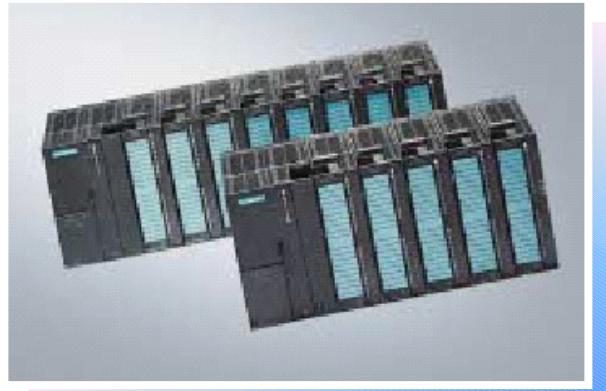
- NCU - 840D central processing unit
- PLC components
- Cable distributor
- 24V supply
- Siemens power supplies, filters, and servo drives
- NCU terminal block for analog and digital inputs/outputs
- Memory card (PCMCIA) that contains the system program
- Distributor box for connection of handheld terminals, handwheel, and e-stop circuit

#### **3.2.1 NCU (NUMERICAL CONTROL UNIT)**

The Siemens NCU (Numerical Control Unit) executes all part program commands, controls axis motions, and drives the spindle.

#### **3.2.2 PLC (PROGRAMMABLE LOGIC CONTROLLER)**

The Siemens PLC monitors and controls all of the machine's auxiliary systems and devices through machine-specific logic programs developed by Ingersoll. Hardware associated with the PLC is contained in the NCU unit, housed in the main control cabinet. Both local input/output (I/O) racks in the main control cabinet, and remote I/O racks located in enclosures on the machine, are used on this machine.



I/O MODULES

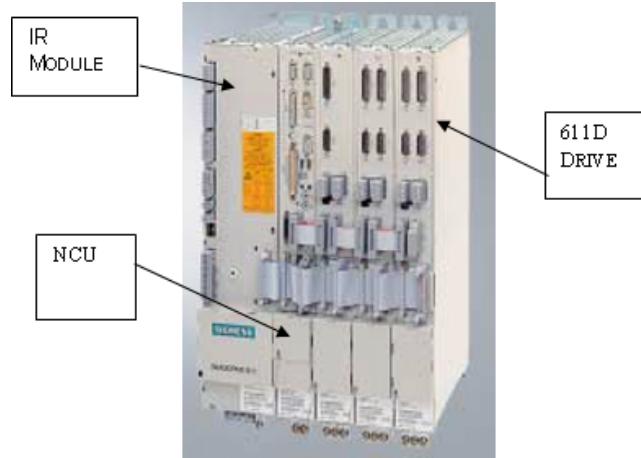
### 3.2.3 PCU (PANEL CONTROL UNIT)

The Siemens PCU serves as the interface between the operator and the machine. The PCU is located in the operator console. The PCU enables the operator to initiate, monitor, and terminate operations by means of a color CRT, alphanumeric keyboard, and software keys. Part programs are stored in the PCU. The PCU also serves as a high-speed interface between the NCU and any host computer.



### 3.2.4 SERVO DRIVES

Siemens SIMODRIVE 611D digital converter systems are used for the servo drive modules for all the servomotors and the spindle motor.



### 3.2.5 CONTROL SOFTWARE

Control software for the CNC and PLC is reloaded into memory each time the control is powered up. Ingersoll provides customized software for operation of this machine. Software for the control contains instructions that the processors execute to perform functions that include:

- Data decoding
- Axis interpolation
- Servo control
- Auxiliary machine functions
- I/O communications functions

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**Machine Tools**

## **CHAPTER 4 - OPERATOR CONSOLE AND PENDANTS**



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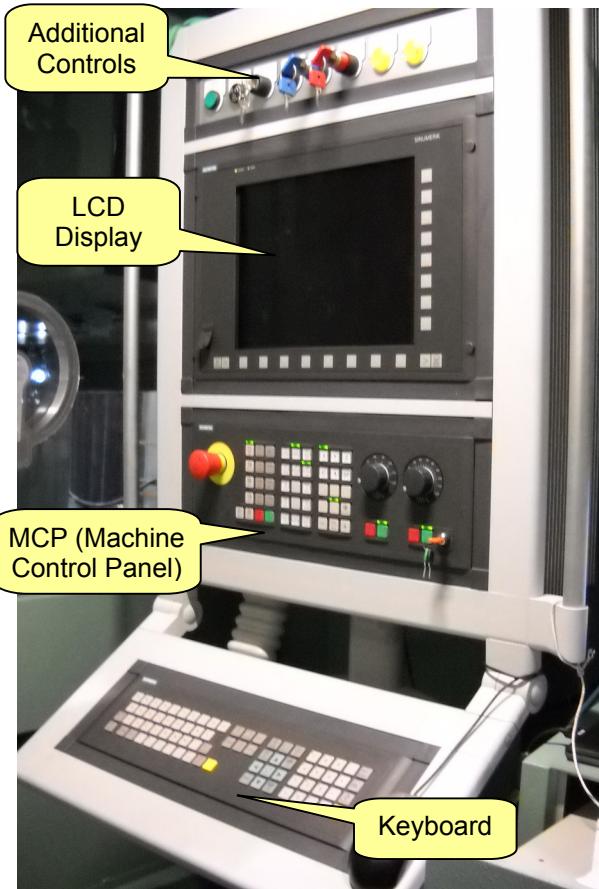


## 4.1 OPERATOR CONSOLE

The main Operator Console provides full control of the machine from a single location. The main Operator Console is mounted on the left side of the machine and includes:

- Siemens OP15 Operator Panel and LCD Display
- Siemens PCU 50 computer
- Machine Tool Builder's Control Panel
- Siemens Keyboard including alpha-numeric keypad, editing/cursor keypad / control keys.
- Additional Controls

The following sections are intended to be a brief overview of the Siemens 840D operation. It is not intended to cover all aspects of operating the Siemens 840D control system. For additional details and information, please see the Siemens 840D Operator's Guide.



### 4.1.1 SIEMENS OPERATOR'S PANEL

The Operator Panel is the monitor for the PCU (Panel Control Unit). A full Siemens keyboard and mouse are supplied.



OP15



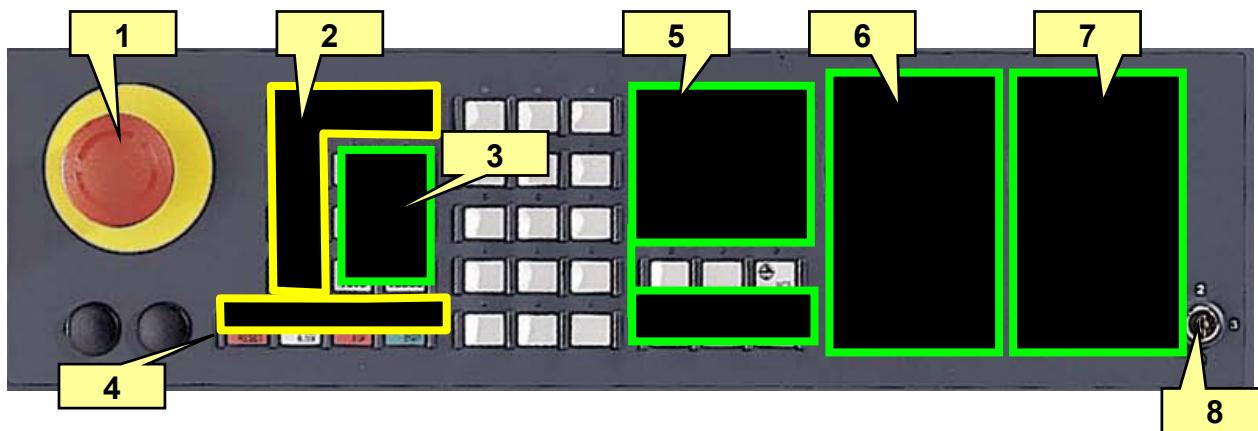
Keyboard

#### 4.1.2 MACHINE CONTROL PANEL

The standard Siemens 19" Machine Control Panel MCP 483C is used as the MTB panel on this machine, mounted below the main operator's panel.

##### 4.1.2.1 STANDARD CONTROLS

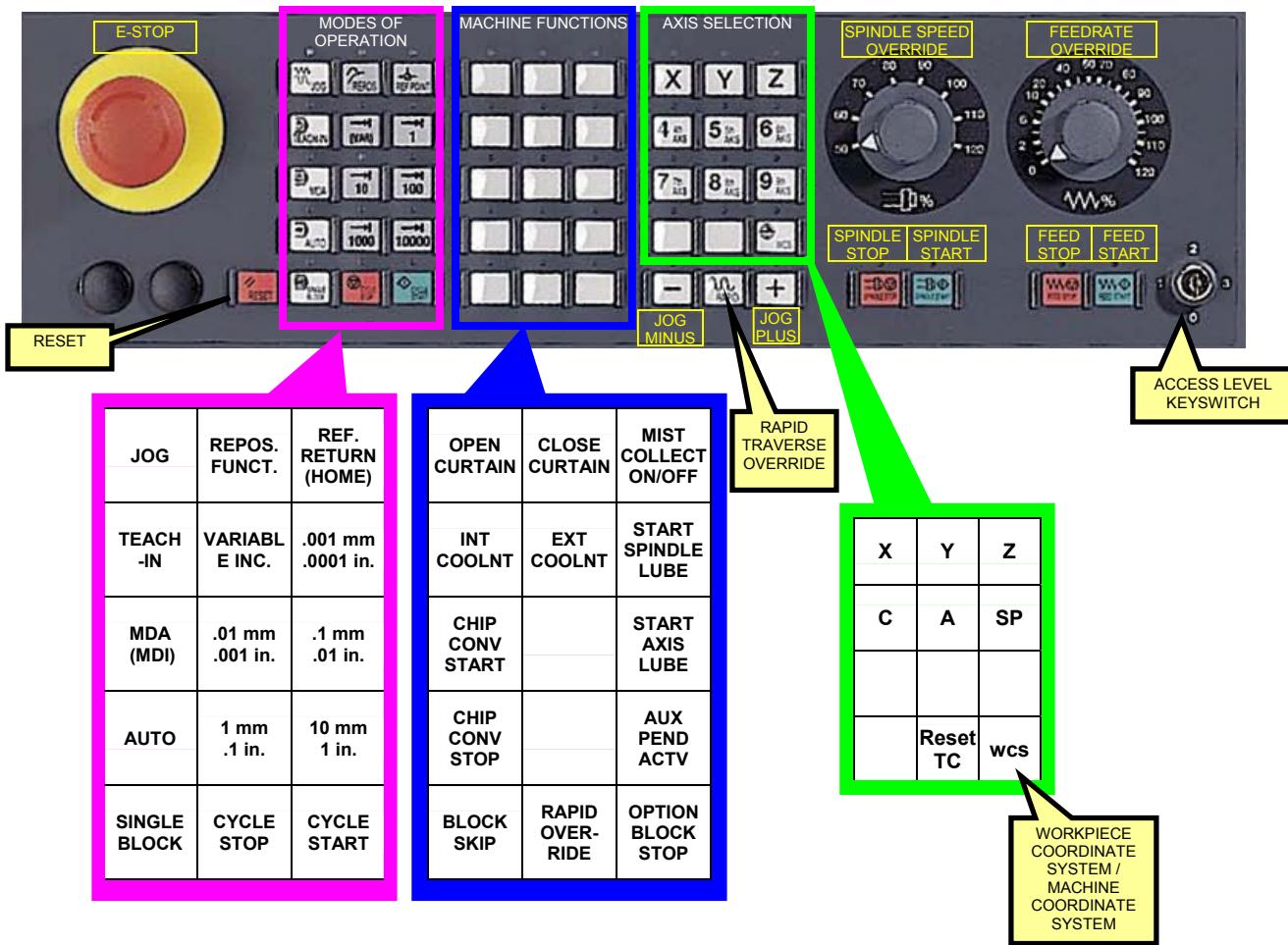
Shown below are the standard pre-assigned controls. Information on the use of these buttons can be found in the Siemens 840D Operator Manual.



#	CONTROL SECTIONS
1	Emergency Stop
2	Mode and Machine Functions
3	Incremental Travel
4	Program Control
5	Axis keys for milling machines
6	Spindle Control
7	Feed Control
8	Keyswitch

#### 4.1.3 CUSTOM CONTROLS

Shown below are the custom assignments labeled by Ingersoll for custom control of this machine:



##### 4.1.3.1 MACHINE FUNCTIONS BUTTONS

CONTROL	DESCRIPTION
MIST COLLECT ON/OFF	This button provides manual control of the mist collection system in the workzone. Pressing this button will toggle the mist collector on and off.
OPEN CURTAIN	Pressing the Open Curtain button will open both mist containment curtains. The curtains will stop at their current position when the button is released. The light will illuminate when both curtains are open.
CLOSE CURTAIN	Pressing the Close Curtain button will close both mist containment curtains. The curtains will stop at their current position when the button is released. The light will illuminate when both curtains are fully closed.

CONTROL	DESCRIPTION
INTERNAL COOLANT	This button provides manual control of the internal coolant through the spindle. The button works in conjunction with part program commands of M12 (Internal Coolant On) and M09 (Coolant Off). This button will toggle the internal coolant on and off.
EXTERNAL COOLANT	This button provides manual control of the external coolant. The button works in conjunction with part program commands of M10 (External Coolant On) and M09 (Coolant Off). This button will toggle the external coolant on and off.
CHIP CONVEYOR START / STOP	Pressing the Chip Conveyor Start button will start all chip conveyors running in a forward direction. When the button is released, the chip conveyors will continue running in the forward direction. The light will illuminate while the conveyors are running. The Chip Conveyor Stop button stops the chip conveyors.
START SPINDLE LUBE	This button can be pressed to manually start the spindle lubrication system. When the light associated with this button is illuminated, it indicates that this lubrication system is running. The Spindle Lube button will flash if a spindle lube fault is present.  Pushing this pushbutton will start a spindle lube cycle and attempt to pump the oil pressure up to the minimum cycle level. If it does not reach the minimum pressure after one lube cycle, logic increments a fault counter and cycles the solenoid off for a few seconds and then on again until either it manages to get the oil pressure up to the minimum cycle level or the counter reaches a set number of allowable failed cycles.
START AXIS LUBE	This button can be pressed to manually start the axes (XYZ) lubrication system. When this light is illuminated, it indicates that the axis lubrication system is running.
AUXILIARY PENDANT ACTIVE	When this light is illuminated, it indicates that one of the auxiliary pendants is turned on. The pushbutton that toggles auxiliary pendant control on and off is located on the auxiliary pendant.
BLOCK SKIP	Pressing this button will toggle the Block Skip function activation On and Off. This lamp "on" informs the operator that one or more program blocks are to be skipped in automatic modes of operation. With Block Skip activation on, a part program block that contains a block skip character "/", will not be executed, skipped.  If no optional skip is selected, the optional block delete lamp is "off", and all program blocks will be executed.
RAPID OVERRIDE	Determines if feedrate override control affects rapid traverse (G00) moves.
OPTIONAL BLOCK STOP	Pressing this button will toggle the Optional Block Stop activation on and off. While the lamp "on", Optional Block Stop is activated, and automatic cycle operation is stopped after a part program block containing M01 is executed. If optional block stop is not selected, the optional block stop lamp is "off". Part program execution will automatically continue, unaffected by the M01 command.

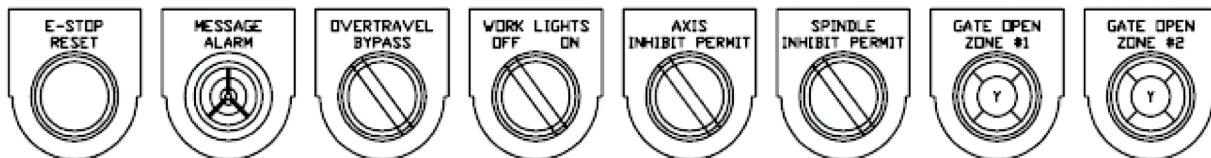
**4.1.3.2 AXIS SELECTION BUTTONS**

The axis selection group of pushbuttons is used to select an individual axis for manual operation, such as jogging.

AXIS	DESCRIPTION
X	This button selects the X Axis (gantry) for manual operations.
Y	This button selects the Y Axis (saddle) for manual operations.
Z	This button selects the Z Axis (ram) for manual operations.
C	This button selects the C Axis (head rotation) for manual operations.
A	This button selects the A Axis (head tilt) for manual operations.
SP	This button selects the Spindle Axis for manual operations.
Reset TC	This button resets the tool changer.

## 4.2 ADDITIONAL CONTROLS

The following additional buttons are mounted in the upper left corner of the operator console.



CONTROL	ACTION
E-STOP RESET	An Emergency Stop Reset pushbutton is provided to activate the servos and bring the machine out of emergency stop once the hydraulic system has been started.
MESSAGE ALARM BUZZER	A beeper is used to indicate that a fault exists. The standard Siemens Alarm Cancel function turns the beeper off.
OVERTRAVEL BYPASS	<p>The Over Travel Bypass key switch allows an authorized person to recover from an axis overtravel. If an axis over travel condition occurs, the machine will go into e-stop. The machine cannot be brought out of e-stop while an axis is outside of the normal travel limits.</p> <p>To recover from this situation, the operator must insert a key into the Over Travel Bypass switch and HOLD the key in the ON position until the machine is out of e-stop and the axis has been jogged back within the work zone.</p> <p>To recover from an axis over travel:</p> <ul style="list-style-type: none"> <li>▪ Insert the key into the Over Travel Bypass switch and hold it in the ON position while completing the following steps.</li> <li>▪ Push the e-stop reset button and wait for the machine to come out of e-stop.</li> <li>▪ Jog the over traveled axis back within its normal travel limits.</li> <li>▪ Release the Over Travel Bypass key.</li> </ul>
WORK LIGHTS OFF/ON	This selector switch is used to turn the work lights under the crossrail on or off.
AXIS INHIBIT/PERMIT	This key selector switch must be in the Permit position to allow axis motion. The key switch is removable in the Inhibit position. It prevents anyone from moving the axes during service or troubleshooting.
SPINDLE INHIBIT/PERMIT	This key selector switch must be in the Permit position to allow spindle rotation. The key switch is removable in the Inhibit position. It prevents anyone from starting the spindle during service or troubleshooting.
GATE OPEN IN ZONE #1	This light will illuminate when any gate in zone #1 has been opened, and not reset.
GATE OPEN IN ZONE #2	This light will illuminate when any gate in zone #2 has been opened, and not reset.

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#### **4.3 AUXILIARY PENDANT**

---

A Siemens B-MPI hand held unit (HHU) serves as the auxiliary pendant on this machine. The small hand-held unit (HHU) comprises a hand wheel for manual control of axes and connects on the left column or on the tool carousel electrical box.

This pendant allows the operator to perform machine functions away from the Main Operator's Console. The operator can use the auxiliary pendant in the work area for close examination of the tool and work piece. Maintenance personnel can use the auxiliary pendant to jog an axis while standing next to the axis motor, for axis tuning or debug.

For safety reasons, machine functions are limited while using the auxiliary pendant.



HHU

## 4.4 HAND-HELD UNIT (HHU)

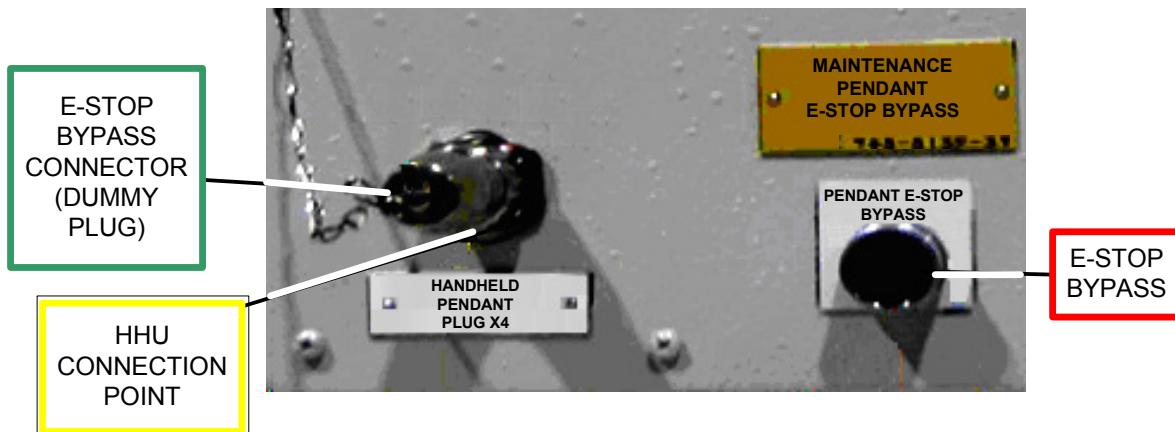


JOG	AUTO		X	EXT COOLNT
FEED STOP	FEED START	PLUS +	Y	INT COOLNT
SPNDL STOP	SPNDL START	RAPID OVERRIDE	Z	TOOL COL-LET
CYCLE STOP	CYCLE START	MINUS -	4	HAND WHEEL

#### 4.4.1 CONNECTION POINT

The auxiliary pendant can be connected to a receptacle located on the left machine column or on the tool carousel electrical box.

The interface consists of a connector for hooking up the HHU, an E-Stop bypass connector (dummy plug) and an E-Stop bypass pushbutton. Any time the HHU or the dummy plug are unplugged, such as moving the HHU from one station to another, it is necessary to press the maintenance pendant E-stop bypass pushbutton until the HHU or dummy plug is plugged back in. Failure to do so will result in the machine being put into E-stop and possibly cause communication errors on the HHU.



#### 4.4.2 ACTIVATING THE HHU

<b>WARNING</b> 	Before operating the machine from the HHU, verify that no person is in a position where they can be injured by machine motion.
--------------------	--

To enable the HHU pendant:

- If axis motion is not idle when attempting to switch control between the main console and the handheld pendant, the feedrate overrides on the Machine control panel and the HHU must match within 10% before control can be switched. The easiest way to avoid problem is to always turn the feedrate overrides on both down to 0% before trying to switch control. If switching control is denied due to mismatched feedrate overrides, the upper right-hand LED on the B-MPI keypad will flash.
- Press the “Enable Remote Pendant” pushbutton on the Machine control panel. The corresponding light will flash and the pushbuttons on the HHU will stop flashing meaning that the pendant can now be activated.

- Turn on the pendant **Enable Key switch**. The main message display on the CNC will post a message saying the HHU has been activated.

To deactivate the HHU:

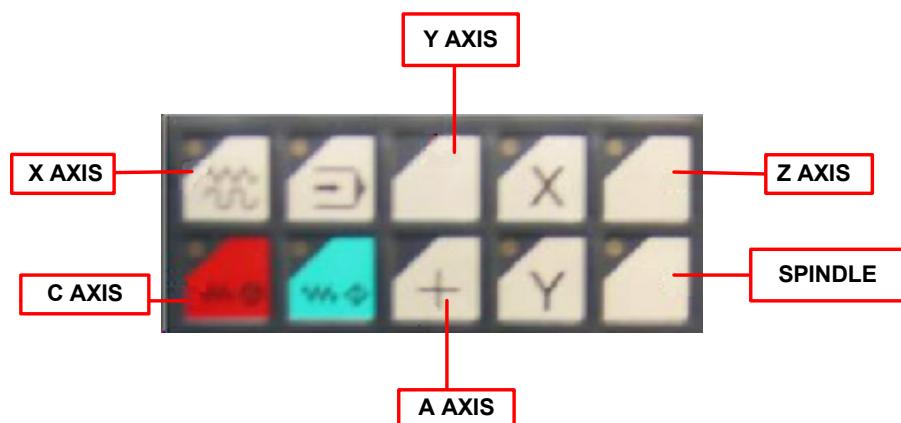
- Turn the pendant enable key switch back to the OFF position.
- Press the “Enable Remote Pendant” on the Machine control panel. The Enable Remote Pendant light should turn off and the lights on the HHU should start flashing again.

#### 4.4.3 SELECTING AN AXIS ON THE HHU

Axis X, Y, Z, C, A and SP can be selected via their axis select button or the axis select sub menu. The axis select sub menu is accessed by pressing the “4” button. The axis-select sub menu displays like this:



To select an axis, you press the button in the position that corresponds to it:



#### 4.4.4 JOGGING AN AXIS ON THE HHU

- Enable the pendant and select the axis you want to jog as described in the steps above. The axis you wish to jog should now be displayed on the HHU screen as well as the current axis position
- Press the “Jog Mode” pushbutton on the HHU, the corresponding light on the jog mode pushbutton should illuminate.
- The HHU is equipped with two “jog enable” or “dead man” switches on either side of the pendant. They inhibit all motion from the pendant until they are pressed and held in. If they are released for any reason, a feedhold will be issued. Press the “Jog Enable” pushbuttons.

- The control must be in feed start mode before any axis movement will be allowed. Check and see if the light corresponding to the “Feed Start” pushbutton is on, if it is not press the “Feed Start” pushbutton.
- Set your feedrate override to the desired level.
- Press the “+” and “-“ keys to jog the axis.

#### 4.4.5 HANDWHEEL CONTROL OF AN AXIS ON THE HHU

- Enable the pendant and select the axis you want to jog as described in the steps above. The axis you wish to jog should now be displayed on the HHU screen as well as the current axis position.
- Press the “Jog Mode” pushbutton on the HHU, the corresponding light on the pushbutton should illuminate.
- Press the **Handwheel Enable** pushbutton on the HHU to enable the handwheel; the corresponding light on the pushbutton should illuminate. The current increment of the handwheel will be displayed under the axis position on the HHU display. To change the handwheel increment, press the “Handwheel Enable” pushbutton again and it should change to the next increment. Continue this process until you arrive at the desired increment.
- Set your feedrate override to the desired level.
- Rotate the handwheel to move the axis.



#### 4.4.6 CYCLE START / STOP

The Cycle Start and Cycle Stop buttons on the HHU gives the operator the means to start and stop the currently loaded part program from the auxiliary pendant. The dead-man switch must be depressed in auto in order to initiate a cycle start, but does not have to be held in to sustain automatic execution.

Note: Automatic operation is prohibited when the operator has entered the work area through one of the interlocked gates.

#### 4.4.7 FEED START / STOP

The Feed Stop button on the HHU gives the operator the means to decelerate the axes, and activate a feedhold on a commanded move, from the auxiliary pendant. The Feed Start button can be used to resume the commanded move.

#### 4.4.8 SPINDLE START / STOP

From the auxiliary pendant, the Spindle Start and Spindle Stop buttons on the HHU gives the operator the means to start and stop the spindle, based on the current loaded spindle command.

#### 4.4.9 EXTERNAL COOLANT

This button provides the operator with manual control of the External Coolant. Pressing the button toggles external coolant on or off. When the external coolant is on, the button will be illuminated. This button works in conjunction with part program commands of M10 (External Coolant On) and M09 (Coolant Off).

#### 4.4.10 INTERNAL COOLANT

This button provides the operator with manual control of the Internal Coolant. Pressing the button toggles internal coolant on or off. When the internal coolant is on, the button will be illuminated. This button works in conjunction with part program commands of M12 (Internal Coolant On) and M09 (Coolant Off).

#### 4.4.11 TOOL COLLET

Pressing this button causes the tool collet to toggle open or closed on the spindle units that support automatic tool changing. If the tool collet is closed, then pressing this button will open the tool collet, and if the tool collet is opened, this button will toggle it closed.

<b>WARNING</b> 	<p>Opening the tool collet will release any tool in the spindle. The operator must be prepared to grasp the tool before pressing the Tool Collet button.</p>
---	--

#### 4.4.12 EMERGENCY STOP

A large red Emergency Stop pushbutton is located on the top of the auxiliary pendant. When pressed, this Emergency Stop button places the entire machine into Emergency Stop condition. All machine axis drives, control power, hydraulics, lubrication and coolant motors will be stopped. Part of the recovery from E-stop process involves twisting the red button, then pulling up to reset it.

# **CHAPTER 5 - MACHINE AXES**



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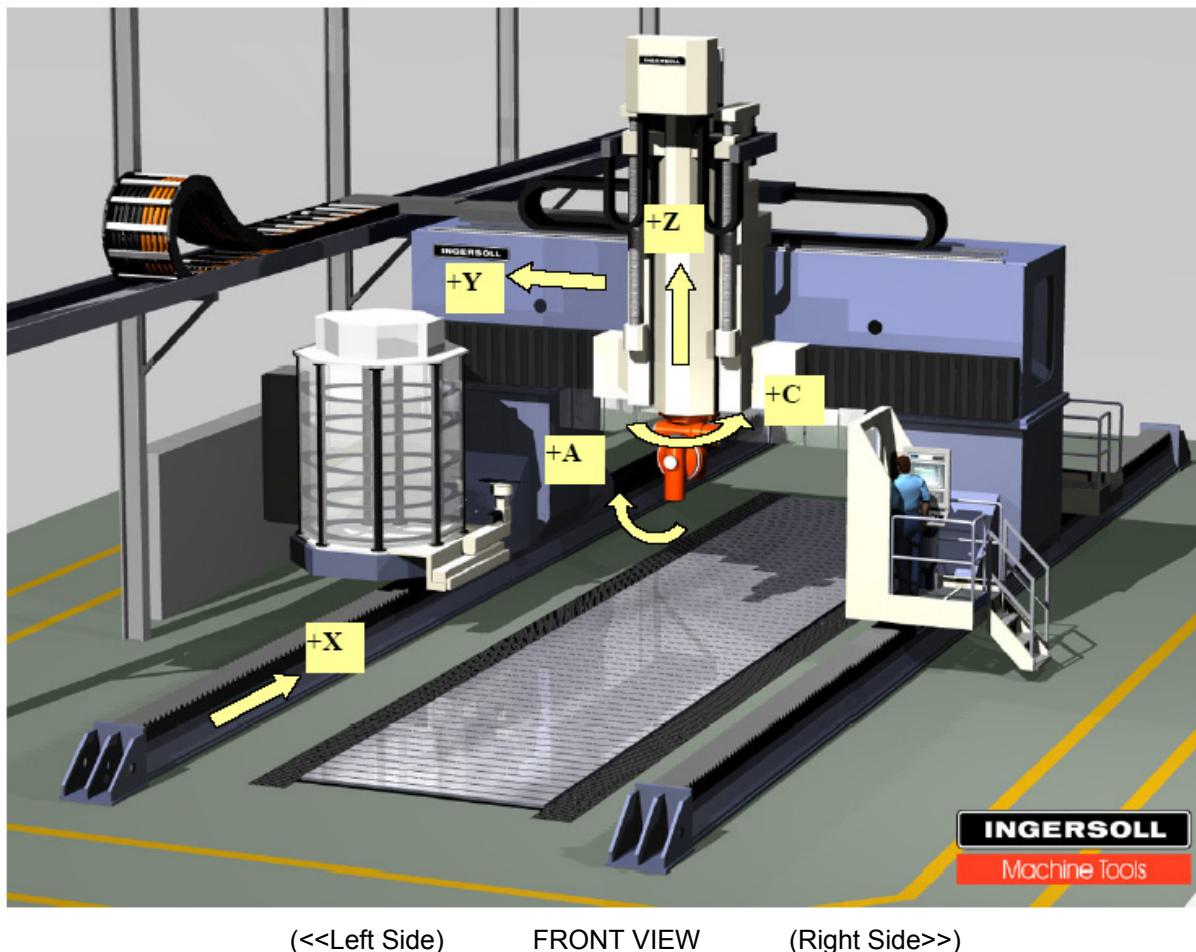
## CHAPTER 5 - MACHINE AXES

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## 5.1 AXIS CONFIGURATION

The Ingersoll MasterMill Gantry machine has a ram (Z-Axis) attached to a crossrail with support columns. The basic machine structure is comprised of a bed, table, columns, crossrail, and ram with a main spindle. Spindle units can be attached to the end of the ram. This machine is supplied with one spindle unit with an additional swivel axis. This spindle unit is permanently attached to the ram. All axes have digital drives for maximum performance.



The machine is comprised of the following axes:

- (4) contouring axes: X, Y, Z, C
- (1) two-winding spindle SP in the ram
- (1) additional contouring A-axis in the spindle unit

The servomotors controlling these axes are:

- X-axis: (4) Phase torque motors
- Y-axis: (2) Phase torque motors
- Z-axis: (2) Siemens servo motors
- C-axis: (1) Phase torque motor

- A-axis: (1) Phase torque motor
- Spindle SP (1) dual winding Phase torque motor in ram

All motors use standard Siemens drives with standard signal monitoring (motor temperature, drive current, etc.).

This chapter describes the features associated with the main machine axes. Refer to the Spindle chapter for details on the spindle motor and the Spindle Unit chapter for a description of the unique features of the spindle units.

### **5.1.1 X-AXIS COLUMNS**

X-axis is the longitudinal travel of the machine's two columns along the runways. It is driven in gantry mode by two racks and double preloaded pinions. X-axis is driven by four (4) Phase torque motors arranged in a gantry format with master/slave coupling. The master/slave motors push against each other, ensuring that there is no looseness in the system. Lubrication for the X-axis pinions and bearing trucks is accomplished through an automatic lube system.

Telescoping, steel way covers are furnished in the front, and rear of the columns. Way covers are slanted so that coolant and chips do not collect on them. The way covers have replaceable wiper seals between the sections.

The torque motors require a separate encoder mounted directly to the rotor of the motor for speed feedback. Feedback is accomplished using four (4) Heidenhain ECN113 rotary encoders. Two (2) Heidenhain linear scales provide positional feedback.

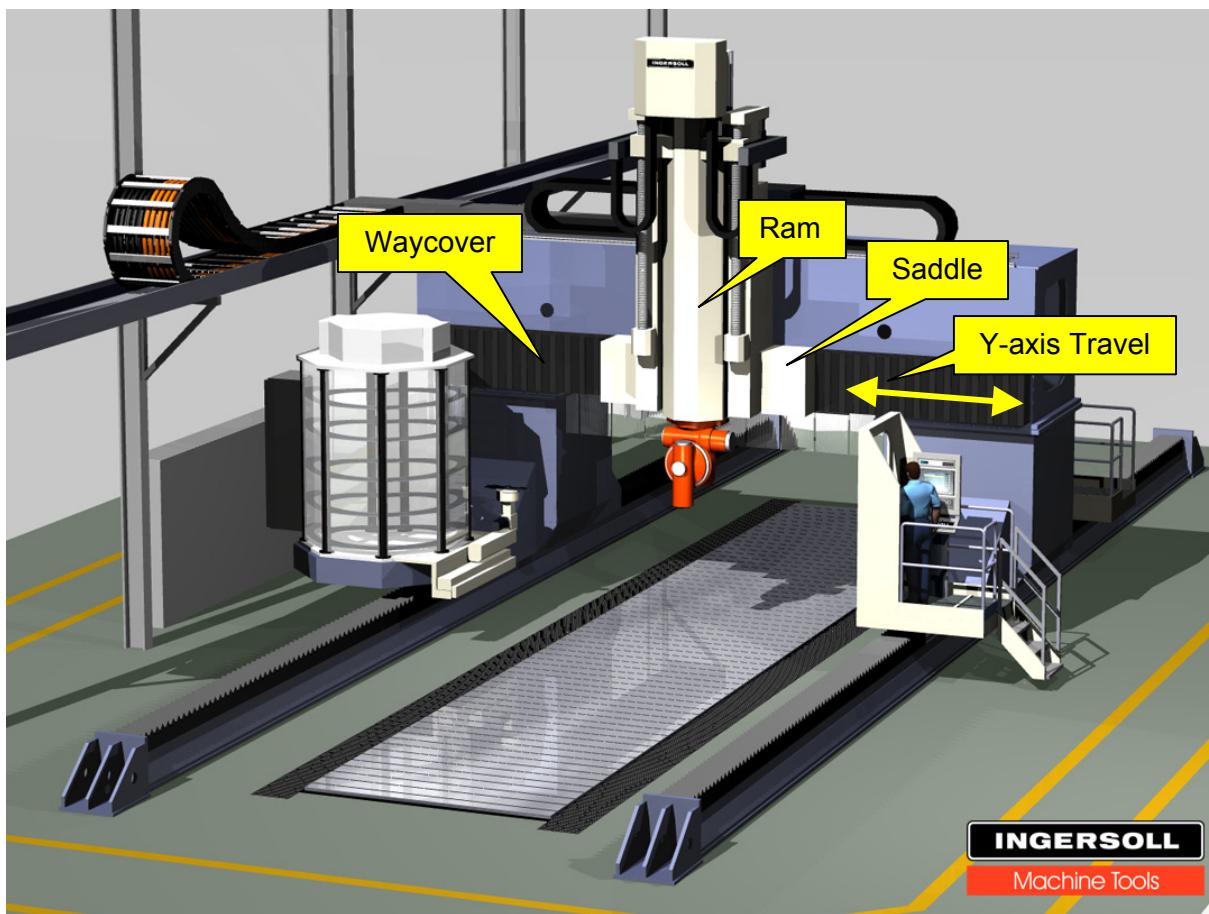
Guiding of the X Axis is comprised of Linear Rails providing low friction and high rigidity. Precision of motion is achieved by the rail preload.

### 5.1.2 Y-AXIS SADDLE

The saddle travels on positive and auxiliary ways along the crossrail, and provides support for the ram, which is mounted within the saddle.

Guiding of the Y Axis is accomplished by linear rails providing low friction and high rigidity. The rails are protected by wipers. Y-axis way covers are provided for the right hand and left hand sides of the lower rail.

Precision of motion is achieved by the rail preload. The rail carriages are fixed to the backside of the Saddle. Lubrication for all carriages is accomplished through an automatic grease lubrication system.



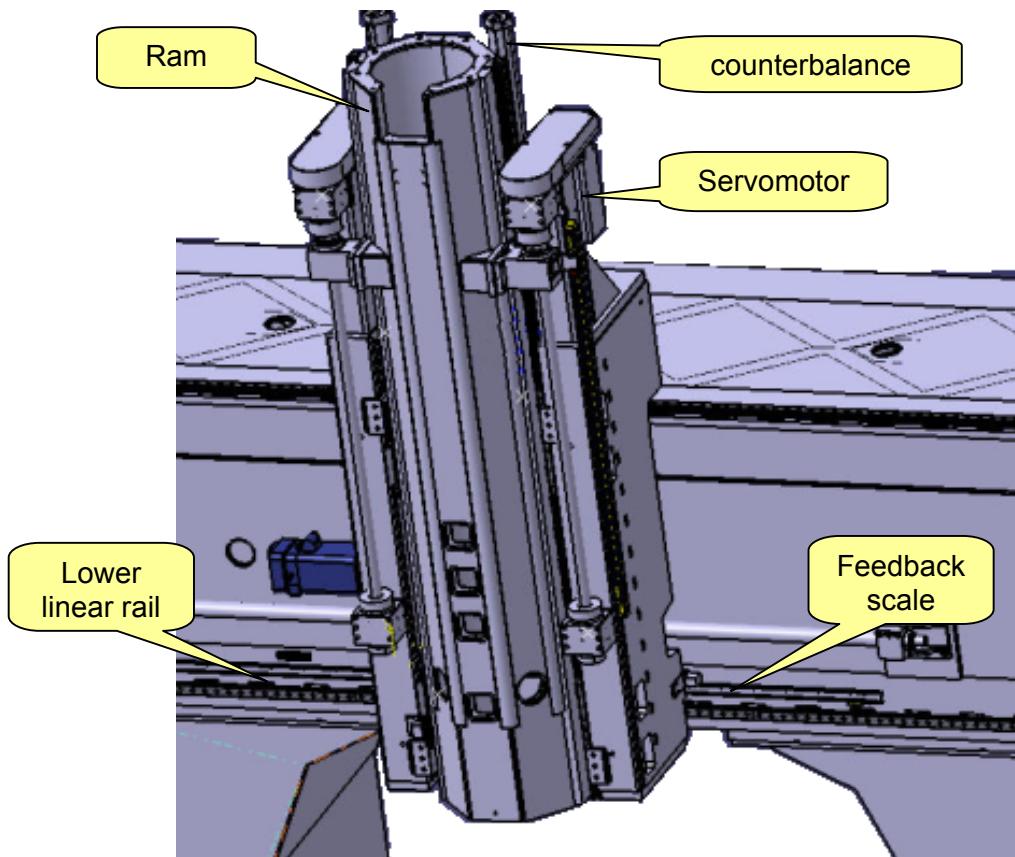
### 5.1.3 Z-AXIS RAM

The Z-axis ram is carried on the saddle of the machine. Ram vertical motion is driven by two high precision preloaded ball screws and preloaded nuts designed for ball bearing recirculation. Each ballscrew is driven by a servomotor. The ram Z-axis uses a passive counterbalanced system. The weight of the ram is assisted by a hydraulic counterbalance on each ballscrew by two hydraulic cylinders. In the event of a power loss, mechanical brakes and motor brakes prevent further motion of the ram assembly. An encoder integral to each servomotor ensures speed feedback. A Heidenhain linear scale provides positional feedback.

Guiding of the Z Axis is accomplished by Linear Rails providing low friction and high rigidity. The rails are protected by wipers.

Precision of motion is achieved by the rail preload. The rail carriages are fixed to the saddle.

Lubrication for all carriages is accomplished through an automatic, grease lube system.



RAM AND SADDLE ASSEMBLY

**5.1.4 C-AXIS ROTATION**

The C Axis is the rotary motion of the ram around Z-axis. C-axis is driven by a Phase torque motor. The torque motor requires a separate encoder mounted directly to the rotor of the motor for feedback. Feedback is accomplished using a Heidenhain ERA180 rotary encoder.

**5.1.5 A-AXIS TILT**

The A-Axis, which is the tilt axis on some spindle units, is driven by a Phase torque motor through a gear train.

The torque motor requires a separate encoder mounted directly to the rotor of the motor for speed feedback. Positional feedback is accomplished using a Renishaw angle encoder.

## 5.2 AXIS MOTORS

The axes of the machine work in concert to provide the motion required for this process. The table below lists each of the axes, along with a descriptive name, the axis type, and the axis motor(s).

Axis	Description	Axis Type	Axis Motor
X	Gantry	4 motor master/slave and gantry drive coupling	(4) Phase TK-450-300-33
Y	Head Saddle	2 motor master/slave drive coupling	(2) Phase TK-450-300-33
Z	Ram	2 motor master/slave drive coupling	(2) Siemens 1FT6 134-6SF71-1AB0
C	Head Rotation	1 motor	(1) Phase TK-570-300-55
A	Tilt / Swivel Axis	1 motor	(1) Phase TK-240-160-050
SP	Spindle	2 winding motor	(1) Phase TK-340-540-010

### 5.2.1 MASTER/SLAVE CONTROL

The Y and Z axes use two motors in a master/slave drive coupling. Two motors are used to generate additional torque in a master/slave control when a single motor cannot generate enough torque to move the mechanism.

Master/slave control is also used to add a pre-load torque, with the two motors always pulling slightly in opposite directions. This opposition reduces the effect of the backlash that occurs between the master and slave axes when the two motors are connected through a series of gears.

The CNC handles master/slave control as a single axis control, however, the control of the servo parameters and monitoring of the servo alarms are handled as two axes, master and slave.

The master motor is used to carry out positioning from the single position feedback device; the slave motor is only used to generate additional torque.

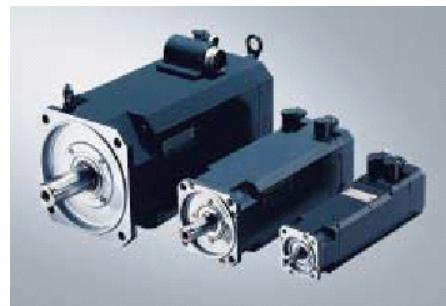
### 5.2.2 MASTER/SLAVE GANTRY CONTROL

A *Master/Slave Gantry Control* is used where a 4-motor, master/slave axis, anti-backlash, load sharing, full synchronous system is required.

Each half of the X-axis gantry system on this machine uses a 2-motor, master/slave axis, anti-backlash, load sharing system.

### 5.2.3 SERVO MOTORS

The Z-axis uses Siemens 1FT6 AC servomotors, which are compact permanent field servomotors. These motors with integrated encoders are controlled using the SIMODRIVE 611D digital converter system drive. These motors are built for dynamic performance, high precision machine tool applications.



SIEMENS 1FT6 MOTORS

### 5.2.4 TORQUE MOTORS

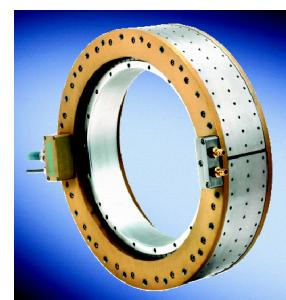
The X, Y, C and A axes use Phase TK torque motors. This motor is a liquid-cooled permanent-magnet three-phase motor. X-axis uses four motors in an anti-backlash, master/slave, gantry drive coupling system. Y-axis uses two motors in an anti-backlash master/slave configuration. C-axis and A-axis each use one torque motor. The spindle is powered by a 2-winding Phase torque motor.

The motors are supplied as unassembled components that are closely integrated into the machine tool design. Bearings and a rotary encoder are required to form a complete drive unit.

Together with separate encoders, and the digital SIMODRIVE 611D digital converter system drive converters, the Phase torque motors form a complete drive system.

Advantages to these torque motors are:

- Extremely high power density
- High torque with a compact design and low envelope dimensions
- Water cooling to increase the rated power
- The motor is directly flanged to the machine assembly
- Fewer gearbox components in the mechanical transmission which are subject to wear



TORQUE MOTOR

#### 5.2.4.1 TORQUE MOTOR COMPONENTS

The following components are required for the complete torque motors assembly:

- **Stator**

This is the iron core and a 3-phase winding. The winding is cast in resin so that the power loss can be easily dissipated and the motor can force-cooled using a liquid cooler.

- **Rotor**

This is the reactionary part of the motor. It is a cylindrical hollow steel shaft that has permanent magnets around its circumference.

- **Cooling Jacket**

A cooling jacket fits around the torque motor. The cooling medium (water) must be fed in and discharged using two holes in this jacket.

- **Bearings**

Torque motors are build-in motors for directly driven rotary or swiveling axes. In order to configure a complete drive unit, a bearing is required between the stator and rotor.

- **Brake**

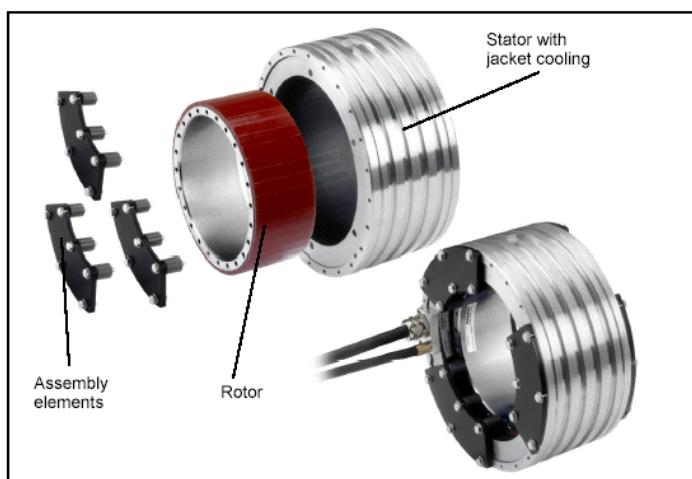
Each axis has one separate mechanical brake/clamp.

- **Motor Encoder**

An integral encoder is not included on the torque motor. A separate encoder is required for each motor (2 per axis), for motor commutation and velocity control.

- **Position Encoder**

In addition to the motor encoders, an angular position encoder is required on the final member of the mechanical drive system.



### 5.2.5 MOTOR COOLING

The torque motors require cooling to dissipate the heat generated in the stator winding due to power loss. A cooling circuit, with chiller and cooling water, is used to remove heat from the X, Y, C, A, and spindle torque motors.

A cooling jacket fits around the torque motor. The cooling medium (water) must be fed in and discharged using two holes in the cooling jacket. An anti-corrosion agent must be added to water as cooling medium.

Cooling water flow is monitored for the X, Y, C, and A axes motors and the spindle motor.

### 5.2.6 MOTOR OVER TEMPERATURE

For the Z-axis with Siemens servomotors, the motor over temperature signal originates within the digital servo drives and is passed to the PLC. When this condition is detected

for any axis, the controller initiates an immediate emergency stop, bringing all of the axes to a halt, and then braking each in place. By enacting an emergency stop, the axes are held in place by the motor brakes as opposed to trying to maintain the position by servo control, which continues to work the motor. Braking the axes allows the motors to cool.

The X, Y, C and A axes and the spindle have torque motors equipped with temperature monitoring circuits to protect the stator against high thermal temperatures and to monitor the stator temperature during commissioning and operation. When the torque motors reach a critical temperature, the current to the stator is immediately switched off and a message is posted.

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## **5.3 BRAKES AND FEEDBACK**

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### **5.3.1 AXIS BRAKES**

The X-axis and Y-axis utilize electronic (dynamic) braking. When an e-stop occurs, a contactor engages, which shorts the motor leads together, creating an electronic holding brake.

The Z-axis servomotors have integral brakes on the motors. The two Z-axis motors also have separate mechanical brakes.

The C-axis is held in position with a hydraulic clamp/brake. For the detailed operation of this clamp, refer to the C-axis Clamping section in this chapter.

A-axis is not equipped with a clamp or brake. The A-axis uses a hydraulic pre-load on the worm drive to hold the axis in position during machining operations.

The spindle has no brakes.

The Z and A axes are considered vertical axes. The hardware emergency stop circuit incorporates a short delay before removing power from these servos. With emergency stop pending during the delay period, logic exerts a feedhold on the axes in an effort to bring them to a controlled stop. After the emergency stop circuit delay time expires, drives are disabled and the brakes are applied.

### **5.3.2 AXIS FEEDBACK**

The X, Y, and Z axes use Heidenhain LB382C distance coded scales for position feedback. Only a short move is required for homing axes with these distance coded scales. The X and Y axes also have Heidenhain ECN 113 rotary encoders (one on each torque motor) for velocity feedback.

C-axis has a Renishaw RESM A 550 incremental encoder on the torque motor. A standard homing sequence is required for the C-axis torque motor.

A-axis has a Heidenhain RCN 226 16384-line Endat absolute encoder on its motor. A-axis also uses a Renishaw RESM A 550 incremental encoder for axis position feedback.

The spindle uses motor encoder feedback.

**Axis Brakes and Axis Feedback Scales** are listed in the table below:

Axis	Brake	Feedback
X	Dynamic braking (electronic)	(4) Heidenhain ECN 113 rotary absolute for velocity feedback (2) Heidenhain LB382C Distance coded scale for position feedback
Y	Dynamic braking (electronic)	(2) Heidenhain ECN 113 rotary absolute for velocity feedback (1) Heidenhain LB382C Distance coded scale for position feedback
Z	Mechanical brake (2) + Motor brake (2)	(1) Heidenhain LB382C Distance coded scale
C	Hydraulic clamp	(1) Renishaw Angle Encoder RESM 550
A	None	(1) Heidenhain RCN226 rotary encoder + (1) Renishaw RESM A 417 angle encoder for position feedback
SP	None	(1) L & B GEL 244 512 line incremental

### 5.3.3 SEPARATE MOTOR ENCODERS

Each torque motor requires a separate encoder mounted directly to the rotor of the motor. This encoder is used for motor commutation and for motor velocity control.

An absolute encoder with EnDat interface, or an incremental encoder with 1Vpp signal, is required to interface the torque motor to the SIMODRIVE 611D digital converter drive.

- **X-axis** and **Y-axis** use a Heidenhain ECN 113, which is a 2048 line incremental encoder on each of the torque motors.



- **C-axis** has a Renishaw RESM A 550, which is an 86,400 line incremental encoder on its motor.



- **A-axis** has a Heidenhain RCN226 rotary encoder, which is a 16,384 line endat encoder.

### 5.3.4 C-AXIS CLAMPING

Motor	Reset, E-stop	Clamp	Unclamp	Switches / Homing
Phase TK-570-300-55 torque motor	Does not reset (default) M-code.	Mechanical spring and hydraulic assist. M86	Hydraulic. M87	Over travel limit switches (plus and minus). Home switch.

#### Unclamp Sequence:

- Receive M87 command.
- Verify C-axis motion is stopped.
- Unclamp C-axis by applying hydraulic pressure; turn on Unclamp C-axis solenoid.
- Verify C-axis is unclamped; verify C-axis Unclamped with pressure switch.
- Enable C-axis (axis #4): Set drive control state, and servo enable = on.
- The C-axis clamp is a multi-piece wedge type clamp device. If a section does not fully or properly disengage, the motor torque will be able to overcome the clamp friction, and force the wedge clamp to disengage.

#### Clamp Sequence:

- Receive M86 command.
- Verify C-axis motion is stopped.
- Turn off Unclamp C-axis solenoid, allowing C-axis clamping mechanism to clamp C-axis in position.
- Verify C-axis Unclamp with pressure switch.
- Disable C-axis (axis #4): Set drive control state, and servo enable = off.

#### Unclamp Sequence due to C-axis Move command:

- Receive C-axis move command (with C-axis clamped, M86 active).
- Unclamp C-axis by applying hydraulic pressure; turn on Unclamp C-axis solenoid.
- Verify C-axis is unclamped; verify C-axis Unclamped with pressure switch.
- Enable C-axis (axis #4): Set drive control state, and servo enable = on.
- Perform C-axis move.
- Turn off Unclamp C-axis solenoid, allowing C-axis clamping mechanism to clamp C-axis in position.
- Verify C-axis Unclamp with pressure switch.
- Disable C-axis (axis #4): Set drive control state, and servo enable = off.
- **Manual** jogging of C-axis is performed from the main operator console or the B-MPI pendant.

#### 5.3.4.1 INTERLOCKS

The C-axis position encoder is continuously monitored during C-axis clamped operations. If the C-axis moves out of position, an immediate feed hold is issued, and a message is posted.

The C-axis Unclamped pressure switch is continuously monitored during machine operations. If the pressure drifts outside the allowable ranges while C-axis is clamped, or while C-axis is unclamped, an immediate feed hold is issued.

### 5.3.5 A-AXIS WORM DRIVE PRELOAD

The Orthogonal Spindle Unit OH150 (Offset Swivel) spindle unit has a contouring A-axis, which includes a worm drive.

Motor	Details	Reset, E-stop	Switches / Homing
(1) Phase TK-240-160-050 torque motor for worm drive located in the spindle unit.	Renishaw RESM incremental encoder for position loop.	Does not reset (default) M-code.	Over travel limit switches (plus and minus). Home switch.

#### Enable A-axis:

- Receive M92 (#) command (Load Spindle Unit Attachment).
- Load spindle unit and read spindle unit ID number.
- Verify spindle unit supports an A-axis (data from spindle unit data tables).
- Set the A-Axis worm drive pre-load pressure with the Clamp Pressure Select proportional (data from spindle unit data tables).
- Apply A-axis worm drive pre-load; turn on the Unclamp A-axis solenoid.
- Verify A-axis worm drive pre-load pressure is correct, with analog pressure switch. If this signal falls outside of the acceptable pressure range for the commanded A-axis pre-load, an immediate e-stop occurs.
- Enable A-axis (axis #5): Set drive control state, and servo enable = on.

#### Disable A-axis:

- Receive M92 (0) command (Unload Spindle Unit Attachment).
- Remove A-axis worm drive pre-load; turn off the Unclamp A-axis solenoid.
- Set A-Axis Clamp Pressure Select proportional valve to zero.
- Verify A-axis worm drive pre-load is removed, with analog pressure switch. If this signal falls outside of the acceptable pressure range for the commanded A-axis pre-load, an immediate e-stop occurs.
- Disable A-axis (axis #5): Set drive control state, and servo enable = off.
- Unload spindle unit.

#### A-axis Worm Drive Pre-load:

The A-axis uses a hydraulic pre-load on the worm drive. The A-axis pre-load pressure is set by a proportional valve, based on a data table setting. An analog pressure switch is used to monitor the pre-load pressure. The pressure must fall within an acceptable range for the type of SU mounted.

- A-axis worm drive pre-load is not changed during e-stop.

**Manual** jogging of A-axis is performed from the main operator console or the B-MPI pendant.

## 5.4 HOMING

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X, Y, and Z axes use Heidenhain distance coded scales, so only a short move is required for homing.

C-axis has one (1) Phase torque motor with a Renishaw RESM A 550 incremental encoder. One home switch is provided.

A-axis has one (1) Phase torque motor. A-axis has a Heidenhain RCN 226 16384-line Endat absolute encoder on its motor. A-axis also uses a Renishaw RESM A 550 incremental encoder for axis position feedback. The A-axis has a worm drive that requires a hydraulic pre-load.

The spindle does not require homing.

### 5.4.1 HOME POSITIONS

**Axis Home Positions** are listed in the table below:

Axis	Home Direction	Home Position	Home Sequence
X	Plus	Varies	Short move with distance coded scale
Y	Plus	Varies	Short move with distance coded scale
Z	Plus	Varies	Short move with distance coded scale
C	Plus	+ 0 °	Standard incremental sequence
A	Plus	+ 90 °	Standard incremental sequence after spindle unit is attached
SP	n/a	n/a	n/a

### 5.4.2 HOMING ROUTINES

**To REFERENCE (HOME) an axis:**

1. Make sure the axes are in a safe position to reference.
2. Select JOG or MDA mode by pressing one of these pushbuttons.
3. Select REF POINT by pressing the REF POINT pushbutton. (Light in pushbutton illuminates and stays on until cancelled by another mode).
4. Select the designated axis by pressing the appropriate pushbutton corresponding to the axis. (Light in axis pushbutton illuminates and stays on until canceled by another axis being picked or an "auto" mode is selected)

5. Determine the correct direction, then depress the **JOG PLUS** or **JOG MINUS** pushbutton. Pressing the wrong button will cause no action.
6. Once an axis has started homing, another axis can be initiated (step 4).

## 5.5 TRAVEL AND FEEDRATES

**Axis Travel Limits** and **Axis Feedrates** are listed in the table below:

Axis	Axis Description	Travel	Travel Limits		Feedrate
			Minus	Plus	
X	Gantry	16,500 mm (649.6 in)	-8250 mm	+8250 mm	30,000 mm/min (1181 in/min)
Y	Head Saddle	4000 mm (157.4 in)	-2000 mm	+2000 mm	30,000 mm/min (1181 in/min)
Z	Ram	1900 mm (74.8 in)	+915 mm	2815 mm	30,000 mm/min (1181 in/min)
C	Head Rotation	+/- 200 °	- 200 °	+ 200 °	10 rpm
A	Spindle Unit Tilt / Swivel	+/- 110 °	- 110 °	+ 110 °	5 rpm
SP	Spindle	360 ° rollover	n/a	n/a	3,300 rpm

### 5.5.1 OVER TRAVELS

This machine has software over travel limits and hardware over travel switches. The hardware over travel switches are mounted just outside the software travel limits. After the axes are homed, the axes are software protected from being commanded to the over travel positions.

X, Y, Z, A, and C axes use the software over travel protection feature of the Siemens CNC. These axes also have emergency over travel limit switches (plus and minus) interlocked in hardware to de-energize the servo drives, and immediately apply the motor brakes for the corresponding axis when travel is exceeded. These over travel switches are monitored in the PLC logic.

The axis plus or minus over travel condition is detected by both the PLC and the CNC. If any axis contacts a hardware over travel switch, as indicated by the input going false, the control shall implement an immediate Emergency Stop, while simultaneously displaying the over travel message of the appropriate axis. The maximum over travel switches are also in a hardware emergency stop string which will disable all servo drives one second after being contacted. The logic shall cause an E-stop first. The hardware switches are a back-up in the event that the logic fails.

The PLC provides for the recovery from over travel by allowing the operator to bypass the emergency stop in order to jog the axis away from the over travel condition. Once the axis is off the over travel, then the fault can be cleared and machine operation resumed.

### 5.5.2 RECOVER FROM AN AXIS OVER TRAVEL

To recover from an axis over travel, follow the instructions below.

- Insert the key into the Over Travel Bypass switch and hold it in the ON position while completing the following steps.
- Push the e-stop reset button and wait for the machine to come out of e-stop.
- Select the over traveled axis. X, Y, Z, C, or A can be selected by pressing the corresponding pushbutton on the axis selection section of the Machine Control Panel. The corresponding light on the pushbutton should come on to show which axis is currently selected.
- Press the “Jog” pushbutton, the corresponding light on the pushbutton should come on.
- Push the “+” or “-“ pushbutton that is in the **opposite** direction of the over-travel fault message. For example if you had an “X axis hardware over-travel plus” alarm you would select X, JOG, and then press the “-“ key while still holding the Over Travel Bypass key on.
- As soon as the axis has moved off the over-travel switch (usually a couple of inches is enough) and back within its normal travel limits, you can let off the “+” or “-“ pushbutton.
- Release the Over Travel Bypass key.
- Now if you hit the message reset button on the CNC, the over travel alarm should be cleared and you can resume normal operations.

---

## 5.6 AXIS E-STOP ROUTINES

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### 5.6.1 COMING OUT OF E-STOP

The following is the start-up sequence that is applied to all servo drives simultaneously when coming out of E-stop.

1. Wait for servo enable request from the E-stop logic.
2. Verify that all of the following conditions are true:
  - Main pneumatic system is enabled and operational.
  - No motors are over temperature.
  - The Siemens drives are “Ready”.
  - No axis is on an over travel limit, or the bypass condition is active.

3. Turn on the “NOT CNC E-STOP” output.
4. Enable the Siemens digital drives. This is accomplished by setting the appropriate enable output that will enable each drive.
5. After a delay of 3 seconds, simultaneously release all brakes.  
If the proper response to the brakes being released is not recognized in logic within 5 seconds after commanding their release, an immediate feedhold and cut free spindle stop will be implemented. Six (6) seconds after the feedhold, the logic will implement an immediate emergency stop. The associated message will tell why power-up was aborted.
6. Send the servo's enabled signal back to the E-stop logic.

### 5.6.2 GOING INTO E-STOP

The following is the power-down sequence that is applied to all drives simultaneously whenever going into E-stop.

1. Wait for servo disable request from the E-stop module.
2. Immediately set all appropriate brakes.
3. Immediately disable X, Y, C, and the spindle axes.
4. Immediately turn off output "NOT CNC E-STOP".
5. After a delay of 1 second, disable Z and A axes. This gives the brakes a chance to grab the vertical axes while still holding servo lock to prevent the axes from falling.
6. Implement software E-stop, if E-stop was not initiated first.

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## 5.7 AXIS DEBUG SCREENS

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The Siemens CNC offers several screens to help a user debug axis control functions. The “Service Axis” and “Service Drive” are two of these screens.

### 5.7.1 SERVICE AXIS SCREEN

The information in the “Service Axis” display is used to:

- check the set point branch (e.g. position set point, speed set point, spindle speed set point program)
- check the actual-value branch (e.g. position actual value, measuring system  $\frac{1}{2}$ , actual speed value), optimize the position control of the axis (e.g. following error, control difference, servo gain factor)
- check the entire control loop of the axis (e.g. through position set point/actual-value comparison and speed set point/actual-value comparison)
- check hardware faults (e.g. encoder check: If the axis is moved mechanically, then the position actual value must change)

- set and check axis monitoring functions

**To display the “Service Axis” screen on the CNC:**

1. On the Siemens CNC monitor, press the “*Menu Select*” key 
2. Select the horizontal softkey “*Diagnosis*”.
3. Select the menu headed “*Service displays*”.
4. The horizontal softkey bars change. Select “*Service Axis*” softkey.
5. The “*Service axis*” window displays information about the machine axis together with axis name and axis number.
6. You can page up and down with the “*Axis +*” and “*Axis –*” softkeys. The service values of the next (+) and the previous (–) axis are displayed.
7. You can display a selection of important axis data by pressing the “*Partial view*” key.

### 5.7.2 SERVICE DRIVE SCREEN

The information contained in the “*Service drive*” display is used to:

- check the status of the enable and control signals (e.g. pulse enable, drive enable, motor selection, set point parameter set)
- check the status of the drive operating modes (e.g. setup mode, parking axis)
- display temperature warnings check the current set point/actual-value display (e.g. position actual value measuring system 1/2, speed set point, speed actual value)
- check the drive status
- display the current ramp-up phase
- display a group error message (message status class 1)
- display the status messages of the drive (e.g. threshold torque not reached, actual speed = set speed)

**To display the “Service Drive” screen on the CNC:**

1. On the Siemens CNC monitor, press the “*Menu Select*” key 
2. Select the horizontal softkey “*Diagnosis*”.
3. Select the menu headed “*Service Displays*”.

4. The horizontal softkey bars change. Select “Service Drive” softkey.
5. The “Service Drive” window displays information about the axis drive together with axis name and number.
6. You can page up and down with the “Drive +” and “Drive –“ softkeys. The service values of the next (+) and the previous (–) drives are displayed.

## 5.8 INPUTS & OUTPUTS

The following inputs monitored by the PLC must be in their appropriate states to allow any motion on the corresponding axis. The outputs are set by logic to enable the appropriate axis.

AXIS INPUTS/OUTPUTS			
TYPE	NAME	ADDRESS	DESCRIPTION
DRIVES	RACK #1 INFEED MODULE FAN RUNNING	I032-0	
	RACK #2 INFEED MODULE FAN RUNNING	I032-1	
	RACK #3 INFEED MODULE FAN RUNNING	I032-2	
	RACK #4 INFEED MODULE FAN RUNNING	I032-3	
	RACK #5 INFEED MODULE FAN RUNNING	I032-4	
	X-AXIS AMPLIFIER FAN RUNNING	I032-5	
	XT-AXIS AMPLIFIER FAN RUNNING	I032-6	
	XG-AXIS AMPLIFIER FAN RUNNING	I032-7	
	XGT-AXIS AMPLIFIER FAN RUNNING	I033-0	
	Y-AXIS AMPLIFIER FAN RUNNING	I033-1	
	YT-AXIS AMPLIFIER FAN RUNNING	I033-2	
	SP1 SPINDLE AMPLIFIER FAN RUNNING	I033-4	
	SP1A SPINDLE AMPLIFIER FAN RUNNING	I033-5	
	A-AXIS AMPLIFIER FAN RUNNING	I033-6	

AXIS INPUTS/OUTPUTS			
TYPE	NAME	ADDRESS	DESCRIPTION
	C-AXIS AMPLIFIER FAN RUNNING	I033-7	
	RACK #1 INFEED CONTACTOR ENERGIZED	I034-0	
	RACK #2 INFEED CONTACTOR ENERGIZED	I034-1	
	RACK #3 INFEED CONTACTOR ENERGIZED	I034-2	
	RACK #4 INFEED CONTACTOR ENERGIZED	I034-3	
	RACK #5 INFEED CONTACTOR ENERGIZED	I034-4	
	RACK #1 MONITORING MODULE CONTACTOR ENERGIZED	I034-5	
	X-AXIS DRIVE INHIBITED	I035-0	
	XT-AXIS DRIVE INHIBITED	I035-1	
	XG-AXIS DRIVE INHIBITED	I035-2	
	XGT-AXIS DRIVE INHIBITED	I035-3	
	Y-AXIS DRIVE INHIBITED	I035-4	
	YT-AXIS DRIVE INHIBITED	I035-5	
	Z-AXIS DRIVE INHIBITED	I035-6	
	ZT-AXIS DRIVE INHIBITED	I035-7	
	SP1 SPINDLE DRIVE INHIBITED	I036-3	
	SP1A SPINDLE DRIVE INHIBITED	I036-4	
	A-AXIS DRIVE INHIBITED	I036-5	
	C-AXIS DRIVE INHIBITED	I036-6	
	Z-AXIS MOTOR FAN RUNNING	I040-0	
	ZT-AXIS MOTOR FAN RUNNING	I040-1	
	ENABLE X-AXIS DRIVES	Q032-0	The corresponding output is turned on to enable the axis drive at the appropriate time
	ENABLE Y-AXIS DRIVES	Q032-1	

AXIS INPUTS/OUTPUTS			
Type	Name	Address	Description
	ENABLE Z-AXIS DRIVES	Q032-2	drive at the appropriate time when executing the "coming out of e-stop" routine.
	ENABLE A-AXIS DRIVE	Q033-0	
	ENABLE C-AXIS DRIVE	Q033-1	
TEMP. MONITORI NG	NOT X-AXIS MOTOR OVER TEMPERATURE	I037-0	This corresponding input goes low when an axis over temperature occurs. When the torque motors reach a critical temperature, the current to the stator is immediately switched off.
	NOT XT-AXIS MOTOR OVER TEMPERATURE	I037-1	
	NOT XG-AXIS MOTOR OVER TEMPERATURE	I037-2	
	NOT XGT-AXIS MOTOR OVER TEMPERATURE	I037-3	
	NOT Y-AXIS MOTOR OVER TEMPERATURE	I037-4	
	NOT YT-AXIS MOTOR OVER TEMPERATURE	I037-5	
	NOT A-AXIS MOTOR MAX OVERTEMP	I037-7	
	NOT C-AXIS MOTOR OVER TEMPERATURE	I038-2	
BRAKES	X-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-2	
	XT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-3	
	XG-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-4	
	XGT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-5	
	Y-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-6	
	YT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-7	
	DISCONNECT X-AXIS MOTOR DYNAMIC BRAKING	Q035-0	When an e-stop occurs, these outputs are turned off, a contactor dis-engages, which shorts the motor leads together, creating an electronic holding brake.
	DISCONNECT Y-AXIS MOTOR DYNAMIC BRAKING	Q035-1	
	AXES BRAKE CIRCUIT BREAKERS OK	I043-0	Loss of this signal causes an immediate e-stop. All brakes will immediately be applied.
	ENABLE AXES DRIVES & BRAKES	I043-1	This output is turned on to release the axis brakes at the appropriate time when executing the "coming out of e-stop" routine. E-stop will immediately apply the brakes.

AXIS INPUTS/OUTPUTS			
TYPE	NAME	ADDRESS	DESCRIPTION
	RELEASE Z-AXIS BRAKES	Q035-2	This output is turned on to release the axis brakes at the appropriate time when executing the "coming out of e-stop" routine. E-stop will immediately apply the brakes.
HOME	A-AXIS HOME	I080-6	The a-axis home switch turns on when the a-axis is at the home position during a home reference cycle.
	C-AXIS HOME	I082-3	The c-axis home switch turns on when the a-axis is at the home position during a home reference cycle.
TRAVEL	NOT X-AXIS PLUS OVERTRAVEL	I041-0	This corresponding input goes low when an axis overtravel occurs. An immediate e-stop is applied. The switch is also included in the hard wired e-stop string.
	NOT X-AXIS MINUS OVERTRAVEL	I041-1	
	NOT Y-AXIS PLUS OVERTRAVEL	I041-2	
	NOT Y-AXIS MINUS OVERTRAVEL	I041-3	
	NOT Z-AXIS PLUS OVERTRAVEL	I041-4	
	NOT Z-AXIS MINUS OVERTRAVEL	I041-5	
	NOT C-AXIS PLUS OVERTRAVEL	I041-6	
	NOT C-AXIS MINUS OVERTRAVEL	I041-7	
	NOT A-AXIS PLUS OVERTRAVEL	I042-0	
	NOT A-AXIS MINUS OVERTRAVEL	I042-1	
	OVERTRAVEL BYPASS	I090-3	During axis overtravel recovery, the spring loaded key selector switch input goes high to indicate the operator is recovering from an axis overtravel.
	PLUS OVERTRAVEL BYPASS	Q034-1	When axis overtravel recovery procedures are followed, this output comes on to temporarily bypass the plus overtravel condition, and allow the axis to jog in the minus direction.

AXIS INPUTS/OUTPUTS			
TYPE	NAME	ADDRESS	DESCRIPTION
	MINUS OVERTRAVEL BYPASS	Q034-2	When axis overtravel recovery procedures are followed, this output comes on to temporarily bypass the minus overtravel condition, and allow the axis to jog in the plus direction.

# **CHAPTER 6 - SPINDLE**



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## 6.1 SPINDLE CHARACTERISTICS

The ram contains a Phase TK-340-540-010 dual winding torque motor that is used to drive the spindle and tool. This motor is a liquid-cooled, permanent magnet, three-phase motor.

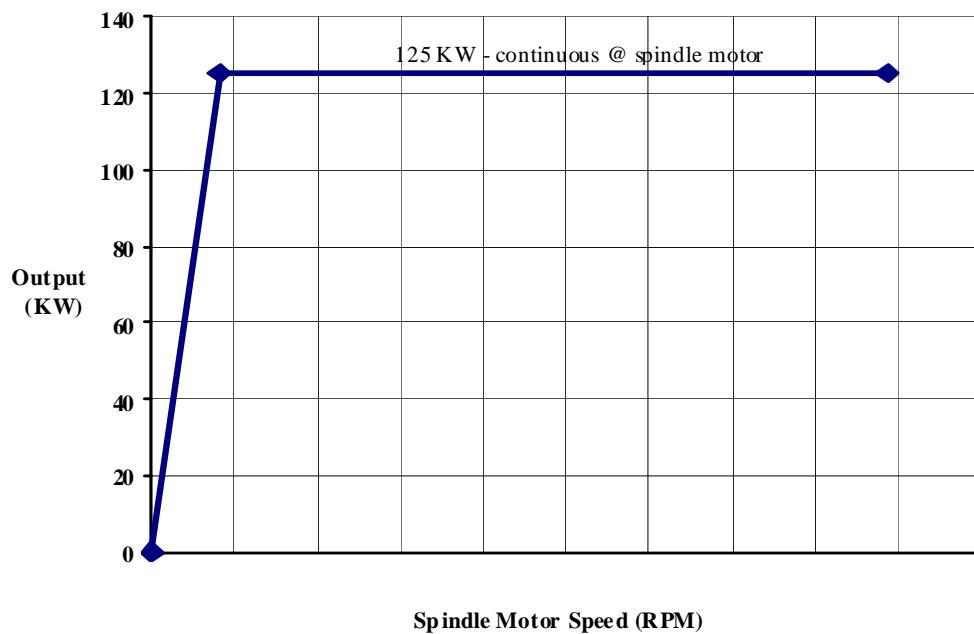
The spindle is run with motor encoder feedback and it does not have a brake. The spindle is not equipped with hardware over travel switches, nor software over travel limits, because the spindle is a continuous rotating axis, essentially having no restriction to its movement.

### 6.1.1 SPINDLE MOTOR INFORMATION

**NOTE:** The values shown below are for the spindle motor only. Power and speed limits for the spindle unit are shown in the spindle unit section.

Spindle Motor Type:	Phase TK-340-540-010 dual winding
Tool Type:	CAT 60 simultaneous fit
Spindle Motor Max Power:	125.2 KW (167.9 HP)
Max Spindle Motor Torque:	2965 NM (2187 ft lb)
Spindle Motor Max Speed:	limited to 4437 rpm
Spindle Motor Base Speed:	405 rpm @ motor

Spindle Motor Speed & Power



### 6.1.2 LUBRICATION AND AIR

The spindle supplied with the machine requires lubrication while operating. An Acumen lubricating unit is used to provide a specific amount of lubricating oil and air to the bearings of the spindle. The spindle lube reservoir is located on the Ram. The lube reservoir supplies oil to two (2) injectors located on the back of the ram. Refer to the Fluids chapter for more details on this system.

A constant air pressure is maintained across the spindle front seal to keep the seal clear of contaminants.

### 6.1.3 BEARING TEMPERATURE

Spindle bearing temperature is monitored with one RTD sensor near the front bearing in the ram. The spindle temperature can be displayed on the CNC screen by pressing the MACHINE soft key, and then pressing the LOG DATA soft key. The current spindle bearing temperature is displayed on a sub-screen. The PLC monitors the spindle bearing temperature signal. When the signal reaches a preset level (55° C), a warning message is posted. If the bearing temperature continues to rise and reaches a preset alarm level (60° C), a cut free e-stop is performed.

### 6.1.4 SPINDLE MOTOR TEMPERATURE MONITORING AND COOLING

The spindle motor temperature is monitored with (2) KTY & (2) RTD sensors.

A refrigerated chiller unit supplies heat removal for the spindle torque motor. The temperatures of the water going into the spindle motor and flowing out of the spindle motor are monitored and displayed. See the Fluids chapter for more details.

### 6.1.5 SPINDLE VOLTAGE PROTECTION MODULE

The dual-winding Phase torque motor requires a Voltage Protection Module. The purpose of the VPM (Voltage Protection Module) and the Pulse Resistor Module is to limit the DC-bus voltage to a value that is not harmful to any component, in the case where there is a malfunction of the drive system.

The Phase spindle motor is a high torque, high speed, motor, which can generate a wire-to-wire voltage (back EMF) of approximately 4000 V (peak), if an open circuit malfunction occurs. In order to safely protect against resultant damages to components or personnel, Ingersoll has installed redundant additional components for over voltage protection.

Four (4) VPM and three (3) Pulse Resistor Modules are used on each of the two (2) DC-bus system drive racks used for the Spindle control. These components are redundant devices; if one single device fails, the remaining devices will still offer protection.

In regular operations, the VPM and the Pulse Resistor Module are not applied.

- a) If the VPM Not Fault signal goes low (input to PLC), indicating the VPM has been applied, an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.

The spindle drives are not allowed to power up again until Maintenance has investigated the problem.

The VPM not fault signal will reset independently after a 2 minute delay, after the VPM internal temperature switch resets. Therefore, the PLC logic must latch up the alarm and prevent the drives from restarting.

- b) If the Pulse Resistor Module Fault / braking module inhibited signal goes low on any of the pulse resistor modules (input to PLC), an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.

The spindle drives are not allowed to power up again until Maintenance has investigated the problem.

- c) If the Pulse Resistor Module Pre-Warning For  $I^2t$  Shutdown signal goes low on one of the pulse resistor modules (input to PLC), a warning message is posted. If the Pulse Resistor Module Pre-Warning For  $I^2t$  Shutdown signal goes low on two or more of the one of the pulse resistor modules, an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.

The spindle drives are not allowed to power up again until maintenance has investigated the problem.

- d) The Inhibit Pulse Resistor Module signal (output from PLC) is set low to enable the pulse resistor module during normal operations.

#### 6.1.5.1 VPM PREVENTIVE MAINTENANCE TESTS

Because a malfunction of the VPM and the Pulse resistor Modules is not detected during normal operations, the VPM and the Pulse resistor Modules must be tested periodically in order to assure their readiness. The spindle consists of two electrically separate motor windings and drives, and DC-bus systems. Therefore, both motor windings are tested.

Required interval for test:

- Every 4 months or
- After any change or repair on any of the Spindle DC bus components (I/R module, drive power section, axis card, etc.), cables, terminals, VPM, resistors, motor, etc.

##### 6.1.5.1.1 INITIATING PERIODIC TESTING

Ingersoll has developed a PLC program that will post a warning message every 3½ months, reminding the operator that the VPM and Pulse Resistor Test must be performed. At his/her next earliest convenience, the operator should run the VPM and

Pulse Resistor Test program. This is a semi-automatic program/sequence, which requires operator intervention.

The operator can ignore the message (although it won't go away), and postpone the sequence for approximately 2 weeks. If this time expires, automatic cycle start is inhibited on the machine and a fault message appears stating that the periodic spindle tests have to be performed.

If the fault message is posted and the machine cycle start is inhibited, the technician needs to enable "Spindle Monitor Test Bypass" on the "Option Manager Screen" to allow him to run part program SPDL\_TEST to perform the tests. The technician should clear all possible alarm messages before he or she begins each test.

After the test sequence is passed successfully, the timer will be reset for another 3½ months.

#### 6.1.5.1.2 TEST 1: PHASE-TO-PHASE VPM TEST

**Overview:** The VPMs of both windings (master & slave) are tested at the same time.

- a. The spindle is commanded to run at 1200 rpm.  
When the drive is disabled, and the motor is freewheeling at this speed, the back EMF voltage is high enough to charge the DC-bus above 830 V. This is just above the trip voltage for the VPM.
- b. Disable all of the Pulse Resistor Modules.  
The pulse resistor modules must be switched off, because they would limit the DC-bus voltage (redundant protection).
- c. Disable the feedback function of both infeed modules.  
The PLC turns this off to both drives to temporarily eliminate this alarm. While the spindle motor is running, the PLC disables the "Enable Spindle Drive" outputs to both spindle drives. The spindle will coast down to a stop; the back EMF voltage from the motor will be applied to the DC-bus.
- d. Evaluate whether both VPMs have tripped.  
If both VPMs have tripped, the test step 1 is passed successfully. The VPM not fault signal will reset independently after a 2 minute delay, after the VPM internal temperature switch resets

#### Detailed Test #1 Sequence:

1. The technician will select SPDL\_TEST.SPF for automatic running from the Manufacturing Cycles screen and press Cycle Start pushbutton on the operator control panel.
2. Operator message "*SPINDLE VPM TEST #1 - SET SPINDLE SPEED OVERRIDE TO 100%*" will be displayed on the screen, and program will be stopped at M0.

3. The technician makes sure that the spindle speed override is set for 100%, because spindle must be run at full programmed speed of 1200 RPM for test #1. He then presses cycle start again to continue with the program.
4. Operator message "*SPINDLE STARTED AT 1200 RPM - SET OPTION SPINDLE TEST 1*" is displayed and the program stops at M0, again.
5. The technician must go to the Option Manager Screen and change "Initiate Spindle Voltage Module Test #1" from 'DISABLED' to 'ENABLED'.
6. As soon as he sets the option with the spindle running at 1200 RPM, the 6 outputs to inhibit the resistor modules are turned on, and the spindle drive infeed modules are inhibited. This causes the motor and drive to feed voltage into the drive bus, and should trigger the phase-to-phase voltage protection modules (#1 & #2) to trip. The six resistor module faults will be displayed because they have been disabled.
7. If the motor is not running at 1200 RPM, or the %SSO value is set lower than 100%, an error message, "*SPINDLE TEST #1 TRIED WITHOUT SPINDLE UP TO SPEED*" will be displayed.
8. If the two VPMs do not show faults (both of them) the spindle will run for 1 second, then be forced to stop, and fault message "*SPINDLE TEST #1 FAILED - FIND PROBLEM AND RESET TEST OPTION BIT AND TRY AGAIN.*"
9. If the two VPMs both show faults as expected, the spindle drives will be shut down immediately, but the logic and the part program wait until the VPMs reset. This may take as long as 6 minutes, so the technician must be patient. Alarm messages "*SPINDLE WINDING #1 VOLTAGE MONITOR #1 FAULT*" and "*SPINDLE WINDING #2 VOLTAGE MONITOR #1 Fault*" will both be displayed.
10. When the VPMs have reset, a message, "*SPINDLE TEST #1 COMPLETED*" is posted.
11. If the VPMs do not reset after 6 minutes, fault message "*SPINDLE TEST #1 FAILED - FIND PROBLEM AND RESET TEST OPTION BIT AND TRY AGAIN*" is posted, and it will be up to the technician to determine what is wrong with the VPMs. When he finds and fixes the problem, he has to reset the "Initiate Spindle Voltage Module Test #1" bit to the DISABLE state, reset the CNC and restart the SPDL\_TEST program until he gets the spindle test #1 done message.
12. When spindle test #1 is complete, the option manager bit "Initiate Spindle Voltage Module Test #1" will be reset automatically, and an internal "DONE" bit will stay on for the next 24 hours. The technician can continue with the program to test #2. If he resets out of the program and restarts, the program knows the condition of the "DONE" bit and jumps straight to test #2.

#### 6.1.5.1.3 STEP 2: PULSE RESISTOR MODULE TEST

**Overview:** All Pulse Resistor Modules are (master & slave) are tested at the same time.

- a. The spindle is commanded to run at max RPM (top speed).

When the drive is disabled, and the motor is freewheeling at this speed, the back EMF voltage will charge the DC-bus. The Resistors will limit the DC-bus voltage and trip when their  $I^2t$  value is exceeded.

- b. Disable the feedback function of both infeed modules.  
The PLC turns this off to both drives to temporary eliminate this alarm.
- c. While the spindle motor is running, the PLC disables the "Enable Spindle Drive" outputs to both spindle drives.  
The spindle will coast down to a stop; the back EMF voltage from the motor will be applied to the DC-bus.
- d. Evaluate whether the Pulse Resistor Modules have tripped.  
It is acceptable if one or two of the pulse resistor modules have tripped, for each motor winding circuit.
- e. Evaluate whether both VPMs have NOT tripped.  
If both VPMs have not tripped, one can be sure that the DC-bus voltage did not exceed the 830 V level. In this case, the pulse resistors must have dissipated the feed back current of the motor. If both tests are acceptable, the test step 2 is passed successfully.

#### Detailed Test #2 Sequence:

1. At the beginning of test #2, an operator message, "*SPINDLE RESISTOR TEST #2 - SET SPINDLE SPEED OVERRIDE TO 100%*" appears, similar to the beginning of Test #1. The technician makes sure that the spindle speed override is set for 100% and presses cycle start to continue with the program.
2. Operator message "*SPINDLE STARTED AT MAX RPM - SET OPTION SPINDLE TEST 2*" is displayed and the program stops at M0, again.
3. The technician must go to the Option Manager Screen and change "Initiate Spindle Resistor Module Test #2" from 'DISABLED' to 'ENABLED'.
4. This time, knowing that the VPMs are doing their job, the resistor modules will be tested, so as soon as the option is set, with the spindle running at max RPM, the spindle drive infeed modules are inhibited. This causes the motor and drive to feed voltage into the drive bus and should trigger at least one of the resistor module warning inputs for each of the 2 motor windings.
5. If the motor is not running at max RPM, or the %SSO value is set lower than 100%, an error message, "*SPINDLE TEST #2 TRIED WITHOUT SPINDLE UP TO SPEED*" will be displayed.
6. If two resistor modules do not show pre-warning faults (one from each motor winding) the spindle will run for 10 second, then be forced to stop, and fault message "*SPINDLE TEST #2 FAILED WITHOUT RESISTOR MODULE FAULTS - NOT ENOUGH CURRENT*" is displayed.
7. If two resistor modules show faults as expected, the spindle drives will be shut down immediately, but the logic and the part program wait until the resistor modules reset.

This should happen within 20 seconds. One of the first motor winding warning messages "*SPINDLE WINDING #1 RESISTOR MODULE WARNING*" and one of the second motor winding warning messages "*SPINDLE WINDING #2 RESISTOR MODULE WARNING*" will be displayed.

8. When the resistor modules have reset, a message, "*SPINDLE TEST #2 COMPLETED*" is posted.
9. If the resistor modules do not reset after 20 seconds, fault message "*SPINDLE TEST #2 FAILED WITH RESISTOR MODULE FAULTS*" is posted, and it will be up to the technician to determine what is wrong with the VPMs. When he finds and fixes the problem, he has to reset the "Initiate Spindle Voltage Module Test #1" bit to the DISABLE state, reset the CNC and restart the SPDL\_TEST program until he gets the spindle test #2 done message.
10. When spindle test #2 is complete, the option manager bit "Initiate Spindle Voltage Module Test #2" will be reset automatically, and an internal "DONE" bit will stay on for the next 24 hours. The technician can continue with the program to test #3. If he resets out of the program and restarts, the program knows the condition of the "DONE" bit and jumps straight to test #3.

#### 6.1.5.1.4 STEP 3: PHASE-TO-GROUND VPM OF THE SLAVE TEST

**Overview:** The (3) VPMs for the slave motor winding are tested independently from the (3) VPMs for the master motor winding.

- a. Open SP/C Spindle Power Circuit for VPM Testing from the PLC.  
This will open the power contactor on slave motor winding circuit and separate the slave motor winding & the (3) Phase-to-Ground VPMs from the drive & the (1) Phase-to-Phase VPM.
- b. The spindle is commanded to run at 1900 rpm, using only the master motor winding.  
The "Enable SP Spindle Drive #2" output for the slave drive is left disabled.
- c. Keep the spindle motor running for 100 ms, then ramp down to zero speed.
- d. Evaluate whether the VPMs of the slave motor winding have tripped.  
All (3) VPMs must have tripped. No VPMs on the master are allowed to trip, no pulse resistor modules are allowed to trip. The VPM not fault signal will reset independently after a 2 minute delay, after the VPM internal temperature switch resets.
- e. If all tests are acceptable, the test step 3 is passed successfully.

#### Detailed Test #3 Sequence:

1. At the beginning of test #3, an operator message, "*SPINDLE VOLT MODULE TEST #3 - SET OPTION SPINDLE TEST 3*" appears on the screen. This time the

option bit is set before the spindle is started because the option bit will disable spindle drive and motor #2 to run only spindle motor #1.

2. The technician must go to the Option Manager Screen and change "Initiate Spindle Voltage Module Test #3" from 'DISABLED' to 'ENABLED', and press cycle start to resume the SPDL\_TEST program operation.
3. The option bit for spindle test #3 not only disables the second spindle motor and drive; it energizes a contactor that separates the second spindle windings from the phase-to-phase VPM and drive. The second motor will become like a generator, producing voltage on its leads that the phase-to-ground VPMs will monitor.
4. Now the first spindle motor is started at 900 RPM, driving the second motor for a period of 5 seconds, to create some heat in the VPMs, and then the program changes the spindle speed to 1900 RPM, which should create enough EMF voltage on spindle #2 to trip all three phase-to-ground VPMs.
5. If the technician tries to start the spindle before he sets the spindle test 3 option, an error message, "SPINDLE TEST #3 TRIED WITH SPINDLE RUNNING" will be displayed.
6. If all three voltage modules of spindle #2 do not show faults (one from each motor winding) immediately, the spindle will be forced to stop, and fault message "SPINDLE TEST #3 FAILED WITHOUT VPM FAULTS " is displayed.
7. If the three VPMs show faults as expected, the spindle drive will be shut down immediately, but the logic and the part program wait until the VPMs reset. This may take as long as 6 minutes, so the technician must be patient. Alarm messages "SPINDLE WINDING #2 VOLTAGE MONITOR #2 FAULT" and "SPINDLE WINDING #2 VOLTAGE MONITOR #3 FAULT" and "SPINDLE WINDING #2 VOLTAGE MONITOR #4 FAULT" will all three be displayed.
8. When the VPMs have reset, a message, "SPINDLE TEST #3 COMPLETED" is posted.
9. If the VPMs do not reset after 6 minutes, then same fault message "SPINDLE TEST #3 FAILED WITHOUT VPM FAULTS" is posted, and it will be up to the technician to determine what is wrong with the VPMs. When he finds and fixes the problem, he has to reset the "Initiate Spindle Voltage Module Test #3" bit to the DISABLE state, reset the CNC and restart the SPDL\_TEST program until he gets the spindle test #3 done message.
10. When spindle test #3 is complete, the option manager bit "Initiate Spindle Voltage Module Test #3" will be reset automatically, and the internal "DONE" bit will stay on for the next 24 hours. The technician can continue with the program to test #4. If he resets out of the program and restarts, the program knows the condition of the "DONE" bit and jumps straight to test #4.

#### 6.1.5.1.5 STEP 4: PHASE-TO-GROUND VPM OF THE MASTER TEST

**Overview:** Same as Step 3 above, except this test is performed on the master motor winding, instead of the slave motor winding.

**Detailed Test #4 Sequence:**

11. At the beginning of test #4, an operator message, "SPINDLE VOLT MODULE TEST #4 - SET OPTION SPINDLE TEST 4" appears on the screen. As is with test #3, the option bit is set before the spindle is started because the option bit will disable spindle drive and motor #1 to run only spindle motor #2.
12. The technician must go to the Option Manager Screen and change "Initiate Spindle Voltage Module Test #4" from 'DISABLED' to 'ENABLED', and press cycle start to resume the SPDL\_TEST program operation.
13. The option bit for spindle test #4 not only disables the first spindle motor and drive; it energizes a contactor that separates the first spindle windings from the phase-to-phase VPM and drive. The first motor will become like a generator, producing voltage on its leads that the phase-to-ground VPMs will monitor.
14. Now the second spindle motor is started at 900 RPM, with the command M2=3 S=900 driving the first motor for a period of 5 seconds, to create some heat in the VPMs, and then the program changes the spindle speed to 1900 RPM, which should create enough EMF voltage on spindle #1 to trip all three phase-to-ground VPMs.
15. If the technician tries to start the spindle before he sets the spindle test #4 option, an error message, "*SPINDLE TEST #4 TRIED WITH SPINDLE RUNNING*" will be displayed.
16. If all three voltage modules of spindle #1 do not show faults (one from each motor winding) immediately, the spindle will be forced to stop, and fault message "*SPINDLE TEST #4 FAILED WITHOUT VPM FAULTS*"
17. If the three VPMs show faults as expected, the spindle drive will be shutdown immediately, but the logic and the part program wait until the VPMs reset. This may take as long as 6 minutes, so the technician must be patient. Alarm messages "*SPINDLE WINDING #1 VOLTAGE MONITOR #2 FAULT*" and "*SPINDLE WINDING #1 VOLTAGE MONITOR #3 FAULT*" and "*SPINDLE WINDING #1 VOLTAGE MONITOR #4 FAULT*" will all three be displayed.
18. When the VPMs have reset, a message, "*SPINDLE TEST #4 COMPLETED*" is posted.
19. If the VPMs do not reset after 6 minutes, then same fault message "*SPINDLE TEST #4 FAILED WITHOUT VPM FAULTS*" is posted, and it will be up to the technician to determine what is wrong with the VPMs. When he finds and fixes the problem, he has to reset the "Initiate Spindle Voltage Module Test #4" bit to the DISABLE state, reset the CNC and restart the SPDL\_TEST program until he gets the spindle test #4 done message.
20. When spindle test #4 is complete, the option manager bit "Initiate Spindle Voltage Module Test #4" will be reset automatically, and the internal "DONE" bit will stay on for the next 24 hours. The date and time of completion of this test is stored as the last time the tests have been completed, and the original messages indicating tests need to be run, will be reset. They will not be re-triggered for another 4 months.

21. The technician must make sure that all VPM test bits, are turned, off, especially "Spindle Monitor Test Bypass" that he may have set at the beginning of these tests. Reset all alarm messages and de-select SPDL\_TEST.SPF program, before retuning the machine to production.

#### 6.1.5.1.6 RESTARTING VPM TESTS

The technician may re-run a test at any time by resetting the done bits stored in the PLC memory, either from a VAT table using Step7, or by resetting them on the PLC diagnostics screen. Once a test is complete, the program, SPDL\_TEST.SPF can be restarted and it will automatically jump to the first incomplete test to begin execution. All tests after the first incomplete test must be re-run to get all tests completed. 24 hours after the first test is completed, the done bit for that test and all of the rest will be reset, so that they will all have to be completed if not done within that 24 hour period.

In the case of restarting tests, checks are made to guarantee that the technician is setting the right option bits at the right time. Messages are displayed if the wrong option bit is set out of sequence.

If any of the tests fails, the spindle drives are not allowed to power up again until Maintenance has investigated and corrected the problem, and then re-run the VPM and Pulse Resistor Test Program.

If one or more of the steps have completed successfully and the next step fails, Maintenance must fix the problem and then re-run the VPM and Pulse Resistor Test Program. The Test Program will automatically bypass the previous successful tests and continue with the next sequential step.

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## 6.2 SPINDLE CONTROL

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The spindle control supports the following functions:

**Spindle Run Control** - This is the basic spindle run control, the speed for spindle run is programmed via S-word.

M03 - spindle clockwise  
M04 - spindle counter-clockwise  
M05 - spindle stop

**Spindle Positioning** - This function provides the capability of orienting the spindle for tool change and single point boring, using the SPOS (angle) command.

**Spindle Axis Mode** – This function allows for the spindle to be run as an interpolated axis, using the M70 code.

**Tapping** - This supports the CNC tapping cycle.

G63 - Tapping With Synchronization mode  
CYCLE840 - Floating Tap Cycle

**Rigid tapping** - This supports the CNC rigid tapping.

G331 - Rigid Tapping mode  
G332 - Retraction Rigid Tapping mode  
CYCLE84 - Rigid Tapping Cycle

### **6.2.1 RUN CONDITIONS**

The spindle is started by programming an M03 or M04, and an S-Word. Once the commanded motor speed and direction are calculated, the following are items checked before turning on the Spindle Run bit.

1. Spindle drive is ready.
2. Spindle tool gripper is closed with a tool loaded.
3. No spindle inhibits active.
4. The Chiller Running signal and Cooling Water Flow Ok signal must be present to allow spindle motion.

### **6.2.2 STOP CONDITIONS**

The spindle run command is cleared by the following:

M00	M05	M70
M01	M06	SPOS
M02	M30	E-STOP
		RESET

These commands reset the active spindle speed to 0 and clear the clockwise/counter-clockwise active bits. An M03 or M04 and an S command must be programmed to restart the spindle.

### **6.2.3 SPEED OVERRIDE**

The Spindle Speed Override selector switch on the Operator Console is used to manipulate the output to the spindle speed from 50% to 120% of the programmed spindle speed (S-word), in 5% increments.

In Automatic and MDA modes, an M49 (Manual Feedrate Override Bypass) will prevent this switch from functioning. When M49 is active, the spindle will run at programmed spindle speed (S-word). A programmed M48 cancels M49 and allows operation of the Spindle Speed Override switch. Manual spindle speed override is also inhibited during canned cycles.

#### 6.2.4 POSITIONING (ORIENT)

The spindle can be positioned to a specific angle using the SPOS (angle) command. Spindle positioning is used for the following functions:

- tool change
- canned cycles

#### 6.2.5 AXIS MODE

The spindle can be switched over to be a rotary axis using the M70 command. After the M70, the spindle is programmed as S (main spindle). Example, X50S150 moves the spindle, interpolated with the X-axis move.

The M70 Spindle axis mode is canceled by the next M3, M4, or M5.

The spindle must be referenced by a M3, M4, or SPOS command to synchronize the spindle to its 0 position, prior to programming a M70 code.

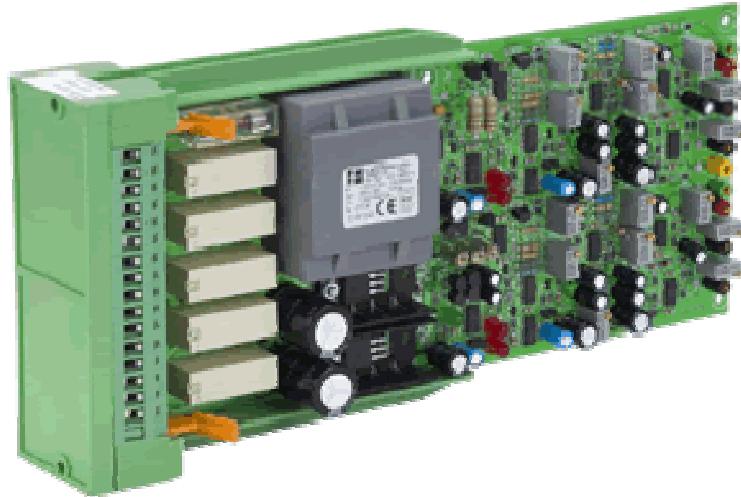
#### 6.2.6 PROTECT MODE

The Ingersoll logic will protect the spindle from exceeding a predefined power limit. If this happens, the logic will issue a feedhold and post a message.

## 6.3 VIBRATION MONITOR

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Separate vibration monitoring equipment is used to continuously monitor the spindle for excessive vibration. Two (2) CEMB vibration monitors, model T1-EA are installed in the control cabinets. One unit monitors the spindle motor in the ram, the other monitors the spindle unit vibration.



CEMB T1-EA VIBRATION MONITOR

This equipment supplies signals monitored by the PLC, one analog output vibration signal and the following three digital signals:

- Spindle Vibration Level High
- Spindle Vibration Level Excessive
- Not Spindle Vibration Monitor Fault

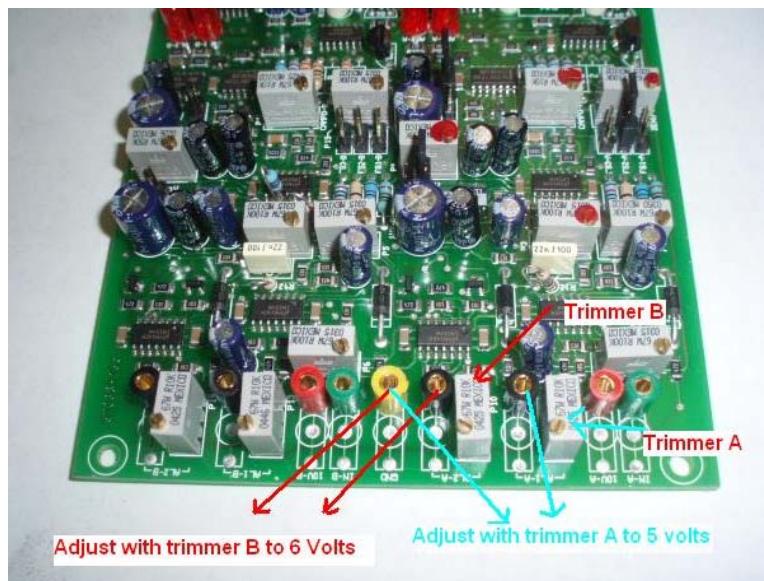
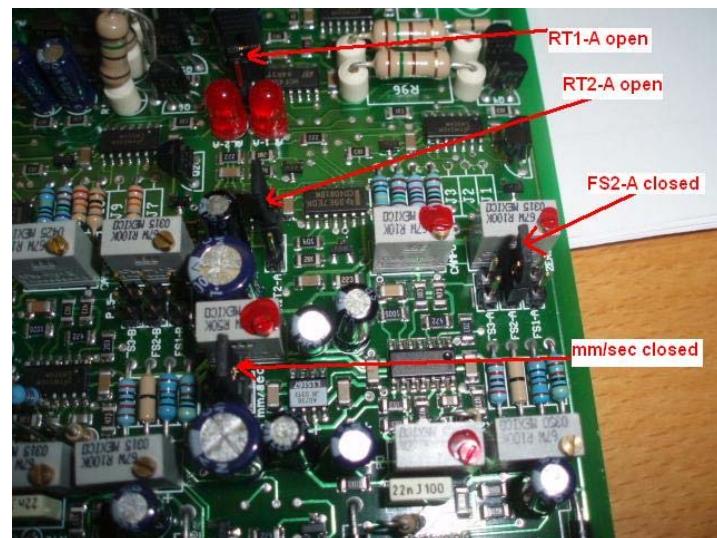
The spindle vibration can be displayed on the CNC screen by pressing the MACHINE soft key, and then pressing the LOG DATA soft key.

### 6.3.1 SET UP OF THE CEMB BOARD

The jumpers on the CEMB board must be set as shown in the pictures below. Refer to the vendor's documentation for detailed information on this board.

- The read range of the board must be set between 0 and 20 mm/sec. (jumper is on F32-A).
- The delay on the digital alarm output must be disabled (jumper for RIT2-A is open).
- The first alarm level is used just to display a warning and it must be set about 10 mm/sec (5V).
- The second output is used for stop the machine. It should be set between 6-8 volts.

After adjusting the board as above, someone with machining experience must tune these two inputs, analyzing the machine during the production.



CEMB T1-EA BOARD SETUP

### 6.3.2 REAL TIME VIBRATION DETECTION

When the PLC detects the first alarm (Level High) from the CEMB board, it starts to decrement a timer. If the PLC timer runs out and alarm 1 is still present, a warning message will be displayed. As soon as the vibration alarm 1 disappears, the PLC timer will be reset and the warning message will be cleared. The PLC timer should be set between 2 and 4 seconds.

The second input (Level Excessive) is used to stop the machine in case of excessive vibration. There is a PLC delay timer also for alarm 2 and the action will be started after this timer runs out. The timer for alarm 2 can have a different setting from alarm 1 timer

and the acceptable range is between 2 and 4 seconds. When an excessive vibration is detected, the PLC will first stop the axis and then the spindle and the program. The machine will not go into emergency stop.

For recovery from the excessive vibration, the operator can decide to reset the program and manually free the spindle from the work piece, or enable the spindle and the axis feed and continue the program.

Because of the delay timers on both alarms, if any excessive vibration is detected for a time shorter than the delay timers, no action will be performed by the PLC.

### **6.3.3 VIBRATION DISPLAY**

The PLC receives an analog vibration signal from the monitoring equipment. The spindle vibration can be displayed on the CNC screen by pressing the MACHINE soft key, and then pressing the LOG DATA soft key. Refer to the Control Screens chapter for a picture of the screen.

The display is updated about every second. Two different values are displayed, the peak value within the last second and the average value for the last second. The color of the values will be green if no alarm was output from the CEMB board within the last second; orange if the Level High (alarm 1) was output; or red if Level Excessive (alarm 2) was output.

### **6.3.4 VIBRATION BOARD FAILURE**

The PLC can detect the breakdown of the CEMB board using a diagnostic input. When a board failure is detected, all the vibration controls will be disabled and an alarm will be displayed. The customer will be able to continue to cut at their own discretion. It is the customer's responsibility at this point to monitor the spindle vibration.

## 6.4 SPINDLE INPUTS AND OUTPUTS

Additional I/O associated with spindle lube, air, and cooling can be found in the Fluids chapter. I/O associated with tool grippers can be found in the Spindle Unit chapter.

SPINDLE CONTROL INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
SPINDLE DRIVE	SP1 SPINDLE AMPLIFIER FAN RUNNING	I033-4	
	SP1A SPINDLE AMPLIFIER FAN RUNNING	I033-5	
	SP1 SPINDLE DRIVE INHIBITED	I036-3	
	SP1A SPINDLE DRIVE INHIBITED	I036-4	
	ENABLE SP1 SPINDLE DRIVE	Q032-6	The corresponding output is turned on to enable the drive at the appropriate time when executing the "coming out of e-stop" routine.
	ENABLE SP1A SPINDLE DRIVE	Q032-7	
VPM TESTING	SP1 SPINDLE RESISTOR MODULE #1 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-0	If the pulse resistor module pre-warning for I2T shutdown signal goes low on one of the pulse resistor modules (input to PLC), a warning message is posted. If the pulse resistor module pre-warning for I2T shutdown signal goes low on two or more of the one of the pulse resistor modules, an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.
	SP1 SPINDLE RESISTOR MODULE #2 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-2	
	SP1 SPINDLE RESISTOR MODULE #3 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-4	
	SP1A SPINDLE RESISTOR MODULE #1 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-0	
	SP1A SPINDLE RESISTOR MODULE #2 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-2	
	SP1A SPINDLE RESISTOR MODULE #3 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-4	
	SP1 SPINDLE RESISTOR MODULE #1 NOT FAULT	I044-1	If the pulse resistor module fault / braking module inhibited signal goes low on any of the pulse resistor modules (input to PLC), an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.
	SP1 SPINDLE RESISTOR MODULE #2 NOT FAULT	I044-3	
	SP1 SPINDLE RESISTOR MODULE #3 NOT FAULT	I044-5	
	SP1A SPINDLE RESISTOR MODULE #1 NOT FAULT	I045-1	
	SP1A SPINDLE RESISTOR MODULE #2 NOT FAULT	I045-3	

SPINDLE CONTROL INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
	SP1A SPINDLE RESISTOR MODULE #3 NOT FAULT	I045-5	If the VPM not fault signal goes low, indicating the VPM has been applied, an immediate spindle stop is issued, the pulse enable to both spindle drive amplifiers are immediately removed, and an e-stop is applied.
	SP1 SPINDLE VOLTAGE MODULE NOT FAULT	I039-0	
	SP1A SPINDLE VOLTAGE MODULE NOT FAULT	I039-1	
	SP1 SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-0	
	SP1 SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-1	
	SP1 SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-2	
	SP1A SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-3	
	SP1A SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-4	
	SP1A SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-5	
	INHIBIT SP1 SPINDLE RESISTOR MODULE #1	Q036-0	The inhibit pulse resistor module signal (output from PLC) is set low to enable the pulse resistor module during normal operations.
	INHIBIT SP1 SPINDLE RESISTOR MODULE #2	Q036-1	
	INHIBIT SP1 SPINDLE RESISTOR MODULE #3	Q036-2	
	INHIBIT SP1A SPINDLE RESISTOR MODULE #1	Q036-3	
	INHIBIT SP1A SPINDLE RESISTOR MODULE #2	Q036-4	
	INHIBIT SP1A SPINDLE RESISTOR MODULE #3	Q036-5	
	DISABLE SPINDLE INFEEDS FOR VPM TESTING	Q037-0	The VPM and the pulse resistor modules must be tested periodically in order to assure their readiness. These outputs are turned on at the appropriate time during the VPM and the pulse resistor modules test sequence.
	OPEN SP1 SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-1	
	OPEN SP1A SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-2	
	RESET INFEED MODULES FROM VPM FAULTS	Q037-3	
<b>SPINDLE MOTOR TEMP.</b>	NOT SP1 SPINDLE OVER TEMPERATURE	I038-3	This input goes low when an axis over temperature occurs. When the torque motors reach a critical temperature, the current to the stator is immediately switched off.
	NOT SP1A SPINDLE OVER TEMPERATURE	I038-4	
<b>BEARING TEMP.</b>	SPINDLE MOTOR FRONT BEARING TEMPERATURE (IN RAM)	PIW 428	The PLC logic displays the spindle bearing temperature on the LOG sub-screen. When the temperature reaches a warning level (55° C), an alarm message is posted. If the temperature reaches 60° C, then a cut free e-stop is done.

SPINDLE CONTROL INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
SPINDLE IN RAM VIBRATION MONITOR	SP1 SPINDLE VIBRATION LEVEL HIGH	I080-5	When this signal goes high, only a message is posted.
	SP1 SPINDLE VIBRATION LEVEL EXCESSIVE	I080-6	When this signal goes high, a feed hold is issued, followed by a spindle stop.
	NOT SP1 SPINDLE VIBRATION MONITOR FAULT	I080-7	When this signal goes low, a feed hold is issued, followed by a spindle stop.
	SP1 SPINDLE VIBRATION SIGNAL	PIW 420	The PLC displays the spindle vibration on the LOG sub-screen.
SPINDLE UNIT VIBRATION MONITOR	SPINDLE VIBRATION LEVEL HIGH	I082-0	When this signal goes high, only a message is posted.
	SPINDLE VIBRATION LEVEL EXCESSIVE	I082-1	When this signal goes high, a feed hold is issued, followed by a spindle stop.
	NOT SPINDLE VIBRATION MONITOR FAULT	I082-2	When this signal goes low, a feed hold is issued, followed by a spindle stop.
	SPINDLE VIBRATION SIGNAL	PIW 402	The PLC displays the spindle vibration on the LOG sub-screen.

## **CHAPTER 7 - SPINDLE UNITS**



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## CHAPTER 7 - SPINDLE UNITS

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## 7.1 INTRODUCTION

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Attachments, called spindle units, can be loaded on the machine ram to provide varying horsepower and machining capability. Each spindle unit is uniquely identified with a number.

This machine is supplied with one, permanently attached, spindle unit as shown in the table below. Additional spindle units could be added in the future.

<b>SU Number</b>	#14
<b>Type</b>	Offset Swivel
<b>Power</b>	125.2 kW (167.9HP) @ 288 to 3169 rpm
<b>Torque</b>	4151 NM (3062 ft lb) @ 0 to 288 rpm
<b>RPM Max</b>	3169 rpm
<b>Gear Ratio</b>	1.4 : 1
<b>Spindle Unit Load/Unload</b>	Future option
<b>Tool Load / Unload</b>	Automatic
<b>Coolant</b>	Internal & External
<b>Spindle Taper</b>	CAT 60 simultaneous fit
<b>C-Axis Range</b>	$\pm 200^\circ$ @ 10 rpm
<b>A-axis Swivel Angle</b>	$\pm 110^\circ$ @ 5 rpm

Detailed information on each spindle unit is retained in the PLC and entered through a custom CNC screen. This information tells the control what type of spindle unit is mounted, characteristics of each unit, dimension offsets, etc.

---

## 7.2 SPINDLE UNIT CHARACTERISTICS

---

This section gives detailed information on each spindle used on this machine.

### 7.2.1 OFFSET INDEXING HEAD (#14)

Spindle Image	Performance Chart
	
<b>SPINDLE UNIT CHARACTERISTICS</b>	
<b>Power</b>	125.2 kW (167.9 HP) @ 288 to 3169 rpm
<b>Torque</b>	4151 NM (3062 ft lb) @ 0 to 288 rpm
<b>RPM Max</b>	3169 rpm
<b>Gear Ratio</b>	1.4 : 1
<b>Spindle Unit Load / Unload</b>	Future Option
<b>Tool Load / Unload</b>	Automatic
<b>Coolant</b>	External and Internal
<b>Spindle Taper</b>	CAT 60 Simultaneuos fit
<b>C-Axis Range</b>	± 200° @ 10 rpm
<b>A-Axis Range</b>	± 110° @ 5 rpm
<b>Lubrication</b>	Grease packed and recirculating lube

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## 7.3 RAM GRIPPERS

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The gripping of the Spindle Units to the head is achieved by the use of four hydro-mechanical clamps. The grippers are contained within the ram. Gripping force is provided by a combination of spring force and hydraulic pressure.

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## 7.4 SPINDLE UNIT BEARING TEMPERATURE

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Bearing temperature in the OH 150 spindle unit is monitored with one RTD sensor within the spindle unit. The spindle temperature can be displayed on the CNC screen by pressing the MACHINE soft key, and then pressing the LOG DATA soft key. The current spindle unit bearing temperature is displayed on a sub-screen. The PLC monitors the spindle unit bearing temperature signal. When the signal reaches a preset level (55° C), a warning message is posted. If the bearing temperature continues to rise and reaches a preset alarm level (60° C), a cut free e-stop is performed.

---

## 7.5 SPINDLE UNIT LUBRICATION

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Different types of lubrication are required for the various types of spindle units. Some spindle units are greased packed and do not require any other lubrication. Other spindle units require recirculating oil, while spindle units with an Omlat motorized spindle only require bearing lubrication done with a separate lube system. The type of lubrication required for each spindle unit must be identified in the spindle unit data table. The various types of spindle unit lubrication are described in the Fluids chapter.

---

## 7.6 SPINDLE UNIT TOOL GRIPPER

---

All spindle units support automatic tool changing. The units with automatic tool changing have a hydraulically activated tool gripper.

Depending on the type of spindle unit, there are different types of switches used for gripper position indicators: analog switch, three digital proximity switches, two digital proximity switches, or pressure switches. The type of indicator switches used must be identified in the spindle unit data table.

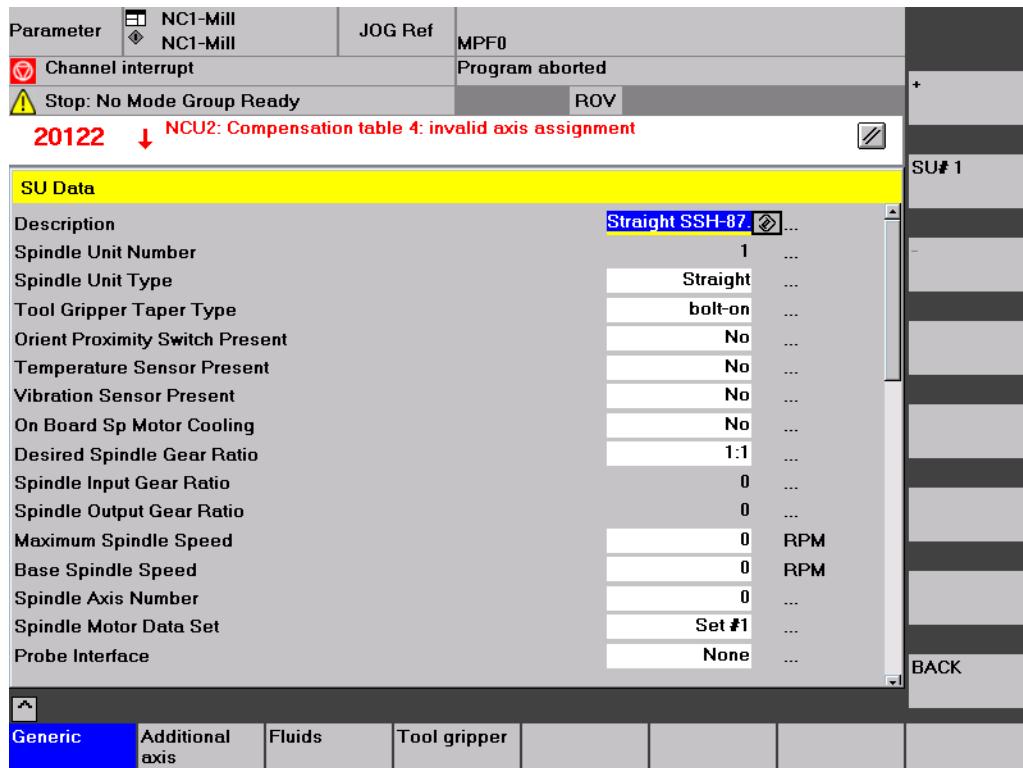
The spindle can only be run, jogged, or oriented with the tool properly clamped in the spindle gripper. A spindle inhibit is issued if the gripper is open, or if the gripper is closed without a tool.

## 7.7 SPINDLE UNIT DATA

Each spindle unit to be used on the machine must be identified to the machine by manually entering its information into the Siemens CNC through the Spindle Unit screen, shown below. This information tells the control what type of spindle unit is in each cradle position on the transporter, characteristics of each unit, dimension offsets, etc.

To get to the Spindle Unit Data screen, press the **Menu Select** softkey, then press the “>” softkey until the **Parameter** function key is displayed along the bottom, horizontal function keys. Click on the **Ingersoll Setup** softkey, then **SU Data Manager**, then **SU Data** function key to bring up the display of the Spindle Unit Data screen.

This screen displays the data associated a single spindle unit. All data must be set up for the spindle unit. including the various fields in subscreens.



SPINDLE UNIT DATA SCREEN

## 7.8 SPINDLE UNIT CHANGE

With only one spindle unit supplied, automatic spindle unit changing is not supported on this machine. There is no storage location for dropping off the spindle unit; it is permanently mounted to the ram. A M92 Spindle Unit change code is supported to be able to modify the spindle unit data as described below.

### 7.8.1 RE-ESTABLISHING SPINDLE UNIT DATA

The spindle unit data (offsets, TRAORI parameters, etc.) for the spindle unit currently attached to the ram face can be re-loaded by re-issuing the M92 (#) command, where (#) is the currently mounted spindle unit number.

## 7.9 SPINDLE UNIT INPUTS / OUTPUTS

SPINDLE UNIT INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
SU NUMBER	SU ID #1	I080-0	These inputs are used to decode the spindle unit pin coding. This number must match the programmed spindle unit number.
	SU ID #2	I080-1	
	SU ID #3	I080-2	
	SU ID #4	I080-3	
SU BEARING TEMP.	SPINDLE UNIT BEARING OVERTEMP	PIW 400	The PLC logic displays the spindle unit bearing temperature on the log sub-screen. When the temperature reaches a warning level (55° c) an alarm message is posted. If the temperature reaches 60° c, then a cut free e-stop is done.
SU RAM GRIPPERS	SPINDLE UNIT ATTACHED TO RAM #1	PIW 444	These two analog inputs verify a spindle unit is attached to the ram. If either input goes out of its individual range while a spindle unit is attached, an immediate e-stop is issued. The allowable range is determined during machine commissioning, and is stored in a data table. This is a single machine setting, not a per spindle unit setting.
	SPINDLE UNIT ATTACHED TO RAM #2	PIW 446	
	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6	This input should be on when no SU is mounted on the head. This input must be on before lowering the ram to pick a new spindle unit. This input must be on before raising the ram to drop a spindle unit.
	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7	This input should be on when a SU is mounted on the head. Loss of this signal with a SU attached will cause an immediate e-stop.

<b>SPINDLE UNIT INPUTS/OUTPUTS</b>			
<b>DEVICE</b>	<b>NAME</b>	<b>ADDRESS</b>	<b>DESCRIPTION</b>
	REDUNDANT UNCLAMP CORNER GRIPPERS	Q0103-0	This output is energized along with the UNCLAMP CORNER GRIPPERS output to release the SU from the head into an empty cradle.
	UNCLAMP CORNER GRIPPERS	Q0103-1	This output is energized along with the REDUNDANT UNCLAMP CORNER GRIPPERS output to release the SU from the head into an empty cradle.
<b>TOOL GRIPPER</b>	SPINDLE/TOOL GRIPPER ORIENT	I081-0	This input is used for orienting the tool in spindle units that have gearing that is not a 1:1 ratio.
	SPINDLE TOOL GRIPPER PISTON RETRACTED	I081-1	This input is used on some spindle units for gripper position indication. This input must be on when the spindle unit tool gripper is closed (with or without a tool), and the piston pushing the gripper is retracted. This input must be on to allow spindle rotation. Loss of this signal will force an immediate spindle stop.
	TOOL GRIPPER OPEN	I081-2	This input will be on when the spindle unit tool gripper is fully opened. If this input is on and the TOOL GRIPPER CLOSED input is also on, this indicates that the gripper is closed with a tool.
	TOOL GRIPPER CLOSED	I081-3	This input will be on when the spindle unit tool gripper is closed (with or without a tool).
	TOOL GRIPPER CLOSED WITHOUT TOOL	I081-4	This input will be on when if the spindle unit tool gripper is closes without a tool.
	SU DRAWBAR (TOOL GRIPPER POSITION)	PIW 404	This analog input is used on some spindle units for gripper position indication. This input must be within an acceptable range when the spindle unit tool gripper is closed (with or without a tool), and the piston pushing the gripper is retracted. This input must be within the acceptable range to allow spindle rotation.
	SPINDLE TOOL GRIPPER CLAMPED/UNCLAMPED PRESSURE	PIW 602	This analog input must be within an acceptable range for the type of spindle unit mounted on the ram when a tool is loaded in the unit. If it falls outside of this range, an immediate feedhold will be issued. This will feedhold any active tool change motion.

SPINDLE UNIT INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
	TOOL GRIPPER PRESSURE	PIW 606	After selecting the appropriate pressure for this spindle unit's tool grippers using the <i>Select Tool Gripper Pressure</i> proportional valve, this analog input is used to verify the pressure is available before the <i>Unclamp Tool Gripper</i> solenoid is energized.
	SELECT TOOL GRIPPER PRESSURE	PQW 300	This analog output sets the proper pressure to open the SU tool gripper. Pressure setting is based on which spindle unit is mounted.
	UNCLAMP TOOL GRIPPER	Q102-1	This output is turned on to release a tool during a tool change. Depending on the type of SU, the <i>Select Tool Gripper Pressure</i> output must first be energized, and then the pressure is verified with the input <i>Tool Gripper Pressure</i> .

**INGERSOLL**

Machine Tools

# **CHAPTER 8 - TOOL MANAGEMENT**



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## CHAPTER 8 - TOOL MANAGEMENT

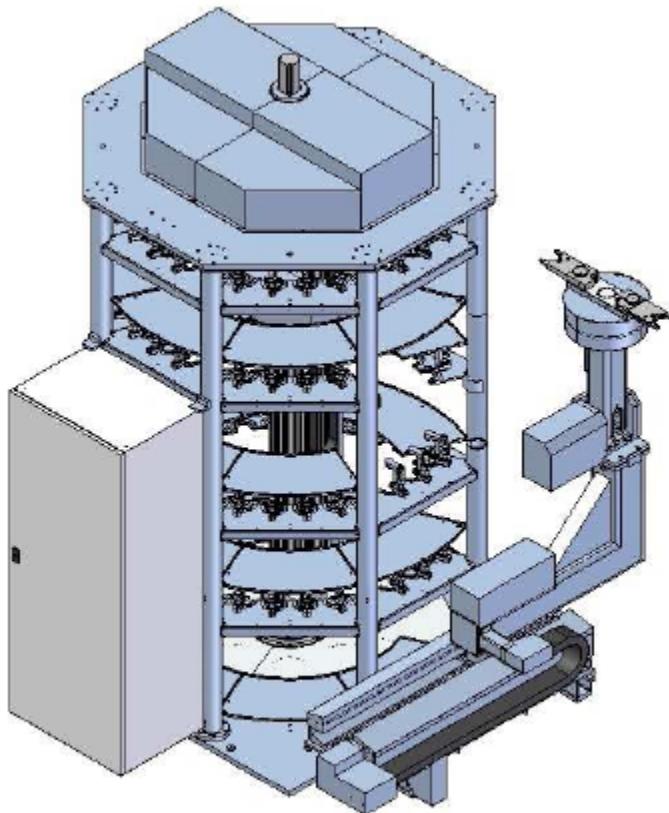
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## 8.1 TOOL STORAGE

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The tool system is a carousel style manufactured Oman, comprising 112 tool pockets. A tool robot picks tools from the pockets and delivers the tools to the spindle. The tool magazine is mounted on the left side of the machine, opposite from the operator console.



TOOL CAROUSEL

The tool carousel is comprised of five levels of tool pockets, with pockets arranged in a circle in each level. The first level has a tool check-in door.

There are a total of 112 pockets, each holding a Cat 60 taper tool. The tools are stored in the carousel in a vertical position, tool holder up. The tool pockets have a locating key for correctly orienting and locating tools in the tool pockets.

In the center of the circle, there is a tool robot arm that can move vertically between the floors, rotate on the center of the floors, and extend and retract (along the floor radius) to retrieve a tool from the carousel.

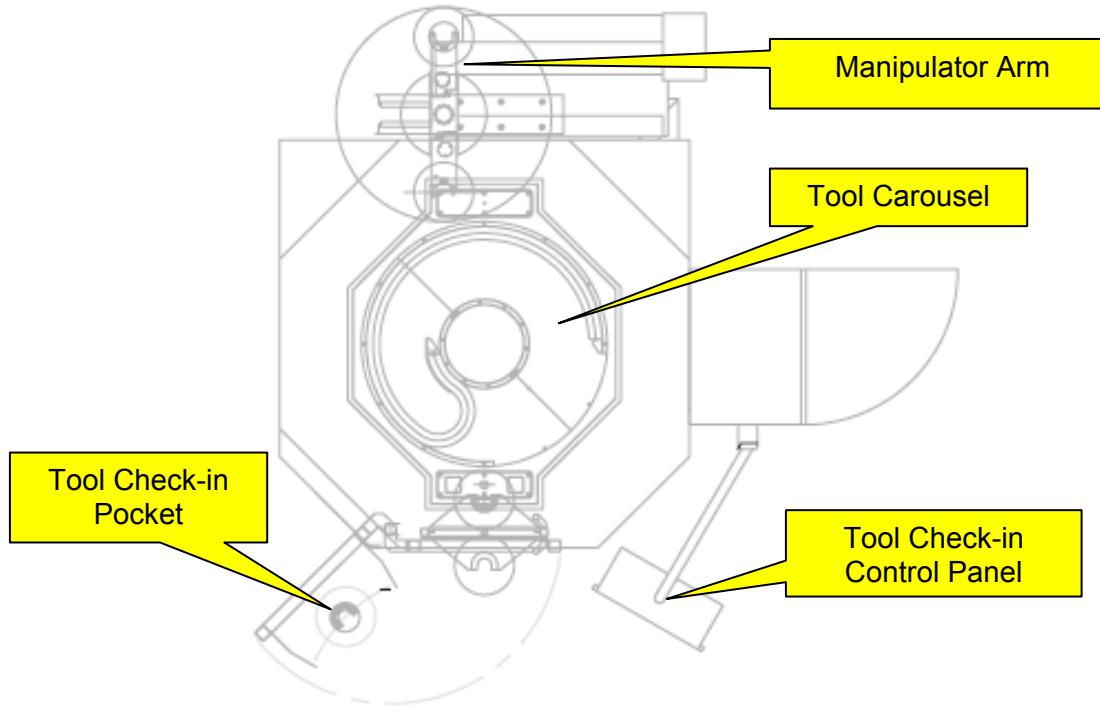
After the tool robot arm retrieves a tool from the carousel, the robot arm moves vertically to the exchange position, and rotates arm to proper angle at the exchange position.

The robot control maintains location of all the tools and keeps a file of the tool data. In case of a power failure, the location of the tools and tool data will be maintained. The following restrictions apply to loading tools into the magazine.

#### Tool Carousel Specifications:

Pocket capacity	112
Tool Shank	Cat 60
Maximum Tool Diameter (non-contiguous)	305 mm
Maximum Tool Diameter (adjacent pockets)	500 mm
Maximum Tool Length (87 pockets)	400 mm
Maximum Tool Length (25 pockets)	500 mm
Maximum Tool Weight	40 Kg

The robot arm extends and gives the tool to the manipulator arm at the exchanger position.



TOOL CAROUSEL - TOP VIEW

A manipulator arm, with dual grippers, is included to move the tools from the tool carousel to the exchange position in order to present the tool to the spindle unit on the machine.

The manipulator is tilted to horizontal or vertical attitude depending on spindle unit type (straight or right angle), and the manipulator arm is rotated to the proper angle to present the tool to the spindle unit. Each gripper has a clamping mechanism to hold a single tool.

The tool changer has its own separate PLC control to position the (5) servo motor axes and control the grippers and arm cylinders.

The tool changer PLC communicates with the main machine CNC/PLC over a profi-bus connection.

#### **8.1.1 TOOL CAROUSEL AXES DESCRIPTION**

NAME	AXIS #	DESCRIPTION
TC-Z	1	Vertical axis inside the tool changer tower
TC-C	2	Rotary axis inside the tool changer tower
TC-X/Y	3	Slide of the external exchanger arm. This axis name is either TC-X or TC-Y based on which machine axis it runs parallel to.
TC-B	4	Rotation of the external exchange arm grippers
TC-A	5	Tilt of the external exchange arm grippers

The 611U drives in the electric cabinet, are double axes drives. The first drive handles TC-Z and TC-C, the second drive TC-X and TC-B and the third drive TC-A.

## 8.2 TOOL CHIP READER

A Balluff BIS C code tag read/write system is mounted in the tool carousel near the tool load/unload door. Tools can be supplied with a chip, and during the tool preset operation (offline from the machine), data such as tool number, offsets, life, etc. can be written to the chip. When the tool is loaded into the machine's tool magazine during a load operation, the tool chip will be positioned in front of the chip read/write head and the tool data can be read automatically. During an unload cycle, the machine logic writes tool data onto the chip.

The components of a BIS Identification System are:

- The data carrier receives the energy signal and uses it to create its own supply voltage. Then it sends its data as a pulse-code modulated signal in the direction of the read/write head.
- The read/write head is the communications partner of the data carrier. It sends a 70 Hz energy signal out and receives the data signal transmitted back from the data carrier. The energy signal, since it is pulsed, is also used for programming the data carrier memory.
- The processor supervises the bi-directional data transfer between data carrier and read/write head and serves as buffer storage. It is the link between the host system and the data carrier. A sophisticated checking algorithm assures safe and reliable data transmission.

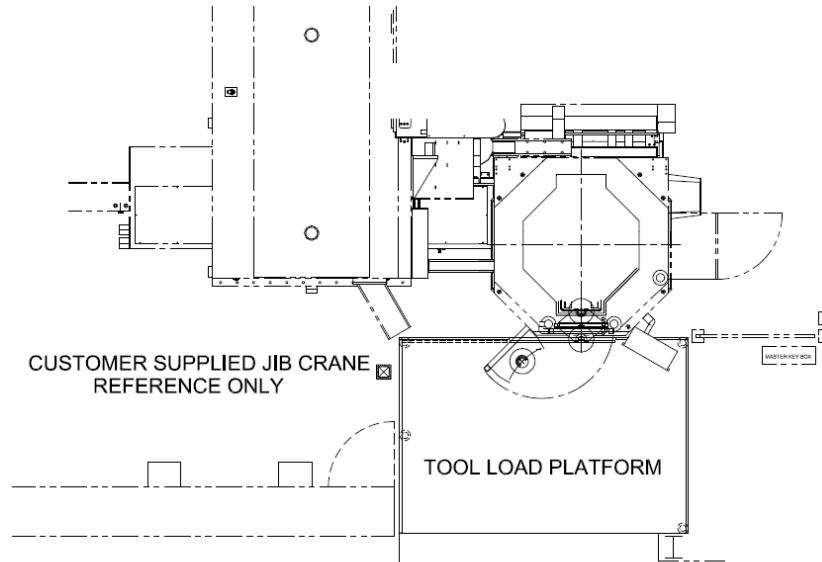


**NOTE:** When loading or unloading tools from the machine using the tool chip reader, the control must be in INCH mode, otherwise the tool data is stored in the wrong dimensions.

### 8.3 TOOL LOAD PLATFORM ACCESS GATE

---

An elevated Tool Load Platform with handrails is provided near the X-axis minus travel limit, to assist the operator in loading and unloading tools from the tool carousel. The tool load platform has one access gate, opening to the tool carousel. A jib crane (provided by the customer) is available to assist in handling heavy tools.



For the gate to be unlocked and opened, the X-axis must be at the tool load position, and all machine motion must be stopped. The X-axis tool load position (range) is stored in a data table entry.

For more details on the interlocking and operation of this gate, refer to the Gate and Zone Control chapter.

---

### 8.4 TOOL LOAD / UNLOAD

---

When a tool is to be loaded or unloaded, the tool carousel can be accessed through its own tool load door on the side of the tool magazine. Through the tool check-in console, the operator can request to open the load door. The tool magazine travels with the machine, along the X-axis, therefore loading or unloading tools can **NOT** be performed while the machine is running.

#### 8.4.1 TOOL CHECK-IN CONTROL PANEL

A tool check-in station is located near the tool carousel load door. This console is a replica of the main console screen and gives the operator access to all machine operational screens. At the tool check-in console, the operator can access the Siemens tool management for handling the tool data and the Oman screens for controlling the tool carousel.

The control panel is composed of three parts: a thin client monitor, control buttons and a keyboard. The thin client is connected by a network cable to the main machine control. The thin client displays a copy of the machine control screen. The keyboard is connected to the thin client and lets the operator input text.

Refer to the Oman Tool Changer User Guide for more information on the tool check-in console.

For ease of tool check in, the tool check in terminal is hung from a pivoting arm, to allow the operator to swing the terminal out over the tool load platform. The arm and tool check in terminal must be returned clear of the tool load platform before any X-axis motion is allowed in automatic or manual modes.



TOOL CHECK-IN CONTROL PANEL

#### 8.4.2 TOOL LOAD/UNLOAD SEQUENCE

Loading and unloading tools can NOT be performed while the machine is running. When loading or unloading tools from the machine using the tool chip reader, the control must be in INCH mode, otherwise the tool data is stored in the wrong dimensions.

##### Tool load sequence:

1. Open the load gate with the help of the tool check-in console.
2. Put the tool to load in the load pocket.

##### CAUTION



The tool needs to be loaded into the pocket with the proper orientation. Failure to load the tool with the proper orientation of the drive keys can cause severe damage to the robot.

3. Close the load gate.
4. On the Tool Management page, select a tool from the tool list and press the load softkey.
5. Input the desired tool pocket in the magazine.
6. At the prompted dialog windows, select the second load interface.
7. As soon as possible, the tool magazine will load the tool.

##### Single Tool unload sequence:

1. On the Tool Management page, select a tool in the carousel magazine.
2. Press the unload softkey.
3. At the prompted dialog windows, select the second load interface.
4. As soon as possible, the tool magazine will unload the tool.
5. Open the load gate with the help of the Tool Check-In Console.
6. Remove the unloaded tool.
7. Close the load gate.

##### All Disabled tools - unload sequence:

1. The operator go in the screen Ingersoll → **Unload Dis. Tools**
2. Enable “Unload all disabled tools”
3. The logic will start to scan all the disabled tools and unload them, one by one.

**Note:** If for any reason, the operator would like to stop the unload of the tools, they need to enable “Abort unload all disable tools”.

---

## 8.5 AUTOMATIC TOOL CHANGE

---

Based on where a tool is stored, it can be loaded into or unloaded from a spindle unit in the following ways:

- Automatic – Tools stored in the magazine are automatically inserted/removed by the robot.
- Manual – Tools not in the magazine must be manually inserted/removed.

An M6 code is used to initiate a tool change, regardless of the type of tool change required. Programming a “T” word followed by a tool number preselects the tool, i.e. that tool will be loaded on the next M6 call. Example, issuing a T1, then a M6 will load tool #1. If there is an existing tool in the spindle unit, it will be removed prior to loading the new tool. A T0, followed on another block with M6, can be programmed to unload the existing tool in the spindle unit without loading another tool.

**Note:** The T# cannot be placed in the same block as the M6, as the M6 calls a subroutine.

To shorten tool change cycle time, a tool should be preselected in advance of programming the M6 tool change code. For an automatically loaded tool, this gives the robot time to pick the tool from the magazine and have it ready in its gripper for the tool change. The next tool can be preselected immediately following the previous tool change cycle, however, to allow the robot time to load new tools into the magazine or unload old tools from the magazine into the tool check-in, the preselect should be issued near the end of machining with the currently loaded tool.

Programming example:

T1; (Preselects tool 1 from the magazine)  
M6; (Loads tool 1 into the spindle unit)  
... (Machining commands using tool 1)  
     (Tools can be loaded/unloaded into the tool magazine during this time)  
T2; (Preselects tool 2 from the tool magazine)  
... (Continue machining commands using tool 1)  
     (The robot will not perform tool load/unload operations during this time)  
M6; (Unloads tool 1 from spindle unit and loads tool 2)

The various types of tool changes are detailed in the next sections. The cycles describe the steps required for inserting a tool in the spindle unit, either automatically or manually. Note that if a tool is loaded in the spindle unit, it will first be removed with an automatic or manual cycle prior to loading the new tool.

---

**Automatic tool change with the permanently attached spindle unit is done with the swivel A-axis at 90°, so it is positioned like a right angle spindle unit.**

---

### **8.5.1 TOOL CHANGER MANIPULATOR DOOR**

A door in the work zone enclosure opens to allow the tool changer manipulator arm access to the machine spindle unit during a tool change cycle. This door must be open to allow tool manipulator motion, and the door must be closed to allow automatic operation to continue.

### **8.5.2 AUTOMATIC TOOL CHANGE FOR CAROUSEL**

A typical sequence for automatically removing an old tool from a spindle unit and inserting a new tool into the spindle unit, involves the following sub-sequences:

1. Pick new tool from the tool carousel
2. Move machine axes to tool change position
3. Exchange tools using the appropriate sub-sequences:
  - Automatic tool unload for right angle spindle unit
  - Automatic tool load for right angle spindle unit
4. Drop old tool into tool carousel

#### **8.5.2.1 PICK TOOL FROM TOOL CAROUSEL**

Tools stored in the carousel can be preselected by issuing a "T" word in the program, without a M6. This causes the robot to pick up the selected tool from the tool carousel and hold it in the exchange arm until the machine is ready for a tool change.

#### **8.5.2.2 MOVE MACHINE AXES TO TOOL CHANGE POSITION**

When a M6 is programmed, the main machine axes Y, Z, C, and A will automatically move for a tool change. The X-axis will not automatically be moved during a tool change.

The positions of the main axes for tool change are determined by the dimensional characteristics of the active spindle unit. Each spindle unit has unique axis positions for tool change. The tool change axis location for each spindle unit is stored in the SU data tables.

1. Receive command to change tools M06.
2. Stop coolant M09.
3. Stop spindle M05.
4. Retract Z to safe plane.

5. Move X-axis to either end of travel depending on which zone machine is in.
6. If needed, move Y-axis towards middle of machine to prevent collision with columns before rotating C and A axis.
7. Move C and A axes to tool change position.
8. Move Y-axis to tool change position and orient spindle for tool change.
9. Open Tool Changer Manipulator Door. Inhibit manipulator motion until door is open.
10. Verify the tool changer manipulator is at “ready/clear” position, clear of tool carousel and clear of machine cutting zone.
11. Continue with Exchange Tools sequence.

---

It is the part programmer's and operator's responsibility to pre-position the axis for tool change to make sure the machine will clear any part on the table.

---

#### 8.5.2.3 EXCHANGE TOOLS

This sequence describes the steps required to remove a tool from the spindle unit and hold it in tool exchange arm and then put a tool held in the exchange arm into the spindle unit.

Starting conditions of this sequence:

The tool changer manipulator is ready at the tool change position, as reported by the OMAN tool changer PLC.

The Machine Axes are ready at the Tool Change Position.

Continue with the **Automatic Tool Unload** sequence and/or the **Automatic Tool Load** sequence for a right angle spindle unit.

#### 8.5.2.4 TOOL UNLOAD FOR RIGHT ANGLE SPINDLE UNIT

1. Open exchange arm unload gripper
2. Move Z-axis (down, minus, small move) to tool change position, placing the tool in exchanger gripper.
3. Close exchange arm unload gripper
4. Open spindle unit tool gripper.
5. Y-axis moves back (minus) away from the tool
6. If T0; M6; command was issued, with no new tool to load:
  - a) Move Z-axis all way up
  - b) Retract tool exchanger arm
  - c) Close Tool Changer Manipulator Door. Inhibit automatic operations (Cycle Start) until door is closed.
  - d) Skip Automatic Tool Load sequence, and continue with Drop Tool Into Tool Carousel sequence.
7. If Txx; M6; command was issued, continue with the appropriate **Automatic Tool Load** sequence.

#### 8.5.2.5 TOOL LOAD FOR RIGHT ANGLE SPINDLE UNIT

1. Rotate exchange arm to point gripper with new tool towards spindle unit on machine
2. Open spindle unit tool gripper.
3. Move Y-axis (plus) to tool change position
4. Close spindle unit tool gripper.
5. Open exchange arm tool gripper
6. Move Z-axis all way up (plus).
7. Retract tool exchange arm
8. Close Tool Changer Manipulator Door. Inhibit automatic operations (Cycle Start) until door is closed.
9. If an old tool was removed from the spindle unit and is still in exchange arm gripper, continue with **Drop Tool Into Tool Carousel** sequence.

#### 8.5.2.6 DROP TOOL INTO TOOL CAROUSEL

After the tool exchange cycle is complete, the robot will unload the tool from the exchange arm and replace it back into the magazine.

## 8.6 RECOVERY PROCEDURE FOR TOOL CHANGE

When the tool magazine fails to perform an operation, it goes in the fault state. When it is in fault state it is not allowed to perform any automatic operation (tool change, tool load/unload, tool relocate, etc...). To identify if the tool magazine is in fault state, the user can check the tool magazine button LED on the MCP. It blinks when the tool magazine is in fault state and it is solid when the fault has been cleared. Alternatively, the tool magazine status can be read in the OPERATIVE MODES tool changer HMI screen.

### 8.6.1 M AND H CODES

The M and H codes can be run on the machine console in MDI. The tool changer needs to be in AUTO mode.

M/H Code	Description
M180	Bypass the safety feed hold when the tool magazine is external arm is not retracted.
M181	Tool magazine external arm axes (TC-X, TC-B and TC-A) move to the tool deposit positions for the current spindle unit. Both, gripper A and gripper B must be empty.
M182	Tool magazine external arm axes (TC-X, TC-B and TC-A) move to the tool pick up positions for the current spindle unit. Gripper A must hold a tool, gripper B must be empty.
M183	Retract all tool magazine external arm axes (TC-X, TC-B and TC-A) back toward the tool magazine
M184	Swap gripper A and gripper B. The purpose of this M code is to simulate the tool change cycle grippers rotation to help the maintenance to take the machine tool change positions.
H19	Open Tool Changer Manipulator Door
H20	Close Tool Changer Manipulator Door
H128	Return all the tool in the buffers (Gripper A, B or internal arm gripper) back into the carousel tower places

### 8.6.2 TOOL STUCK BETWEEN THE EXTERNAL ARM AND THE MACHINE

If the tool is all the way in the external arm gripper, it is easier to leave the tool in the external arm and move away the machine:

- Lock the external arm gripper with the HHU
- Unlock the machine spindle gripper H16
- Program M180 to enable the machine axes to move
- Move the machine away from the external arm
- M183 retract the tool changer external arm

If the tool is half way in the external arm gripper, it is easier to remove the tool from the tool changer external arm:

- Unlock the external arm gripper with the HHU
- Program M180 to enable the machine axes to move
- Move the machine away from the external arm
- M183 retract the tool changer external arm

### 8.6.3 TOOL STUCK BETWEEN THE INTERNAL AND THE EXTERNAL ARM

If the tool is properly clamped in the internal arm gripper, it is easier to keep the tool in the internal arm gripper:

- Unlock the external arm gripper with the HHU
- Retract the internal arm with the HHU

If the tool is properly clamped in the external arm gripper, it is easier to keep the tool in the external arm gripper:

- Open the internal arm gripper with the HHU
- Retract the internal arm with the HHU

### 8.6.4 TOOL STUCK BETWEEN THE INTERNAL ARM AND A TOOL POCKET

It is very difficult to move the tool magazine axes TC-Z and TC-C in this position without arm the tool changer; the easiest way to recover from this case is to leave the tool in the pocket:

- Open the internal arm gripper with the HHU
- Retract the internal arm with the HHU

If, after this procedure, the tool is not properly seated in the pocket, it is necessary to power off the tool magazine, enter in the carousel tower and by hand, correct the tool position.

### 8.6.5 ENABLE MACHINE AXES TO MOVE WITHOUT M180

When the tool changer external arm is not retracted, the machine axes are in hold. In addition to the M180, there is an alternative way to bypass this restriction:

- Switch the tool changer in manual mode
- Enable the machine HHU

### 8.6.6 CONDITIONS FOR THE AUTO TOOL EXCHANGE

Follow the conditions to meet before trying to clear the tool magazine fault status:

- Internal arm gripper
  - Closed if holding a tool
  - Open if not holding a tool
- Both external arm grippers closed
- External arm TC-A almost vertical ( $\pm 1$  deg)
- External arm TC-B axis in a position where gripper A or B are aligned with the unlock cylinders
- External arm TC-X axis retracted toward the tool magazine
- Load gate closed

### 8.6.7 CLEAR THE MAGAZINE FAULT STATUS

First, the user must check that the actual tool location and the Siemens tool management tool list match. In particular, check the following buffer places:

- Spindle
- Internal arm gripper
- External arm gripper A
- External arm gripper B

**If there is any discrepancy, the user must fix it before proceeding.** The next step when the tool list table is up to date is to put the tool magazine devices in a safe position. Please refer to topic “ENABLE MACHINE AXES TO MOVE WITHOUT M180” for the details. Finally, the user can clear the fault status.

If the user is standing at the machine operator console, he can use the tool magazine button on the MCP. Holding the button for three seconds will clear the fault. If the fault status does not clear, it means that the tool changer is still in error. Check the tool changer and the machine alarms/messages to find the problem.

If the user is standing in front of the tool magazine, there is an alternative procedure to clear the fault. On the tool changer console, he must press the RESET push button until it stops blinking, then he must press the ENABLE push button until the light became solid. If the reset button keeps blinking, it means that there is an error on the tool changer. Check the tool changer and the machine alarms/messages to find the problem. Once ENABLE is solid, the user must go on the tool changer HMI OPERATIVE MODES screen. There, using the softkey “Clear fault”, he can clear the tool magazine fault status.

### 8.6.8 RECOVER THE TOOL MAGAZINE AFTER PLC CPU FAILURE

#### 8.6.8.1 REPLACE THE PLC CPU AND KEEP THE MMC CARD

If the PLC MMC memory card has not been damaged it is enough to:

1. Replace the PLC CPU
2. Put the old MMC memory card on the new PLC CPU
3. Restart tool magazine PLC CPU
4. Execute an NCK reset on the machine
5. Reboot the machine HMI

The hardware configuration, the PLC program, and all the setting will be the same as before the fault. Maintenance does not need to perform other actions.

#### 8.6.8.2 REPLACE THE PLC CPU AND THE MMC CARD

In the unlikely event that the MMC memory card is damaged too, the procedure is a little longer, but still very easy. Here what the maintenance needs to do:

1. Replace the PLC CPU
  2. Put a new MMC memory card
  3. Using Step 7 reload the tool magazine hardware configuration
  4. Using Step 7 reload the tool magazine PLC program
  5. Restart tool magazine PLC CPU
  6. Execute an NCK reset on the machine
  7. Reboot the machine HMI
  8. Load a back up file from the tool carousel screen
- 

## 8.7 MANUAL TOOL CHANGE

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Tools not assigned to a pocket in the tool magazine utilize a manual tool change. An M6 will initiate a manual tool change if the preselected tool number is not listed in the magazine.

Manual Tool Change Sequence performed by logic:

1. Receive command to change tools M06.
2. Stop coolant M09.
3. Stop spindle M05.
4. Retract Z to safe plane.
5. Move X-axis to either end of travel depending on which zone machine is in.
6. If needed, move Y-axis towards middle of machine to prevent collision with columns before rotating C and A axis.
7. Move Y, C and A axes to manual tool change position (rapid move).
8. Move Z-axis down to manual tool change position.
9. Operator manually opens spindle gripper and removes old tool.
10. Operator manually inserts new tool and closes spindle gripper.
11. Retract Z to safe plane.
12. Operator presses cycle start to continue program.

---

## 8.8 TOOL DATA MANAGEMENT

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Each tool to be used on the machine must be manually entered into the Siemens CNC through use of the Tool List screen, described below.

For more details on the Siemens Tool Management screens, please refer to the Tool Management section in the Siemens 840D Operator's Manual.

As part of the tool data, tools can be assigned to a magazine number. This identifies to the machine logic the location where a tool is stored. The following magazines are assigned for this machine:

- Magazine #1 = Carousel Level #1
- Magazine #2 = Carousel Level #2
- Magazine #3 = Carousel Level #3
- Magazine #4 = Carousel Level #4
- Magazine #5 = Carousel Level #5

Tools that are to be manually loaded into the spindle units are listed in the tool catalog with no magazine assigned.

### 8.8.1 TOOL LIST SCREEN

To get to the Tool List screen, press the **Menu Select** softkey, then press the “>” softkey until the **Parameter** function key is displayed along the bottom, horizontal function keys. Press the **Tool Management** function key and then the **Tool List** to bring up the display of the tool list.

Parameter	Machine	JOG Inc 1000	SYF.DIR OSTORE1.SYF Program interrupted ROV																							
Channel interrupt			Program interrupted																							
701641 ↓ DB2.DBX313.1 Pallet exchanger in fault																										
Tool list 1																										
Row	MagPI	Tool ID	Dupl	TNo	L	R	T	B	T	T	T	T	T	Mpl												
1	40		1	14	1	1	1	1	A	P	-	-	-	U	1											
2	1	255025		15	1	1	1	1	A	P	-	-	-	L	U	1										
3	1	275027		16	1	1	1	1	A	P	-	-	-	L	U	1										
4	1	295029		17	1	1	1	1	A	P	-	-	-	L	U	1										
5	1	305030		18	1	1	1	1	A	P	-	-	-	L	U	1										
6	1	315031		19	1	1	1	1	A	P	-	-	-	L	U	1										
7	1	325032		20	1	1	1	1	A	P	-	-	-	L	U	1										
8	1	335033		21	1	1	1	1	A	P	-	-	-	L	U	1										
9	1	345034		22	1	1	1	1	A	P	-	-	-	L	U	1										
10	1	355035		23	1	1	1	1	A	P	-	-	-	L	U	1										
11	1	365036		24	1	1	1	1	A	P	-	-	-	L	U	1										
12	1	375037		25	1	1	1	1	A	P	-	-	-	L	U	1										
13	1	385038		26	1	1	1	1	A	P	-	-	-	L	U	1										
14	1	395039		27	1	1	1	1	-	P	-	-	-	L	-	1										
15		38		28	1	1	1	1	A	P	-	-	-	U	1											

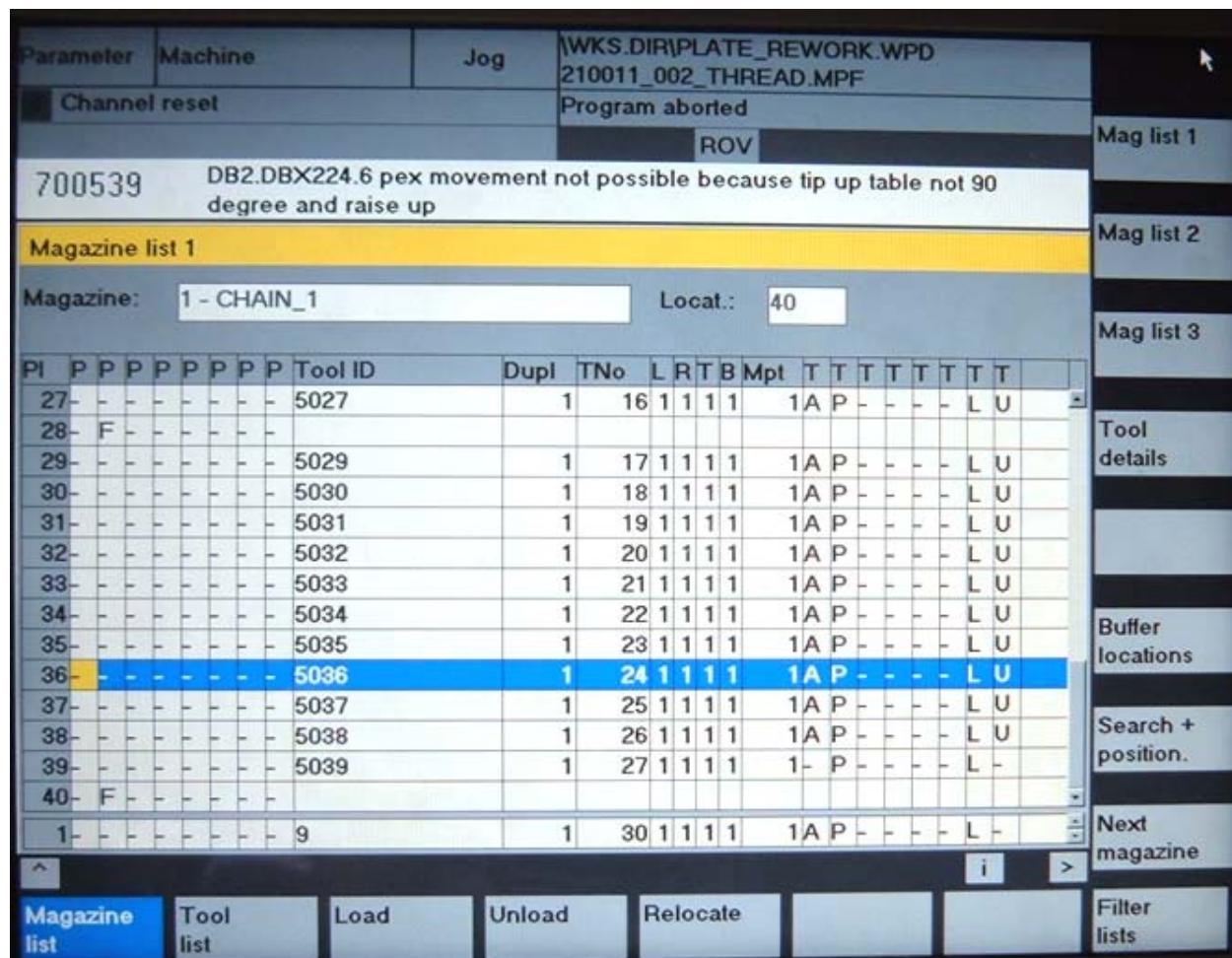
TOOL LIST SCREEN

A tool is selected in the program by means of the T function. In the tool list screen, the tools are displayed in the order of ascending T numbers (tool id. numbers). Additional data for the tools can be displayed by pressing the Tool List 1, 2, and 3 vertical function keys. A tool can be added to the list using the New Tool vertical function key.

Tool offset data consists of data which describes the geometry, wear, identification, tool type and other tool parameters depending on the tool type.

### 8.8.2 TOOL MAGAZINE LIST

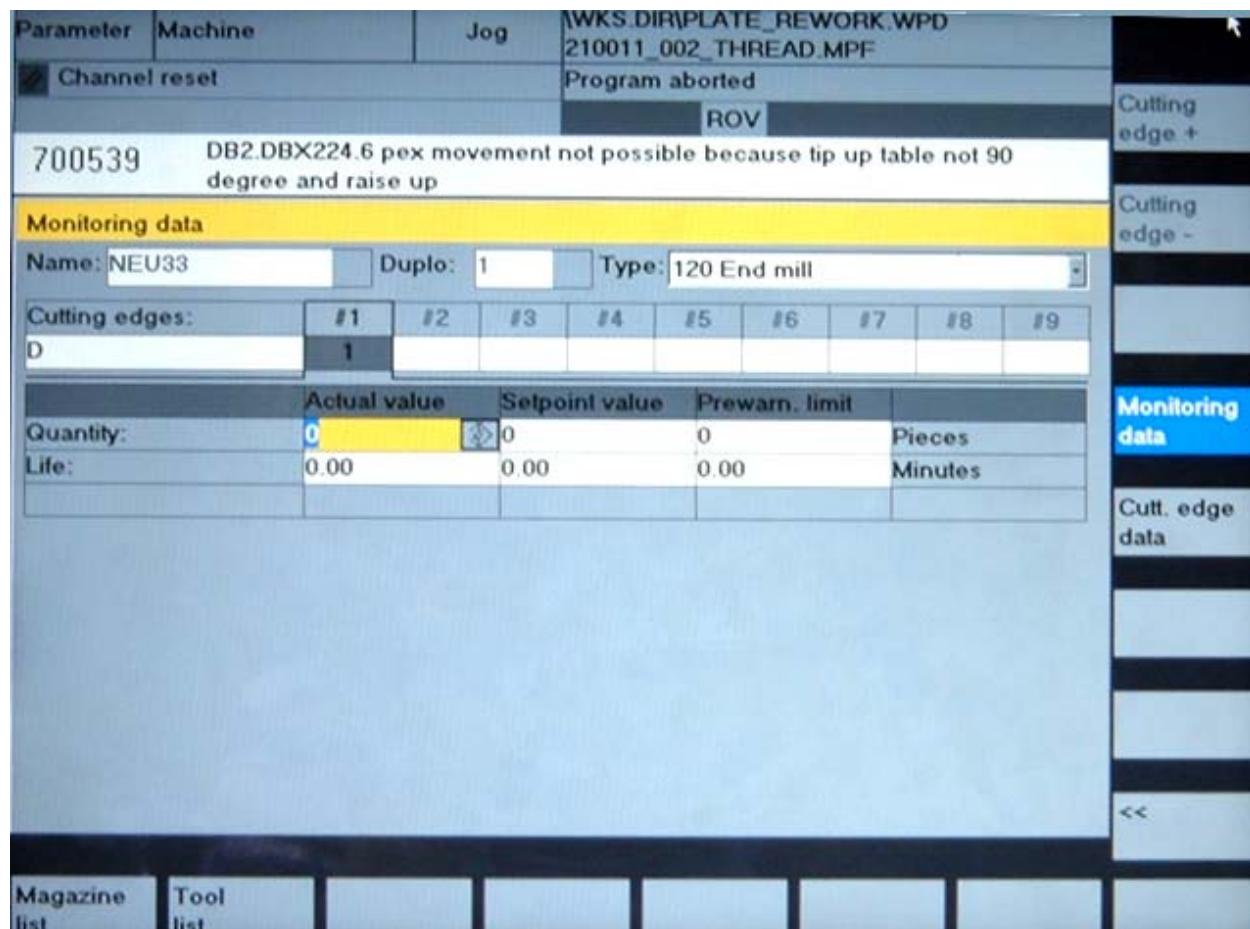
The Tool Magazine list in the Siemens CNC displays what tools are in each pocket of the tool carousel. In the "Magazine List", the tools of a magazine are displayed in order of ascending magazine location (pocket) numbers. This list is mainly used to load and unload tools during setup, and to move tools between magazines.



The Load and Unload horizontal function keys are used to assign tools to pockets in the magazine and remove tools from the tool magazine. The Relocate horizontal function key is used to move tools between pockets.

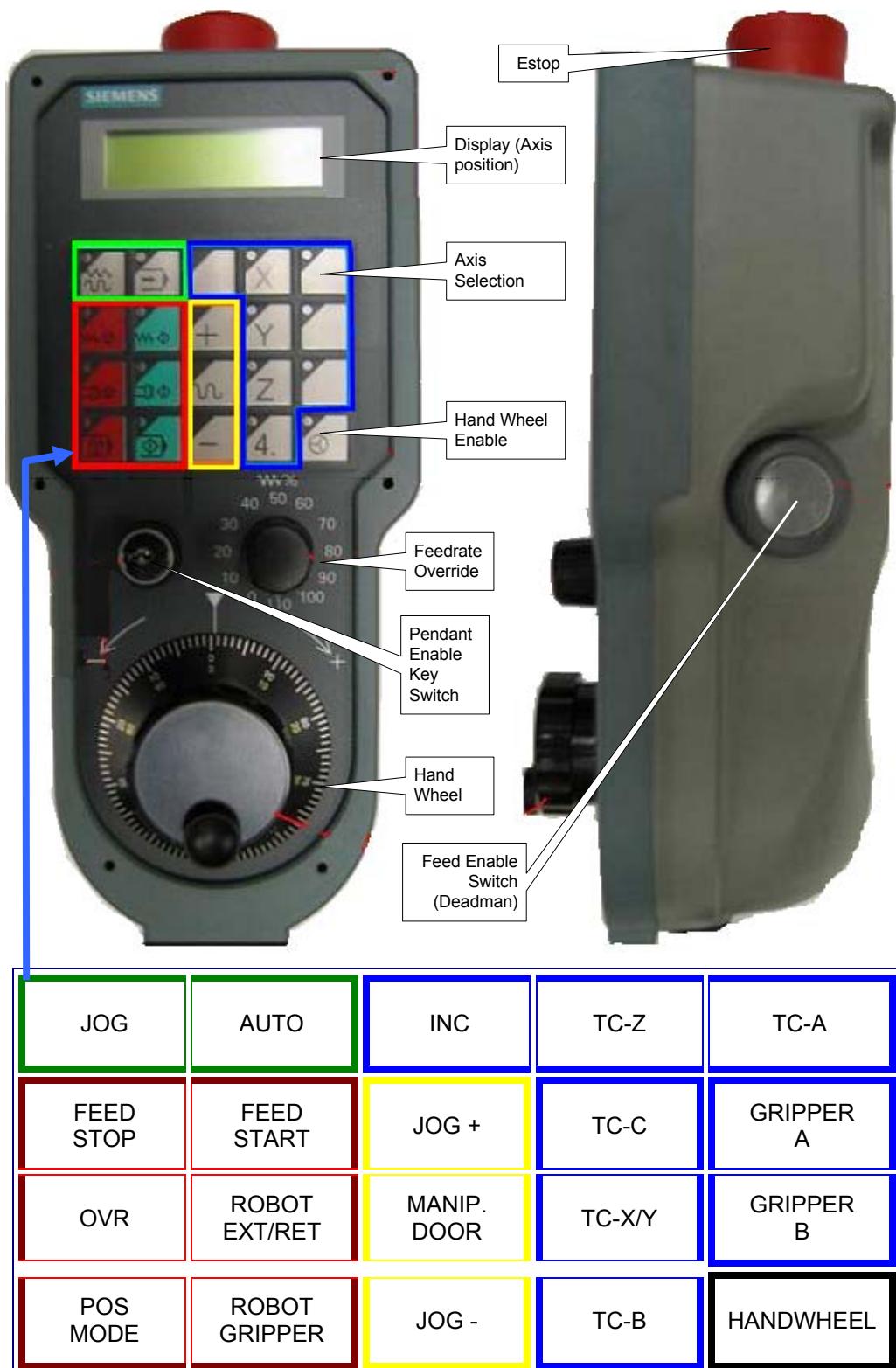
### 8.8.3 TOOL LIFE MANAGEMENT

Through the use of the "Monitoring Data" screen, the operator has the ability to set a "working time" for each tool that is automatically decremented by the control when the tool is turning. When the life timer reaches zero, the tool is marked as "disabled" (it is not immediately removed from operation) and the tool will not be allowed to be put back into use after it is removed from the spindle unit. If a replacement tool is available, it is inserted in its place. There is a parameter in the tool table to remove the disable flag and reset the tool after the operator changes the cutter or inserts.



TOOL LIFE DATA

## 8.9 TOOL CAROUSEL HAND-HELD UNIT (HHU)



The Tool Carousel has its own handheld unit that can be used for maintenance purposes to set-up the tool changer.

### 8.9.1 BRIEF KEY DESCRIPTION

KEY	DESCRIPTION
Enable Key	It is located just under the keypad. When it is in the vertical position, enable the functionality of the HHU.
JOG	Same function as in the HMI Operative mode, switches the tool changer in MANUAL mode. The HHU functions are enabled only when the tool magazine is in manual mode.
AUTO	Same function as in the HMI Operative mode, switches the tool changer in AUTO mode. When the operator is done with the HHU, the tool changer needs to be switched back into AUTO mode to enable the automatic tool exchange (Txx; M6;).
FEED STOP	Prevent all the tool changer axes to move (regardless the operative mode).
FEED START	Enable the tool changer axes to move (regardless the operative mode).
Feed override selector	Like any other feed override selector, lets you reduce the tool magazine speed from the full speed (100%) to a complete stop of the axes (0%). The feed override is active only when the HHU is enabled (regardless the operative mode), but this behavior can be altered with the OVR button.
OVR	This button lets the operator keep the feed override enabled when the HHU is disabled. When the OVR key LED is on, this function is selected. To alter the status of this function (select/deselect), the HHU must be enabled.
POS	Provide the support to move the tool changer axes to a specific position. Example: pockets, grippers etc. For a comprehensive description of this function, please to the specific topic later in this document.
HANDWHEEL	Enable the handwheel to move the tool magazine axes. To disable the handwheel, you must press the JOG button. The INC button scrolls between the selectable increments.
INC	When the handwheel is enabled, lets you select the increment. The actual increment is displayed on the second line of the LCD. The increment value is related to the drive internal unit, it isn't mm, inch or degree. The increment function does not work with the JOG plus and minus buttons.
JOG+	When an axis is selected and the JOG function is enabled, it moves the axis in the plus direction. When a cylinder is selected, it executes different functions based on the selected cylinder: extend or close. When the POS mode is selected, it initiates an axis movement.

KEY	DESCRIPTION
JOG -	When an axis is selected and the JOG function is enabled, it moves the axis on the minus direction. When a cylinder is selected, it executes different functions based on the selected cylinder: retract or open.
MANIPULATOR DOOR	When the JOG function is active, this button enables the opening and closing of the tool changer manipulator door. Jog plus will open the door and jog minus will close the door.
TC-Z TC-C TC-X/Y TC-B TC-A	Select the named axis for JOG or handwheel movement.
ROBOT GRIPPER	When the JOG function is active, this button enables the opening and closing of the tower internal arm tool gripper. Jog plus will open the gripper and jog minus will close the gripper. Note: If the internal arm does not hold any tool, the user must leave it open, or else the automatic tool exchange will not run.
ROBOT EXT/RET	When the JOG function is active, this button enables the extending and retracting of the tower internal arm tool gripper. Jog plus will extend the arm and jog minus will retract the arm.
GRIPPER A	When the JOG function is active, this button enables the opening and closing of the external arm tool gripper A. Jog plus will open the gripper and jog minus will close the gripper.
GRIPPER B	When the JOG function is active, this button enables the opening and closing of the external arm tool gripper B. Jog plus will open the gripper and jog minus will close the gripper.

## 8.9.2 DETAILED FUNCTION DESCRIPTION

### 8.9.2.1 POS FUNCTION

The positioning function allow the user to move one or more tool magazine axes to a specific position, like a tool pocket, a tool gripper etc.

The positions are identified by the means of a unit/location schema.

<b>Unit</b>	<b>Axes</b>	<b>Description</b>
1...9	TC-X TC-C	The units from 1 to 9 represent the floors inside the tool changer tower. The locations stand for the tool pockets of the specified floor.
101	TC-X TC-C TC-X/Y TC-B TC-A	The unit 101 represents the external exchange arm. The locations are the grippers (A or B) of the external arm. Selecting this unit is possible to move all the tool magazine axes in position for exchange tools between the internal and the external arm.
102	TC-X TC-C	The unit 102 represents the load/unload gate. The locations are the load/unload pockets.

Based on the selected unit/location, some axes are involved in the movement, some are not. Please refer to the above table to determine which axes are involved with each unit/location.

To enable the POS function, the user must press the POS button. If the last unit/location selected is compatible with the selected axis, the axis will be ready to move. If not, the HHU will prompt the user to select a new unit/location. To understand how to select a new unit/location please read the subsequent section.

When the unit/location is selected, it is enough to press the Jog + button to initiate the movement. If the user desires to move another axis at the same unit/location, he just needs to select the new axis and press Jog + again.

To disable the POS function the user can disable the HHU or press the JOG button.

### 8.9.2.2 HOW TO SELECT A NEW UNIT/LOCATION

To prompt the selection for a new unit/location, the user must press the POS button when the position function is already active.

The LCD display will prompt the user to select the new unit, Jog + will scroll the units.

When the desired unit is displayed, press the POS button again and the display will move on the location selection. Using Jog + and Jog -, the user can select the location. When done, press the POS button again.

### 8.9.3 BYPASS SAFETY RESTRICTIONS

This section is only for trained maintenance personnel. It is not advisable to make a general operator aware of this function.

There are some safety interlocks to prevent the user from executing dangerous operations. These restrictions usually do not affect recovery operations; instead they may prevent some maintenance operations. To bypass the interlocks, the user must press together and hold the JOG and INC button for 3 seconds. The JOG key LED will blink to remind the user that the safety interlocks are disabled. When the user desires to re-enable the safety interlocks, he must disable the HHU with the key selector.

## 8.10 TOOL CAROUSEL HMI SCREENS

To reach the carousel HMI screens, the user must open the Inggersoll setup screens and push the “Carousel Setup” softkey.

Carousel Setup	Tool Change Setup	Tool ID	SU Data Manager		Machine Status	Machine Setup	Option Manager
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When the Carousel Setup screen is opened, the horizontal softkeys bar displays the main carousel HMI tool changer functions as shown:

Operative mode		Tool relocate	Diagnosis			Backup restore	Param
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### **8.10.1 OPERATIVE MODES**

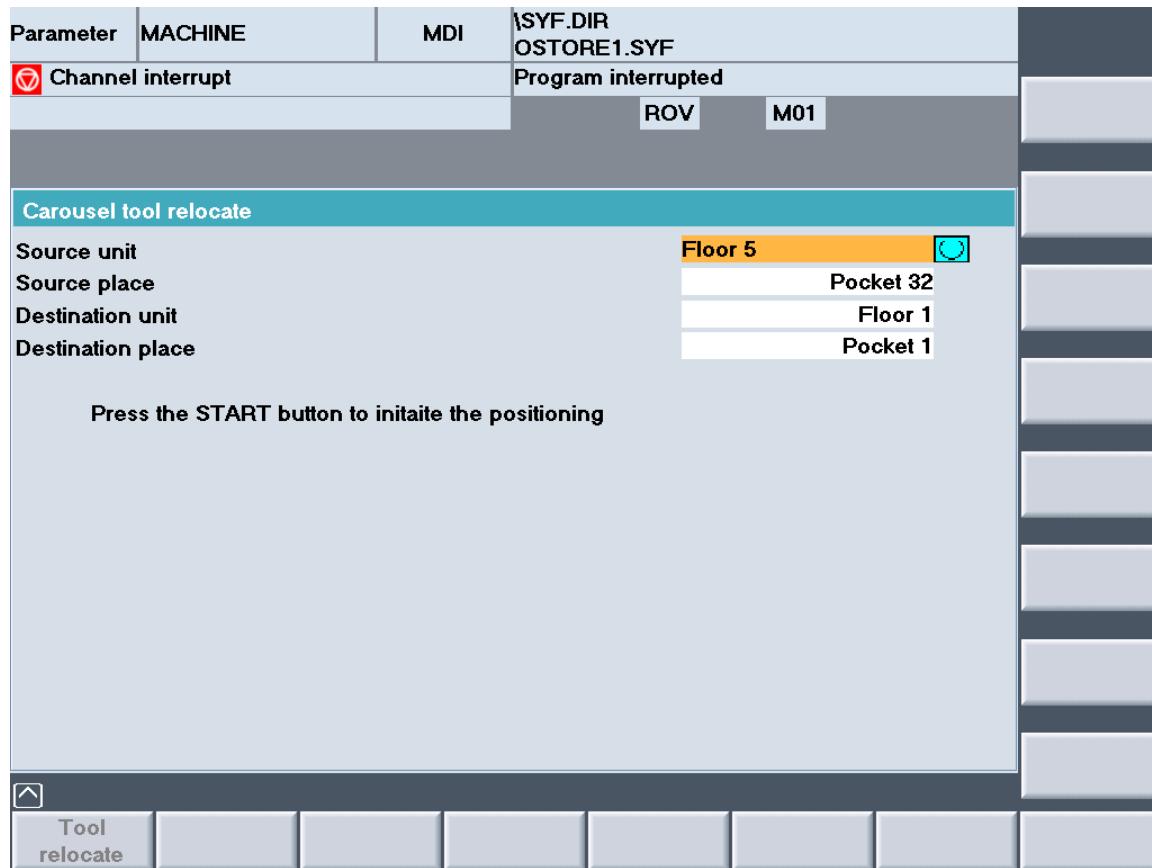
Parameter	MACHINE	MDI	\SYF.DIR OSTORE1.SYF	
 Channel interrupt			Program interrupted	
			ROV	M01
Carousel operative mode			AUTO	
Actual operative mode			AUTO	
Tool magazine status			OK	
				
				
				
				
				
				
Operative mode				

Through the operative mode screen, it is possible to alter the active tool magazine mode. The tool changer will activate the operative mode only when is in idle, even if requested from the operator. The active operative mode can be read from the displayed "Actual operative mode". A short description of the operative modes follows:

MODE	DESCRIPTION
OFF	The tool magazine cannot perform any action. It is a way to disable the tool magazine
MANUAL	This mode lets the operator perform manual operation through the tool magazine HHU. The manual mode can be selected also from the tool magazine HHU.
TEST	This mode is for set up/demo only. It is used by the tool changer manufacturer.
AUTO	The AUTO mode is the most used. It allows the tool changer to receive commands from the machine and therefore, perform automatic tool exchange. The AUTO mode can also be selected from the tool magazine HHU.

In addition to the mode selection, this screen lets the operator clear the fault status of the tool changer. The “clear fault” softkey replicates the function of the MCP button that clears the magazine fault. The “Tool magazine status” field provides feedback to the operator if the tool changer is in fault.

### 8.10.2 TOOL RELOCATE



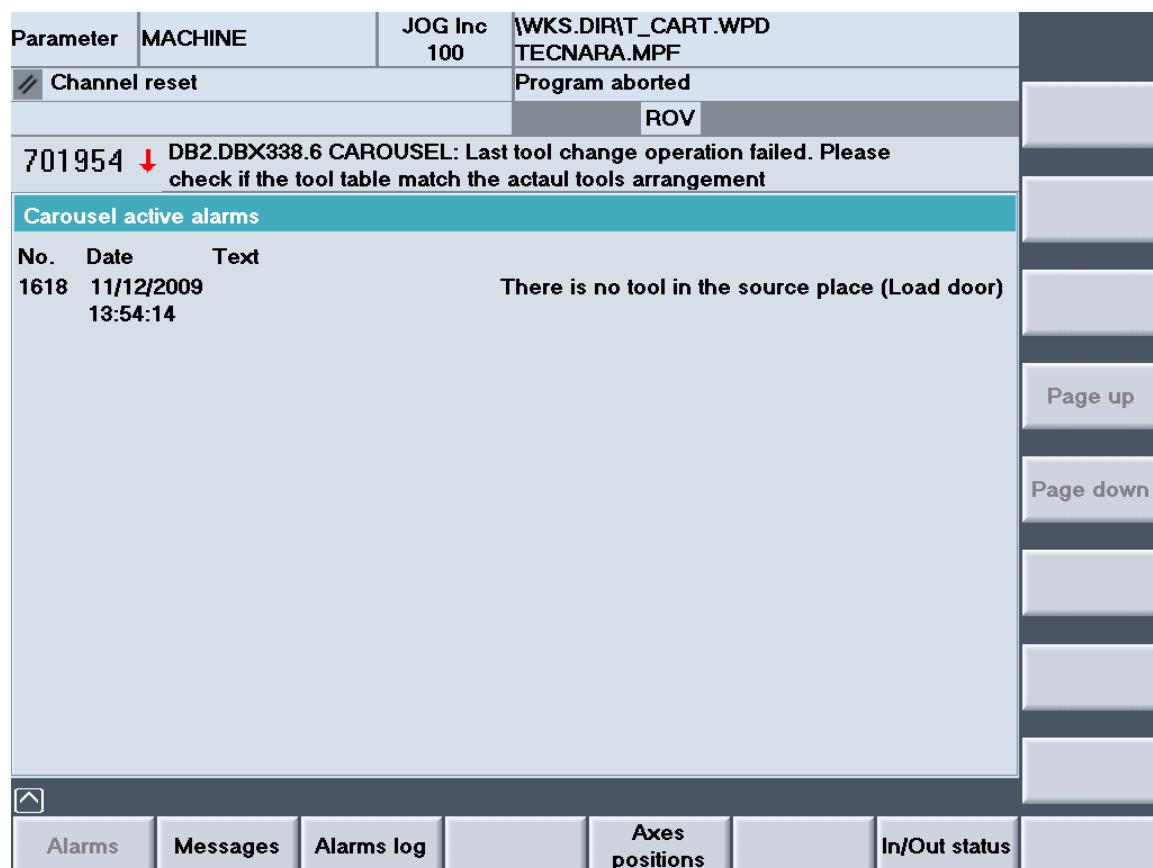
This screen is used to relocate a tool inside the tool carousel. To run, it needs the tool magazine in TEST mode. Using the four toggle fields, it is possible to select any location inside the tool carousel tower as source and destination. Pushing the START button on the tool changer console initiates the relocation. The Siemens tool management table is updated as well.

### 8.10.3 DIAGNOSIS



The Diagnosis area provides the operator/maintenance with useful information about the tool changer.

## 8.10.3.1 ALARMS



The Alarms screen shows the active alarms on the tool magazine. It mimics the look of the Siemens HMI alarm page. If there are more alarms than the page can display, the softkey page up and page down will enable to let the user scroll the pages.

### 8.10.3.2 MESSAGES

The Messages screen shows the active messages on the tool magazine. It mimics the look of the Siemens HMI messages page. If there are more messages than the page can display, the softkey page up and page down will be enabled to let the user scroll the pages.

## 8.10.3.3 ALARMS/MESSAGES LOG

Parameter	MACHINE	MDI	\SYF.DIR OSTORE1.SYF	
<input checked="" type="checkbox"/> Channel interrupt			Program interrupted	
<b>Carousel alarms/messages log</b>				
No.	Raised	Cleared	Text	
1790	10/31/2009 10:08:18	10/31/2009 10:08:41	TC-Y - Fault or warning active in the 611U drive	
1806	10/31/2009 10:08:18	10/31/2009 10:08:41	TC-B - Fault or warning active in the 611U drive	
1822	10/31/2009 10:08:18	10/31/2009 10:08:41	TC-A - Fault or warning active in the 611U drive	
5016	11/02/2009 8:31:14	11/02/2009 8:31:22	Tool magazine not ready. Press Cycle Start to restart it	
1599	11/06/2009 14:38:16	11/06/2009 14:52:35	Gripper B tool present switch do not match the tool table. Cycle aborted	
5016	11/06/2009 14:38:16	11/06/2009 14:49:17	Tool magazine not ready. Press Cycle Start to restart it	
1599	11/06/2009 14:52:35	11/06/2009 14:53:07	Gripper B tool present switch do not match the tool table. Cycle aborted	
5016	11/06/2009 14:53:11	11/06/2009 14:53:18	Tool magazine not ready. Press Cycle Start to restart it	
<b>Carousel alarms/messages log</b>				
<input type="button" value="Page up"/> <input type="button" value="Page down"/> <input type="button" value="Clear log"/>				
<input type="button" value="Alarms"/>	<input type="button" value="Messages"/>	<input type="button" value="Alarms log"/>	<input type="button" value="Axes positions"/>	<input type="button" value="In/Out status"/>

The alarms/messages screen mimics the look of the Siemens HMI alarm log page. If there are more alarms/messages than the page can display, the softkey Page up and Page down will be enabled to let the user scroll the pages. There is no way to save the log file.

The softkey "Clear log", as its name says, removes all the entry in the log. It is not possible to recover the log once it has been cleared.

## 8.10.3.4 AXES POSITIONS

Parameter	MACHINE	MDI	\SYF.DIR OSTORE1.SYF				
<input checked="" type="checkbox"/> Channel interrupt			Program interrupted				
			ROV	M01	axis position		
<b>Carousel axes positions</b>							
TC-Z axis position				802.701	mm		
TC-C axis position				-247.500	deg		
TC-Y axis position				-14.613	mm		
TC-B axis position				67.051	deg		
TC-A axis position				0.000	deg		
							
Alarms	Messages	Alarms log		Axes positions		In/Out status	

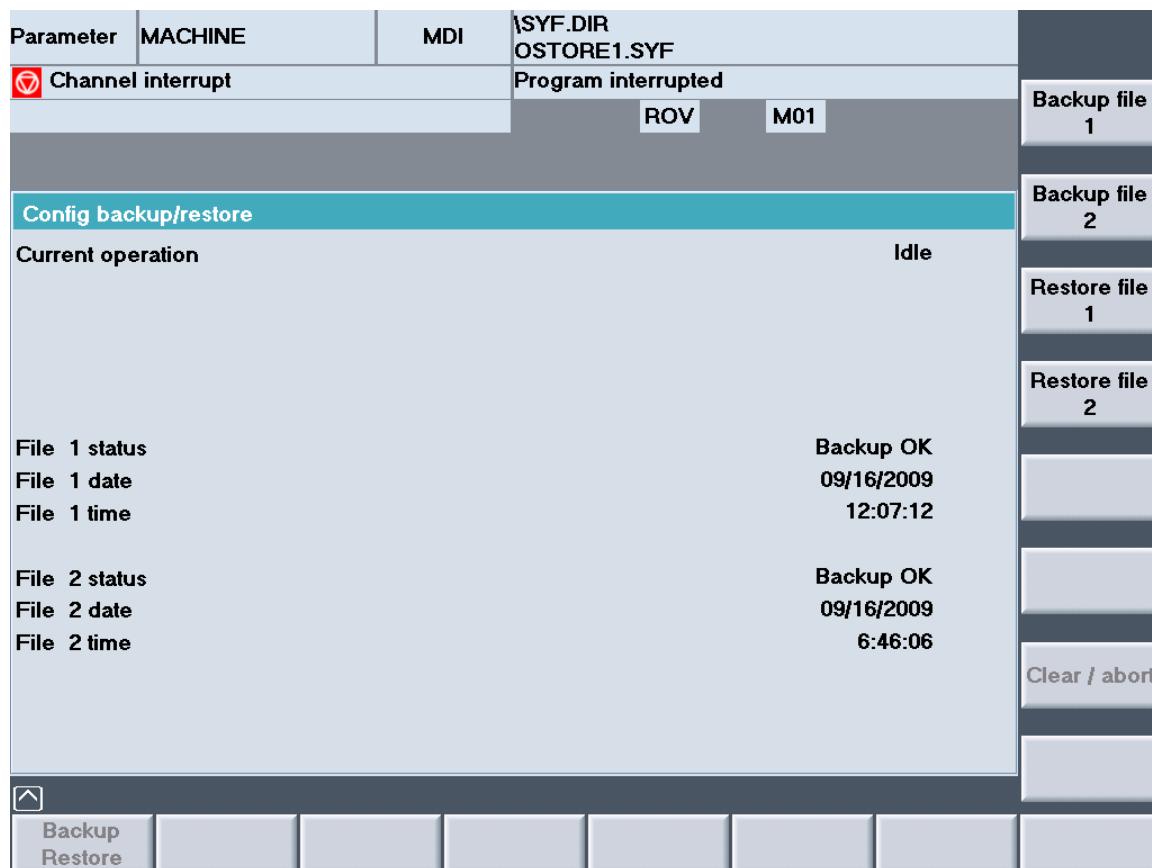
This screen simply displays the actual positions of the tool magazine axes.

## 8.10.3.5 IN/OUT

Parameter	MACHINE	MDI	\SYF.DIR OSTORE1.SYF	ROV	M01		Bank 0
<input checked="" type="checkbox"/> Channel interrupt			Program interrupted				
<b>Carousel I/O status</b>							
I0.0 eAttuRwGroup_1						True	Bank 1
I0.1 eAttuFwGroup_1						False	Bank 2
I0.2 eAttuRwGroup_2						True	Bank 3
I0.3 eAttuFwGroup_2						False	Bank 4
I0.4 eCyl1GrpOpenOrCloseWTool						False	Bank 5
I0.5 eCyl2GrpOpenOrCloseWTool						False	Bank 6
I0.6 eCyl1GrpCloseWoutTool						False	Bank 7
I0.7 eCyl2GrpCloseWoutTool						False	
I1.0 eFuseOp015_Ok						True	
I1.1 eFuseAxles_Ok						True	
I1.2 eFuseBrakes_Ok						True	
I1.3 eFusePanel_Ok						True	
I1.4 eFuseTower_Ok						True	
I1.5 eFuseArm_Ok						True	
I1.6 eFuseEV_Ok						True	
I1.7 eFuseDpDp_Ok						False	
Alarms	Messages	Alarms log		Axes positions		In/Out status	

The in/out screen displays the actual value of the tool magazine inputs/outputs. The signals are displayed using the address and their symbolic name used in the PLC. Using the Bank softkeys, the user can toggle between all tool magazine inputs/outputs. It is not possible to override the status of any input or output.

#### 8.10.4 BACK UP AND RESTORE



The back up and restore screen is one of the most important screen of the tool changer HMI. It allows maintenance personnel to back up the entire tool magazine setting data and restore it in case of failure of the tool changer. There are two files where Maintenance can save the setting data, these files are resident in the machine PLC memory. Making a machine PLC archive on the Siemens HMI will save also the tool magazine back up files.

To back up the data, Maintenance must first switch the tool magazine in MANUAL mode and after push the softkey “Backup file 1” or “Backup file 2”. The back up procedure will start immediately and it will require a few minutes.

To restore the setting data, Maintenance must again switch the tool magazine in MANUAL mode and push the softkey “Restore file 1” or “Restore file 2”.

The screen displays the actual status of the back up files. The file contains a valid back up, only if the status field shows “Backup OK”.

The back up screen may be used to recover after a PLC CPU failure.

### 8.10.5 PARAMETERS

Axes parameters	Cylinders parameters	Floors positions	Buffer positions		Axes generic	Wheel cnbalance	Edit
-----------------	----------------------	------------------	------------------	--	--------------	-----------------	------

The parameter area holds all the setting data for the tool changer. When the user enters the parameter area for the first time, all the pages are in read only mode. To gain the ability to change the data, the user must press the “Edit” softkey. The edit mode will be enabled until the user exit the parameters area.

**Note:** Most of the parameters are active immediately after the change. It is not advisable to change any parameter when the tool magazine is not in idle. To be sure that the tool magazine will not start any action while the user is changing the parameters, it is advisable to put the tool changer in manual mode.

#### 8.10.5.1 AXES PARAMETERS

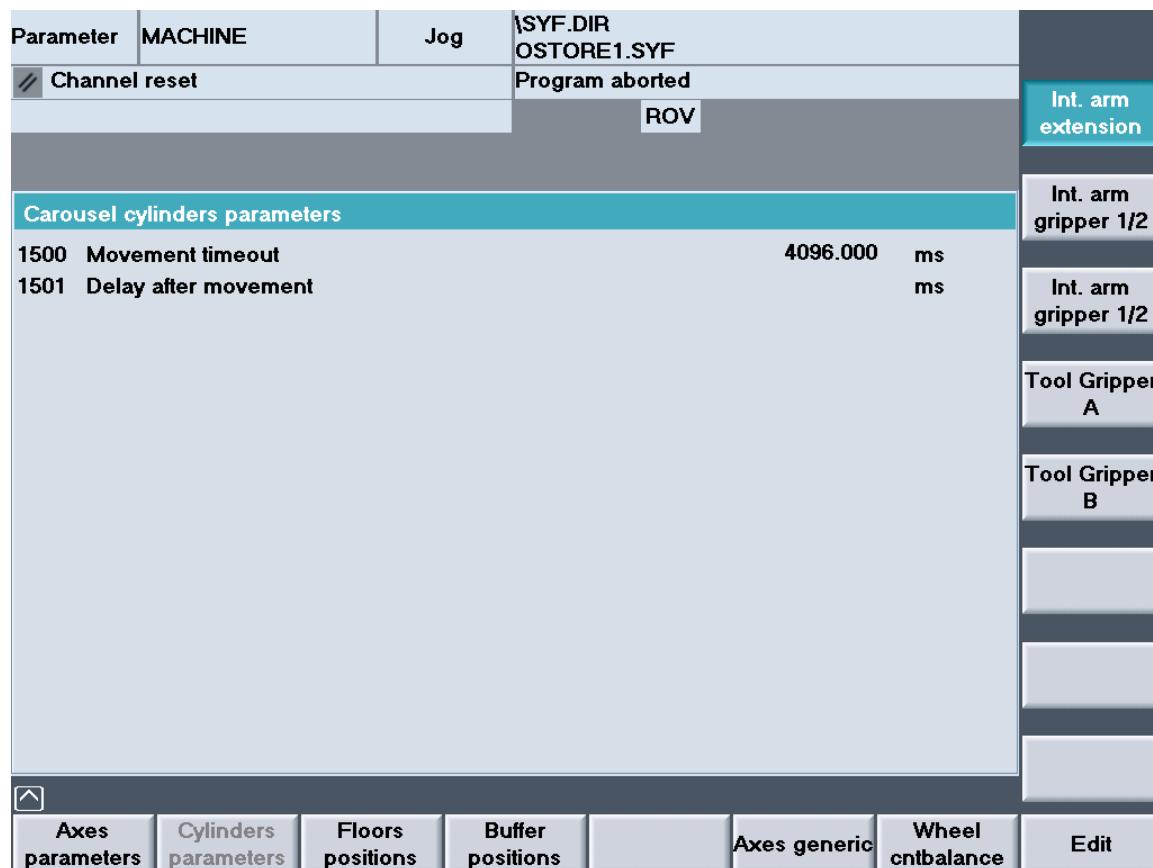
Parameter	MACHINE	MDI	\SYF.DIR OSTORE1.SYF	ROV	M01	TC-Z
<input checked="" type="checkbox"/> Channel interrupt			Program interrupted			
<b>Carousel axes parameters</b>						
1000	Not used		0.000	.		
1001	JOG speed		20.000	%		
1002	Not used		0.000	.		
1003	Work speed low		2.000	%		
1004	Work speed medium		5.000	%		
1005	Work speed high		100.000	%		
1006	Not used		0.000	.		
1007	JOG torque reduction		0.000	%		
1008	Not used		0.000	.		
1009	Work torque reduction low speed		0.000	%		
1010	Work torque reduction medium speed		0.000	%		
1011	Work torque reduction high speed		0.000	%		
1012	Not used		0.000	.		
1013	JOG acceleration ramp		100.000	%		
1014	Not used		0.000	.		
1015	JOG acceleration low speed		100.000	%		
<input type="button" value=""/>						
Axes parameters	Cylinders parameters	Floors positions	Buffer positions		Axes generic	Wheel cnbalance
						Edit

The axes parameter numbers range between 1000 and 9999. Each axis, start its parameters with the formula 1000 X AxisNumber. Example:

- Axis #1 Jog speed parameter number = 1001
- Axis #2 Jog speed parameter number = 2001
- Axis #5 Jog speed parameter number = 5001

<b>Number</b>	<b>Range</b>	<b>Description</b>
1001	1 – 100%	Speed used when the axis is jogged velocity control loop. The drive active this mode only for recovery from faults
1003	1 – 100%	Work low speed used in the tool change cycle.
1004	1 – 100%	Work medium speed used in the tool change cycle.
1005	1 – 100%	Work high speed used in the tool change cycle.
1007	0 – 99%	Torque reduction. Feature not used at this stage, keep it always at 0%
1009	0 – 99%	Torque reduction. Feature not used at this stage, keep it always at 0%
1010	0 – 99%	Torque reduction. Feature not used at this stage, keep it always at 0%
1011	0 – 99%	Torque reduction. Feature not used at this stage, keep it always at 0%
1013	1 – 100%	Active percentage of the requested acceleration. Feature not used at this stage, keep it always at 100%
1015	1 – 100%	Active percentage of the requested acceleration. Feature not used at this stage, keep it always at 100%
1016	1 – 100%	Active percentage of the requested acceleration. Feature not used at this stage, keep it always at 100%
1017	1 – 100%	Active percentage of the requested acceleration. Feature not used at this stage, keep it always at 100%
1100	-9999.999 9999.999	Software limit minus. This limit must be slightly greater than the 611U drive P0315
1101	-9999.999 9999.999	Software limit plus. This limit must be slightly minor than the 611U drive P0316
1104	0 – 20	In-position window

## 8.10.5.2 CYLINDERS PARAMETERS



The cylinder parameters are limited to time settings. Their text is self-explanatory.

## 8.10.5.3 FLOORS POSITIONS

Parameter	MACHINE	Jog	\SYF.DIR OSTORE1.SYF			
			Program aborted			
			ROV			
<b>Carousel floor positions</b>						
		TC-Z	TC-C	TC-Y	TC-B	TC-A
Pocket 1		1.500	0.000			
Pocket 2		1.500	11.250			
Pocket 3		1.500	22.500			
Pocket 4		1.500	33.750			
Pocket 5		1.500	45.000			
Pocket 6		1.500	56.250			
Pocket 7		1.500	67.500			
Pocket 8		1.500	78.750			
Pocket 9		2.500	90.000			
Pocket 10		2.500	101.250			
Pocket 11		2.500	-247.500			
Pocket 12		2.500	-236.250			
Pocket 13		1.500	-225.000			
Pocket 14		1.500	-213.750			
Pocket 15		1.500	-202.500			
Axes parameters	Cylinders parameters	Floors positions	Buffer positions		Axes generic	Wheel cntbalance
						Edit

The floor positions are the axes positions of all the pockets inside the carousel tower except the load/unload pocket. The load/unload pockets axes positions can be found in Buffer positions. The pocket positions inside the tool magazine tower involve just TC-Z and TC-C axes. Using the + and – softkeys it is possible to scroll between the floors. The actual selected floor is display on the second vertical softkey from the top. If the number of the tool pockets for each floor exceeds 15, the user must use the Page Up and Page Down softkeys to reach all the pockets.

## 8.10.5.4 BUFFERS POSITIONS

Parameter	MACHINE	Jog	\SYF.DIR OSTORE1.SYF	ROV	Gripper A
			Program aborted		
<b>Carousel buffers positions</b>					
		TC-Z	TC-C	TC-Y	TC-B
Robot		-49.098	-185.948	-14.613	247.050
SU 1				1949.000	1.300
SU 2				0.000	0.000
SU 3				0.000	0.000
SU 4				0.000	0.000
SU 5				1912.400	0.000
SU 6				0.000	0.000
SU 7				0.000	0.000
SU 8				0.000	0.000
SU 9				0.000	0.000
SU 10				1900.000	0.000
SU 11				0.000	0.000
SU 12				0.000	0.000
SU 13				0.000	0.000
SU 14				1899.000	179.000
					-89.800
<b>Load/Unload</b>					
<input type="button" value="Axes parameters"/> <input type="button" value="Cylinders parameters"/> <input type="button" value="Floors positions"/> <input type="button" value="Buffer positions"/> <input type="button" value="Axes generic"/> <input type="button" value="Wheel cntbalance"/> <input type="button" value="Edit"/>					

The buffer positions cover a lot of different area. Using the vertical softkey the user can select the different area

## 8.10.5.4.1 GRIPPER A/B/C OR D

When one of the gripper softkeys is selected, all the displayed positions are related to that softkey. The first line, robot, is the exchange tool position between the internal arm and the external arm selected gripper. The following lines are the exchange position between the selected gripper and the different machine spindle units.

## 8.10.5.4.2 LOAD/UNLOAD

Here the user can access the axes positions for the load/unload pocket inside the tool carousel tower.

## 8.10.5.5 AXES GENERIC PARAMETERS

Parameter	MACHINE	Jog	\SYF.DIR OSTORE1.SYF	
/ Channel reset			Program aborted	
ROV				
<b>Axes generic parameters</b>				
TC-Y-axis position outside the magazine			1370.000	mm
TC-Y-axis position outside work area			1370.000	mm
TC-A-axis vertical position minus limit			-1.000	deg
TC-A-axis vertical position plus limit			1.000	deg
TC-A-axis horizontal position minus limit			-95.000	deg
TC-A-axis horizontal position plus limit			-85.000	deg
TC-B-axis gripper A on cylinder 1 minus limit			350.500	deg
TC-B-axis gripper A on cylinder 1 plus limit			2.000	deg
TC-B-axis gripper A on cylinder 2 minus limit			170.500	deg
TC-B-axis gripper A on cylinder 2 plus limit			182.000	deg
TC-B-axis gripper A on cylinder 3 minus limit			238.500	deg
TC-B-axis gripper A on cylinder 3 plus limit			249.000	deg
TC-B-axis gripper B on cylinder 3 minus limit			58.500	deg
TC-B-axis gripper B on cylinder 3 plus limit			70.000	deg
			.	
			.	
<a href="#">[ ]</a>				
<a href="#">Axes parameters</a>	<a href="#">Cylinders parameters</a>	<a href="#">Floors positions</a>	<a href="#">Buffer positions</a>	<a href="#">Axes generic</a>
				<a href="#">Wheel cntbalance</a>
				<a href="#">Edit</a>

These are miscellaneous settings for various axes positions that do not fit in the previous screens.

**TC-X-axis position outside the magazine** - After this position the tool magazine external arm is considered outside the tool changer tower. After this position, TC-A is allowed to tilt.

**TC-X-axis position outside work area** - After this position the tool magazine external arm is considered inside the machine working area

**TC-A-axis vertical position minus limit** - Minus position limit value for considering TC-A axis vertical

**TC-A-axis vertical position plus limit** - Plus position limit value for considering TC-A axis vertical

**TC-A-axis horizontal position minus limit** - Minus position limit value for considering TC-A axis horizontal.

**TC-A-axis horizontal position plus limit** - Plus position limit value for considering TC-A axis horizontal

**TC-B-axis gripper A on cylinder 1 minus limit** - Minus position where gripper A is aligned with unlock pneumatic cylinder #1.

**TC-B-axis gripper A on cylinder 1 plus limit** - Plus position where gripper A is aligned with unlock pneumatic cylinder #1.

**TC-B-axis gripper A on cylinder 2 minus limit** - Minus position where gripper A is aligned with unlock pneumatic cylinder #2.

**TC-B-axis gripper A on cylinder 2 plus limit** - Plus position where gripper A is aligned with unlock pneumatic cylinder #2.

**TC-B-axis gripper A on cylinder 3 minus limit** - Minus position where gripper A is aligned with unlock pneumatic cylinder #3. If the unlock cylinder #3 does not exist, leave 0.0 in this field.

**TC-B-axis gripper A on cylinder 3 plus limit** - Plus position where gripper A is aligned with unlock pneumatic cylinder #3. If the unlock cylinder #3 does not exist, leave 0.0 in this field.

**TC-B-axis gripper B on cylinder 3 minus limit** - Minus position where gripper B is aligned with unlock pneumatic cylinder #3. If the unlock cylinder #3 does not exist, leave 0.0 in this field.

**TC-B-axis gripper B on cylinder 3 plus limit** - Minus position where gripper B is aligned with unlock pneumatic cylinder #3. If the unlock cylinder #3 does not exist, leave 0.0 in this field.

#### 8.10.5.6 WHEEL COUNTERBALANCE SETTINGS

Parameter	MACHINE	Jog	\SYF.DIR OSTORE1.SYF	
Channel reset			Program aborted	
			ROV	
<b>Wheel counterbalance settings</b>				
Enable wheel hydraulic counter balance (>0 == Enable)		1		
Spare			0	
Pump startup time (ms)		2500		
Maximum running time prior fault (s)			600	
<input type="button" value="Axes parameters"/> <input type="button" value="Cylinders parameters"/> <input type="button" value="Floors positions"/> <input type="button" value="Buffer positions"/> <input type="button" value="Axes generic"/> <input type="button" value="Wheel cntrbalance"/> <input type="button" value="Edit"/>				

Some tool magazines have a wheel to help to support the tool magazine. This wheel is located under the tool changer tower and uses one hydraulic counterbalance cylinder.

In this page, with first field, the user can enable/disable the hydraulic counterbalance. In the second field, it is possible to specify the maximum time allowed for the hydraulic pump motor relay reaction in milliseconds. The third field sets the maximum allowed time for the counterbalance cylinder to reload.

## 8.11 INTERLOCKS

When the arm of the tool changer is not retracted, the machine axes are in hold.

Exception: If the manual mode is enabled on the tool magazine and the active mode is JOG or MDA, the machine axes can move. When the tool changer is in manual mode, the machine axes are always in feed hold if AUTO mode is selected.

## 8.12 TOOL INPUTS AND OUTPUTS

The following inputs and outputs are associated with the tool magazine.

TOOL MAGAZINE INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
TOOL CAROUSEL	TOOL CHANGER NOT ESTOP	I061-4	This input goes low when the e-stop button is pressed. This switch is also included in the hard wired e-stop string.
	TOOL CHANGER MANIPULATOR DOOR OPEN	Input to Tool Changer PLC	This input must be on, indicating the tool changer door is open, to allow tool changer manipulator motion.
	TOOL CHANGER MANIPULATOR DOOR CLOSED	Input to Tool Changer PLC	This input must be on, indicating the tool changer door is closed, to allow automatic operations (allow cycle start).
	OPEN TOOL CHANGER DOOR	Output from Tool Changer PLC	This output is turned on to open the tool changer door.
	CLOSE TOOL CHANGER DOOR	Output from Tool Changer PLC	This output is turned on to close the tool changer door.
	TOOL CHANGER OPERATOR PANEL CLOSED	I061-3	This input must be on to allow any x-axis motion.

For details on the messages sent between the machine logic and the tool changer logic, refer to the appendix on Tool Carousel Communications.

# **CHAPTER 9 - MISCELLANEOUS SYSTEMS**



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## CHAPTER 9 - MISCELLANEOUS SYSTEMS

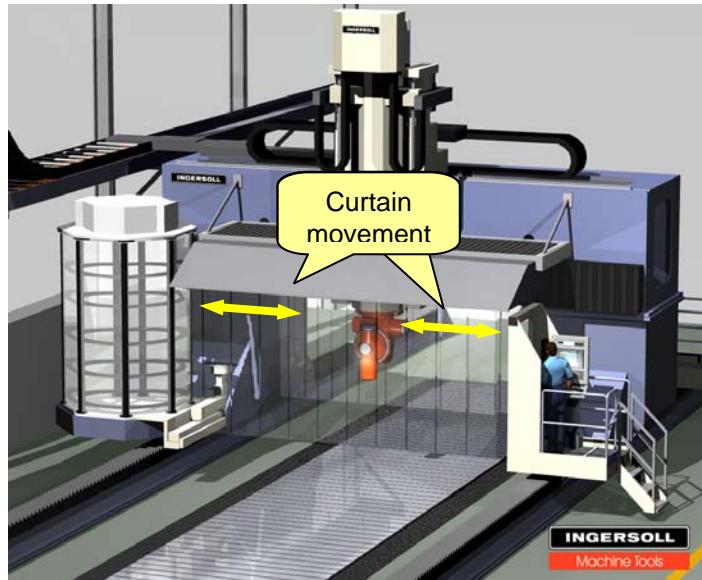
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## 9.1 MIST COLLECTION & COOLANT CONTAINMENT SYSTEM

A mist collection system is provided to remove mist during machining operations. A curtain is connected to the front of the crossrail to help contain coolant and a mist collection shroud is installed near the spindle on the ram to collect mist during machining. The mist collection system pulls air from the work area through ductwork located in the crossrail and into the mist collection unit mounted on the right column of the machine.

The mist containment curtains consist of vertical strips of heavy-duty vinyl in front of the machine. Each end of the curtain can be automatically opened to allow operator access to the work zone. Both ends of the curtain open and close at the same time. Pushbuttons on the operator console allow the curtain to be opened and closed. Switches monitor when both curtains are fully opened or closed, and then logic lights the appropriate pushbutton light on the operator console.



The mist collector unit is a WSO Model 25-1 system (shown at right) built by Donaldson Co. Industrial Air Filtration. See the Installation, Operating, and Maintenance Instructions from Donaldson for full detail on the mist collection system.

The mist collection system features two standard stages of filtration. The first stage filter is cleanable and is designed to remove large mist droplets and dust. The second stage filter cartridge features 286 sq. ft. of media especially designed for coolant application. Any liquid recovered drains into a bucket at the bottom of the collection unit.

The mist collection system has a 3 HP, 3450 rpm TEFC motor, which is directly coupled to a fan mounted on the clean air side to prevent build up of contaminant and vibration problems. Unit performance is rated at 1800 cfm with clean filters. The motor starter for the mist collector motor is located in the main electrical cabinets.



### 9.1.1 MIST COLLECTION SYSTEM OPERATION

The Mist collection system is enabled in automatic mode by the Mist Collection On/Off pushbutton located on Ingersoll main operator console.

### 9.1.2 FILTER REPLACEMENT

A gauge on the front of the mist collection unit is calibrated with green and red zones to indicate filter condition. The unit needs to be manually serviced when the gauge reads in the red zone.

### 9.1.3 MIST COLLECTION INPUTS/OUTPUTS

MIST COLLECTION INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
MIST COLLECTOR MOTOR STARTER ENERGIZED	Q033-7	THIS OUTPUT IS TURNED ON TO RUN THE MIST COLLECTOR MOTOR. IT IS TURNED ON AND OFF BY TOGGLING THE MIST COLLECTOR ON/OFF PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
OPERATOR SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-0	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY OPEN.
OPERATOR SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-1	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY CLOSED.
TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-2	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY OPEN.
TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-3	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY CLOSED.
OPEN OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q103-2	THIS OUTPUT IS TURNED ON TO OPEN THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE OPEN CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
CLOSE OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q105-1	THIS OUTPUT IS TURNED ON TO CLOSE THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE CLOSE CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
OPEN TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-2	THIS OUTPUT IS TURNED ON TO OPEN THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE OPEN CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
CLOSE TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-3	THIS OUTPUT IS TURNED ON TO CLOSE THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE CLOSE CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.

## 9.2 PART PROBE

This machine has one Renishaw RMP60 touch-trigger probe unit, which can be automatically loaded into the spindle from the tool magazine.

Probe	Taper	Tool Change
1	CAT 60 Simultaneous Fit	Automatic

### 9.2.1 PROBE HARDWARE

The Renishaw 3D touch trigger probe is used for workpiece set-up and inspection. The probe can sense directions  $\pm X$ ,  $\pm Y$ ,  $+Z$ .

The probe operates with frequency hopping spread spectrum (FHSS) radio transmission for communication with its control unit. Spread spectrum transmissions give more robust communication than single channel transmissions by distributing their signals across a wider frequency range. Utilizing frequency hopping, a signal is transmitted using a coded pattern of different frequencies identified to the radio transmitter and receiver. The radio probe system operates in a band defined for industrial products between 2.402 and 2.481 GHz.



RENISHAW RMP60 PROBE

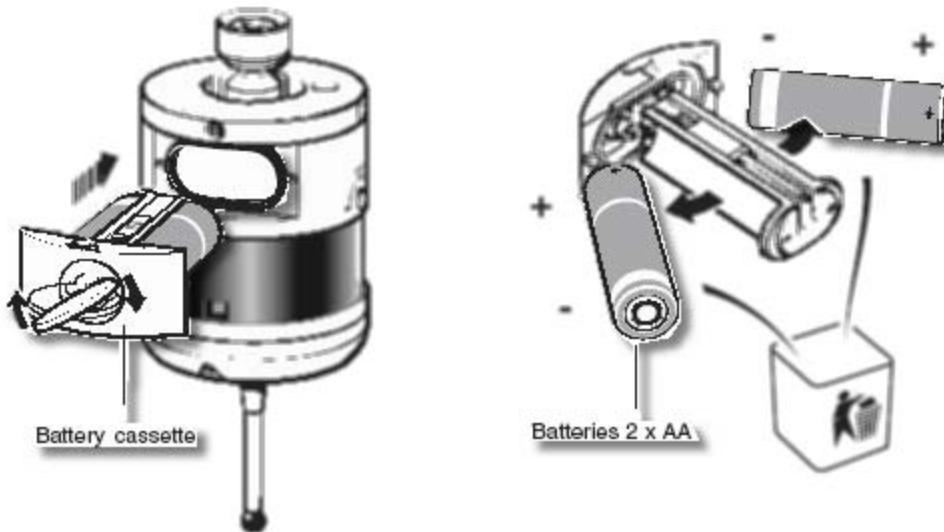
The probe consists of four primary components:

- stylus
- probe head/transmitter
- receiver
- interface unit.

The stylus (a rod that makes contact with the surface being measured) is fitted into the probe head/transmitter module and sends contact signals to the receiver module. This information travels to the interface unit via a hardwired connection, which converts the data into outputs used by the Siemens controller. The interface unit also displays probe system diagnostics and allows some adjustment of the probe hardware.

### 9.2.2 PROBE BATTERIES

The probe requires two (2) AA 1.5 V alkaline batteries. Batteries should be inserted as shown in the following diagram.

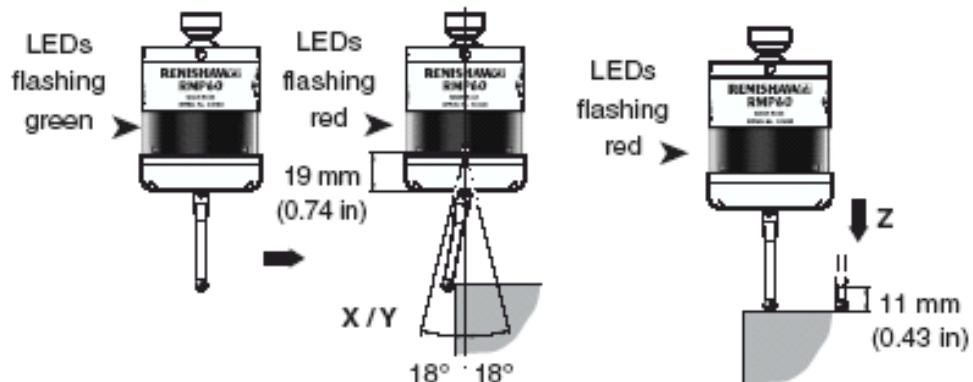


The probe is turned on and off by spinning it. The probe is automatically switched on and off in the measuring subprograms, L1006 (Part probe on) and L1007 (Part probe off).

When the batteries are low, an alarm message will be posted on the CNC and the LED on the probe body will flash as shown in the chart below.

PROBE STATUS LED			
LED Status	Probe Status		Graphic Hint
No illumination	Stand-by mode		
Flashing Green	Operating mode	Probe seated	● green
Flashing Red	Operating mode	Probe triggered	● red
Flashing green and blue	Operating mode	Probe seated	● green ● blue
		Low battery	● green ● blue
Flashing red and blue	Operating mode	Probe triggered	● red ● blue
		Low battery	● red ● blue
Constant red	Battery dead		██████████
Rapid flashing red	Extremely dead alkaline batteries or unsuitable lithium thionyl chloride batteries		● red ● red ● red ● red ● red ● red

## Probe status LEDs



Note: Indicators shown in the "Graphic hint column" are colored.

### 9.2.3 PROBE SOFTWARE

The Renishaw Inspection Plus software package is provided on this machine. This is a totally integrated package of software that includes vector and angle measure options, print options, and an extended range of probe cycles. These probe cycles include:

- 3-point bore / boss cycle
- 4<sup>th</sup> axis measure cycle
- Angled surface cycles
- Angled web / pocket
- Bore / boss cycle
- Bore / boss on a Pitch Circle Diameter

- Feature to feature
- Internal / external corner cycle
- Stock allowance cycle
- Web / pocket cycle
- X/Y/Z surface measure

For more information on using the part probe, see the Renishaw Inspection Plus Software Manual.

#### 9.2.4 PROBE INPUTS

PROBE INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
PART PROBE BATTERY OK	I060-4	When the <i>Part Probe Battery OK</i> input to the PLC goes low and the probe has been turned on", an alarm is issued to signal the operator that the probe battery is low and should be changed. The probe will continue to operate for a short period of time under this condition.
PART PROBE NOT ERROR	I060-5	When this input to the PLC goes low, either the probe is out of range from the receiver or a hardware error has occurred. If this happens, and the probe has been loaded onto the head, then an alarm is issued that will cause an immediate feedhold.
SELECT PART PROBE	Q034-3	
ENABLE PART PROBE	Q060-1	This output is pulsed on, then off, to activate the probe when a M72 (Probe Enable) is issued. This output is pulsed on and off to deactivate the probe when a M73 (Probe Disable) is issued.

## 9.3 TOOL SETTING LASER

A Renishaw Tool Setting Laser on this machine allows for the measuring of length and radius of tools.



RENISHAW NC4 TOOL SETTING LASER

### WARNING

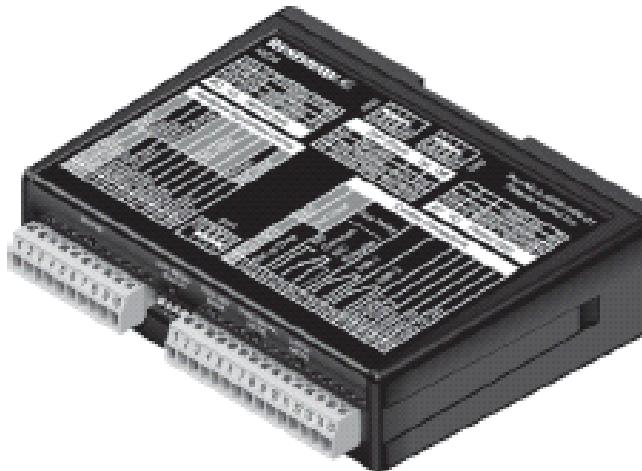


**DO NOT STARE INTO LASER BEAM!**  
The tool setting laser is a class 2 laser product.  
**1mW Maximum Output**  
**Emitted wavelength 670 nm**

### 9.3.1 LASER HARDWARE

The Renishaw NC4 is a flexible laser system, with ultra-compact laser tool setting transmitter and receiver units that can be mounted as a single fixed unit. The NC4 allows fast, non-contact, tool setting and tool breakage detection.

The NCi-4 interface is used with the NC4 non-contact tool setting system. It processes signals from the non-contact unit and converts the signals into a voltage-free solid-state relay (SSR) output, for transmission to the CNC machine control.



RENISHAW TOOL LASER INTERFACE NCi-4

### 9.3.2 TOOL LASER SOFTWARE

Renishaw Tool Setting software is provided in the Siemens CNC. This provides for calibration cycles, tool length and diameter setting cycles, and broken tool detection

cycles. For information on programming the tool laser cycles, see the Operator & Programmer Manual.

### **9.3.3 TOOL LASER SETUP PROCEDURE**

During machine setup or re-calibration, the tool laser may need to be setup on a machine. The following sections describe how to set up a tool probe.

#### **9.3.3.1 ARCHIVING**

---

**NOTE: Archive cannot be done with a tool loaded in the control.**

---

- Make an archive of the machine data in order to prevent any accidental loss of data.
- To make an archive, press **Menu Select→Services→Series Start-up**.
- Select the options “**NC**” and “**with compensation data**”. When archiving data, the standard Ingersoll filename is: “**NC\_MM/DD/YY**.” Press **Archive** once the file is named, to begin archiving.

#### **9.3.3.2 PROGRAM INSTALLATION**

Load all Ingersoll and Renishaw provided tool-setting files into the user cycles folder on the CNC (if not already loaded).

Create **TOOL\_PROBE.WPD** (if not already created) and load the following inside it:

- **BEAM\_ALIGN**
- **CALIB\_TOOL**

---

**NOTE: When REN\_SU\_CAL (Located in user cycles) is run, the resultant will be put into the SPF directory.**

---

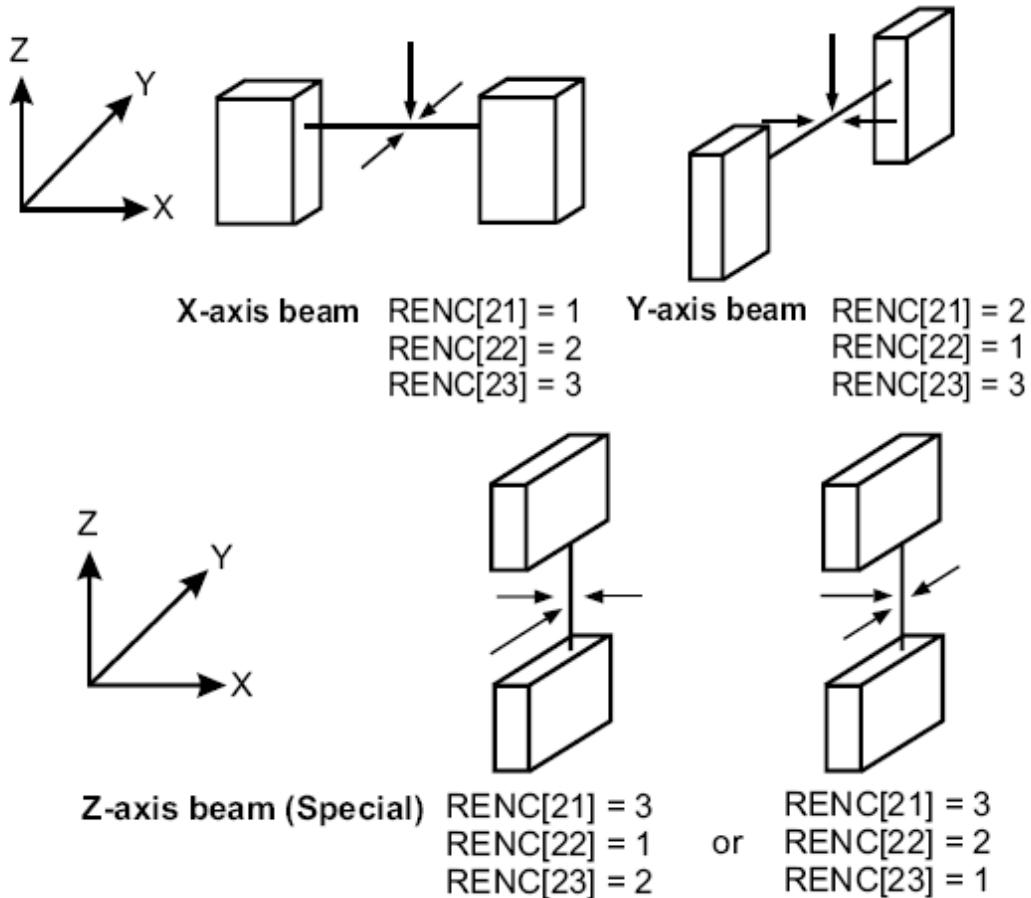
#### **9.3.3.3 SETTING MEASUREMENT VECTORS**

Before running any of the following programs, the direction of the tool laser with respect to the machine must be set. The parameters to change are RENC[21], RENC[22], and RENC[23]. These parameters can be changed in **REN\_SU\_SETUP.SPF** under the respective head number.

The **REN\_SU\_SETUP** program contains information for each head on a particular machine. When this program is called, the computer will jump to the code corresponding to what head is loaded.

The following diagram can be used to determine what tool vectors will be used for each head. It is possible that each head will have its own respective vector.

- RENC[21] is the direction of the beam with respect to the machine axes. The number 1 represents the X-axis, 2 for Y, and 3 for Z. This parameter will stay constant for all heads since the laser will always run in the same direction.



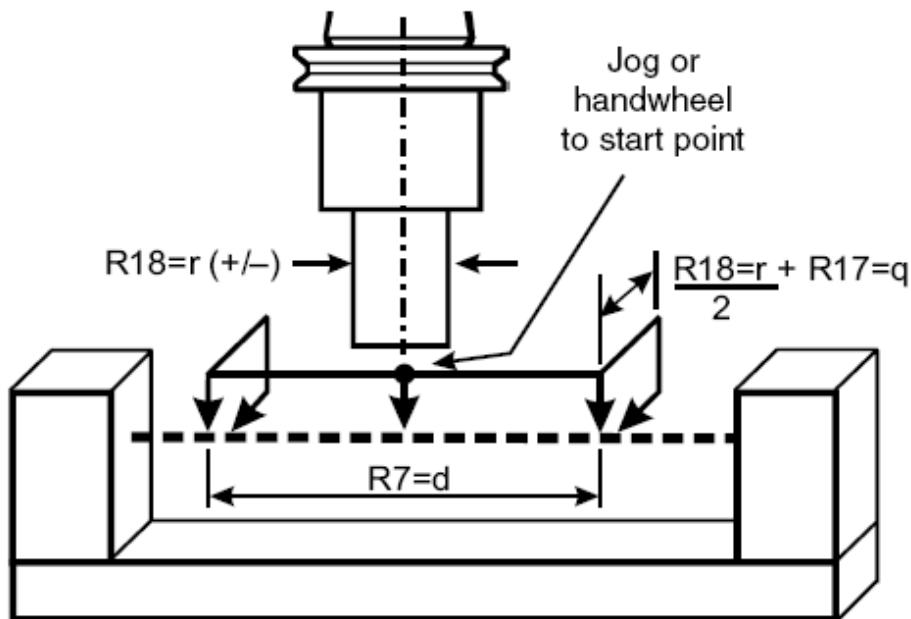
- RENC[22] is the direction in which the radial dimension of the tool will be measured.
- RENC[23] is the direction in which the axial dimension of the tool will be measured.
- It should be noted that the direction (1, 2, & 3), can be negative in situations where the tool is measured from a negative axis move. An example would be when the tool is picked up past the laser beam and there must be a negative Y or X-axis jog to break the beam.
- In addition to these, there are several other parameters that need to be changed in REN\_SU\_SETUP.SPF. These include the following:

RENC [6]	Safe return position along tool vector.
RENC [10]	Max tool length.
RENC [11]	Min tool length.
RENC [12]	Max tool diameter.
RENC [19]	Spindle speed (Cannot exceed the maximum for that head).

### 9.3.3.4 RUNNING BEAM ALIGN

The next step is to select the BEAM\_ALIGN program and load it into the control. This program will recognize what head is loaded on the machine and display a message with the desired orientation.

You will now need to orient the head to the given values displayed in the message. The following diagram shows the possible position of the head and what values are stored in the R variables.



After the head has been oriented, you must jog the calibration tool (tool of known length and radius) to the laser beam within 15 mm. in the direction of the tool vector. The tool must be placed in close proximity to the center of the beam as to allow room for the machine to move. The program will call a subroutine to check the alignment of the beam.

The machine will move the head on top of and into the beam in two positions to calculate its position and then output the results to the operator.

### 9.3.3.5 RUNNING CALIB TOOL

After the alignment of the tool laser has been checked, the next step is to verify the length and radius of the calibration tool.

Select the program CALIB\_TOOL and load it into the control. Before running the program, the tool geometry must be loaded into tool details as well as the program. Open the program in the editor and input the diameter at line N10. Run the program.

The program will run its calibration routine and save head-specific variables into subroutine REN\_SU\_CAL\_\*.SPF, where the “\*” in the file name will be replaced by a head number.

The tool laser calibratration step must be performed for each head that will be used for tool setting.

### 9.3.3.6 RUNNING VERIFICATION PROGRAMS

After the laser has been set up, it is possible for the operator to run various programs to check the length, radius, and other parameters of a tool. Refer to the Operator & Programer Manual for more details on the tool setting programs.

**NOTE:** A tool must be loaded in the control and spindle for this verification.

### 9.3.4 TOOL LASER INPUTS AND OUTPUTS

TOOL LASER INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
BROKEN TOOL PROBE HIGH SPEED BREAK	Q060-2	This output is turned on by a M142 code in the Renishaw tool probe cycles and turned off by a M143 code.
BROKEN TOOL PROBE LATCH MODE	Q060-3	This output is turned on by a M140 code in the Renishaw tool probe cycles and turned off by a M141 code.

---

**9.4 VIDEO SYSTEM**

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Due to the large size of the work area, two color cameras are provided to allow the operator more visibility of the work area. The camera output is displayed on a 19", flat panel, color, LCD monitor located near the operator console. The monitor is capable of split-screen display so the output of the cameras can be viewed simultaneously.

The cameras are supplied by CCTV Dynamcis. They are a dome-type camera designed for use outdoors, so they are sealed against the ingress of dirt and moisture. The cameras include pan/tilt/zoom mechanisms with a 26X zoom.

## 9.5 SPINDLE RUN TIME METER

A run-time meter is installed in the control cabinet (door #1) to record the spindle's total run time. This meter tracks the total accumulated time that the spindle is running and an axis is moving on the machine.



Run-Time Meter

### 9.5.1 RUN-TIME METER SPECIFICATIONS

SPECIFICATIONS	
<b>Model</b>	Redington 711-0160
<b>Figures</b>	7 figures, 0.14" high [3.6mm], 99,999.99 hours
<b>Reset</b>	Non-reset
<b>Voltage</b>	115 VAC / 60 Hz
<b>Power</b>	3 watts AC
<b>Termination</b>	1/4" [6.3mm] spade terminals, with removable screws
<b>Mounting</b>	Panel
<b>Temp. Range</b>	-22°F to +158°F [-30°C to +70°C]
<b>Approvals</b>	UL Recognized and CSA Certified, CE Approved
<b>Weight</b>	2 oz. [57g]

### 9.5.2 RUN-TIME METER INPUTS AND OUTPUTS

RUN-TIME METER INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
ENABLE RUN-TIME METER	Q034-5	This output is energized whenever any axis is moving and the spindle is running.

## 9.6 LIGHT TOWER

A light tower (stack light) is mounted on top of the electrical cabinets on the left hand side when facing the front of the cabinets. The light tower is an Allen-Bradley 24v assembled stack light (part #855TE-B24Y4Y5Y3). The machine logic will turn on the appropriate light to indicate the status of the machine.

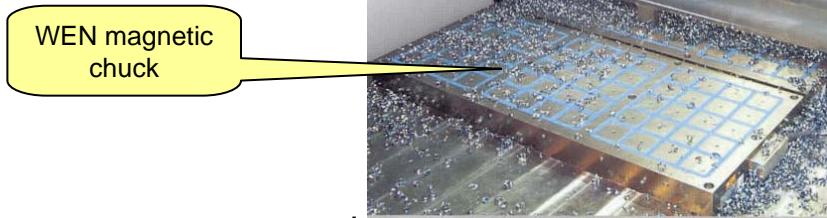
LIGHT COLOR	MACHINE STATUS
Green	The machine is operating with no alarms.
Yellow	The machine is operating with a warning alarm (minor fault).
Red	The machine has a critical fault condition.

### 9.6.1 LIGHT TOWER INPUTS AND OUTPUTS

LIGHT TOWER INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
MACHINE OPERATING	Q051-5	Green - if this light is on, the machine is operating with no alarms
MACHINE OPERATING - MINOR FAULT	Q051-6	Amber – if this light is on, the machine is operating with a warning alarm (minor fault)
MACHINE IN FAULT CONDITION	Q051-7	Red – if this light is on, the machine has a critical fault condition

## 9.7 MAGNETIC CHUCKS

Boeing will be using magnetic fixturing chucks from WEN technology to hold their parts to the machine table. There will be twelve magnetic chucks in each machining zone.



A control stand will be provided at each end of the machine, two stands total. Magnetic chuck control equipment will be mounted to this stand. Each stand will include the following devices:

- Power distribution terminals junction box
- EC204M control (IP65 rated)
- EC200R pushbutton pendant (IP65 rated)
- DC-TSB1 discharge cable (2M)

WEN provides:

- Magnets NG75.1.60.30 normal, 12 each
- Magnets NG75.1.60.30 reverse, 12 each
- All wiring and junction boxes from magnets to magnet controller on stand
- Magnet controller with 1 meter power cable, pigtail ends, #12
- Pushbutton pendant with cable and connector
- Discharge cable (to magnets) with 2 meter length and connectors

Ingersoll provides:

- 460 VAC, 60 HZ, 60 Amp service
- Fuses and disconnects in main control cabinets
- Wires from fuses to power distribution terminal on stands (60 amp intermittent, #10)
- Power distribution terminals junction boxes on stands
- Magnet control stands; (1) magnet control stand will be added at each end of the machine, (2) stands total

Magnets are magnetized and demagnetized from the pushbuttons on the WEN-provided pendant located on the magnet control stand.

- To **turn on** the magnets, press the blue (Enable) pushbutton and the green (Magnetize) pushbutton.
- To **turn off** the magnets, press the blue (Enable) pushbutton and the red (Demagnetize) pushbutton



Advanced Electronic Controller

The controller will turn on the 12 magnets in a four-step sequence, energizing three magnets in each step. Each sequence step will last approximately 1 second, resulting in a 4 second magnetize routine. Once magnetized, the power is removed from the magnets and they retain their magnetized state.

A comparable sequence is used to demagnetize the magnets.

### 9.7.1 MAGNETIC CHUCKS INPUTS AND OUTPUTS

MAGNETIC CHUCKS INPUTS/OUTPUTS		
NAME	ADDRESS	DESCRIPTION
MAGNETIC CHUCKS ZONE 1 MAGNETIZED	I042-4	Magnets in zone #1 must be magnetized to permit a Cycle Start when the machine is in Zone #1, M23 active. Magnets in both zones must be magnetized to permit a Cycle Start when the machine is in both zones, M24 active.  If the magnets in the Active Zone become demagnetized (loss of magnetized input), a cut free spindle stop, followed by a cycle stop is issued. Cycle start and automatic operations are inhibited. Manual operations are allowed.
MAGNETIC CHUCKS ZONE 2 MAGNETIZED	I042-6	Magnets in zone #2 must be magnetized to permit a Cycle Start when the machine is in zone #2, M24 active. Magnets in both zones must be magnetized to permit a Cycle Start when the machine is in both zones, M24 active.
MAGNETIC CHUCKS ZONE 1 DEMAGNETIZED	I042-5	Used for diagnostic purposes only.
MAGNETIC CHUCKS ZONE 2 DEMAGNETIZED	I042-7	Used for diagnostic purposes only.
ENABLE MAGNETIC CHUCKS ZONE 1	Q033-5	When the machine is in zone #2, M24 active, magnets in zone #1 are enabled. (Magnet control must be enabled to allow magnets to be magnetized or demagnetized.) When the machine is in both zones, M22 active, both sets of magnets are enabled when the gate interlock indicates a gate is open.

<b>MAGNETIC CHUCKS INPUTS/OUTPUTS</b>		
<b>NAME</b>	<b>ADDRESS</b>	<b>DESCRIPTION</b>
ENABLE MAGNETIC CHUCKS ZONE 2	Q033-6	When the machine is in zone #1, M23 active, magnets in zone #2 are enabled. When the machine is in both zones, M22 active, both sets of magnets are enabled when the gate interlock indicates a gate is open.

**INGERSOLL**

**Machine Tools**

# **CHAPTER 10 - GATES AND ZONE CONTROL**



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## CHAPTER 10 - GATES AND ZONE CONTROL

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## 10.1 PERIMETER FENCING

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Perimeter fencing and gates are provided by the customer.

Gate closed limit switches, gate lock solenoids, and gate interface pushbuttons are provided by Ingersoll. Gate wiring, PLC input and output blocks, and logic for the gate interlocks are provided by Ingersoll.

The end user must ensure that all guarding, interlocks and safety equipment are in good condition and in place during the operation of the machine.

**WARNING**

**Under no circumstances should interlocks be bypassed! Risk of severe injuries may occur if proper safety procedures are not implemented.**

## 10.2 ZONE CONTROL OVERVIEW

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The machine's floor plate can be divided into two zones using a movable/removable mechanical barrier placed between the zones.

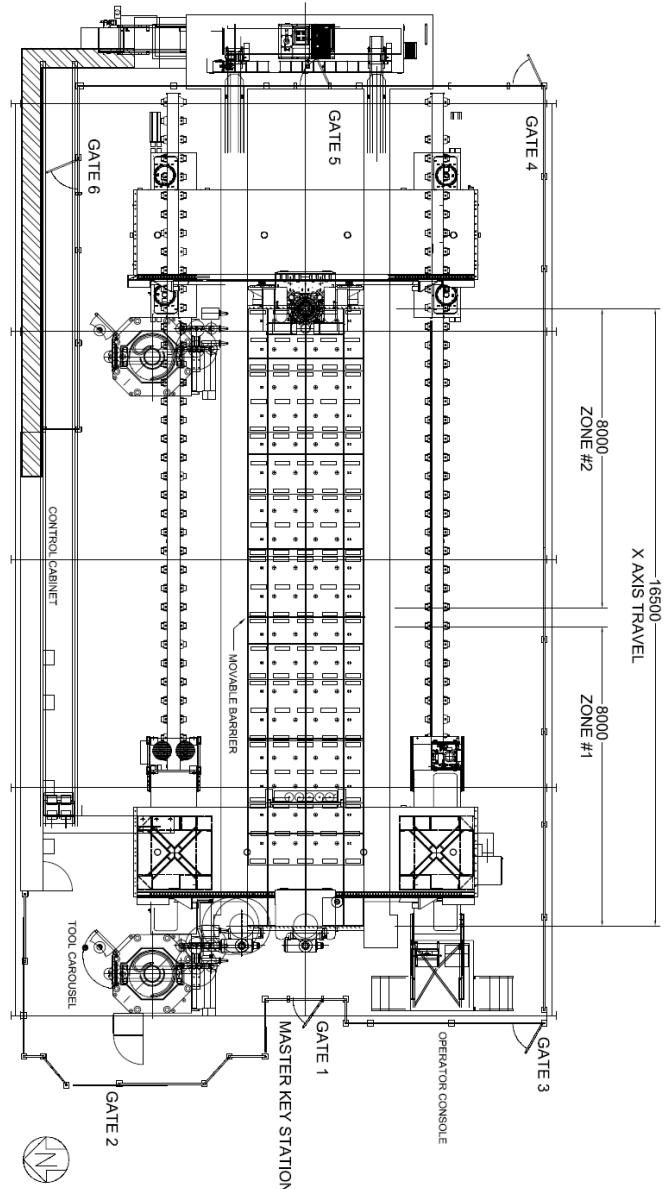
Zone 1 is towards the front of the machine (towards X-axis minus travel). Zone 2 is located towards the rear of the machine (towards X-axis plus travel). M-codes are programmed to select the currently active zone.

Zone 1 and Zone 2 travel limits are stored in non-volatile data words. These data entries can only be changed by qualified maintenance personnel. During machine installation, these limits are set as shown below.

ZONE	M-CODE	TRAVEL	MACHINE COORDINATES
Total X-axis	M22	16,500 mm	-8250 mm to +8250 mm
Zone 1	M23	8000 mm	-8250 mm to -250 mm
Zone 2	M24	8000 mm	+250 mm to +8250 mm

## 10.3 GATE LOCATIONS

Six (6) gate interlocks are provided for the perimeter fencing to allow access to the work area as shown in the diagram below. The Operator Platform also has two access gates; one on the aisle side of the platform and the other opening to the machine's floor plate.



Gate 1 = in Zone #1 at front end of machine

Gate 2 = in Zone #1 next to tool carousel

Gate 3 = in Zone #1 on operator console side of machine

Gate 4 = in Zone #2 on operator console side of machine

Gate 5 = in Zone #2 at back end of machine

Gate 6 = in Zone #2 next to cross chip conveyor

## 10.4 FLOOR PLATE ACCESS FROM PERIMETER GATES

---

To access the floor plate, the operator or maintenance person must enter any gate, and then walk to either end of the machine, where he/she can step onto the floor plate. The X-axis runways and racks prevent the operator from accessing the floor plate from the sides of the machine.

### 10.4.1 PERIMETER GATE INTERLOCKS

There is a solenoid lock on each of the six perimeter gates. Limit switches are used to indicate a gate is closed.

If machine must access both zones (M22 active):

- Opening Gate 1, 2, 3, 4, 5, or 6 will cause machine feedhold

If machine is in Zone #1 (M23 active):

- Opening Gate 1, 2, or 3 will cause machine feedhold
- Opening Gate 4, 5, or 6 will not affect machine operations

If machine is in Zone #2 (M24 active):

- Opening Gate 4, 5, or 6 will cause machine feedhold
- Opening Gate 1, 2, or 3 will not affect machine operations

### 10.4.2 ACCESS GATE MASTER KEY STATION

An Access Gate Master Key Station, where all gate keys reside, is located outside of the perimeter fencing, next to gate #1 at the front end of the machine. Gate devices and the master key station are tied into machine logic for zone control.

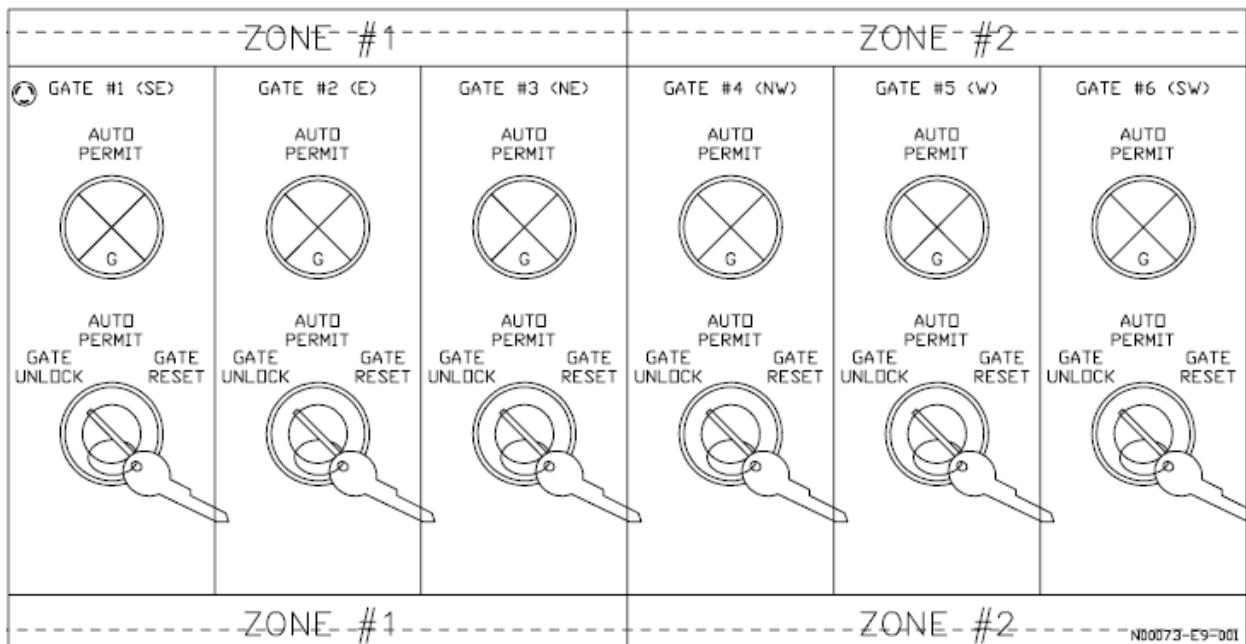
Each gate key will be numbered to identify its specific gate. Each zone will have a different type (cut) key. The (3) Zone #1 keys will all be of one type (blue), and the (3) Zone #2 keys will be of a different type (red). The different key types will prevent the operator from accidentally inserting a key into the wrong zone and consequently resetting the wrong zone.

To switch the machine from one zone to the other zone, all gate keys must be in the access gates master key station, and all perimeter gates must be closed and reset.

Each gate interlock solenoid has a mechanical Manual Bypass on the solenoid lock to allow access in case of emergency. When the gate is opened (as indicated by the limit switch) without using the access gate master key station, a feedhold is applied to the machine if the open gate is in the active zone. Any open gate must be closed, then reset at the master key station, to resume automatic operations in the corresponding zone.

For the gate to be unlocked, all machine motion must be stopped, or the machine must be in the opposite zone.

While the gate is open, all automatic operations in the corresponding zone are inhibited, including automatic execution of part programs. Manual or maintenance commands are permitted. Functions from the auxiliary pendant are permitted.



ACCESS GATE MASTER KEY STATION

To open a gate, the corresponding key selector switch is moved to the "gate unlock" position. When the controller detects the selector switch in the "gate unlock" position, and logic ensures the machine is in a safe state to unlock the gate, a solenoid will be energized to open the gate.

When the gate is opened, the operator should remove the key and take it with him or her, leaving the selector switch in the "gate unlock" position, thus inhibiting any automatic motions. Manual control of devices for maintenance purposes will still be allowed with the gate open.

When the operator returns to the master key station, he or she closes the gate, inserts the key back into the selector switch, and then turns the selector switch to the "gate reset" position. This action will de-energize the solenoid and lock the gate.

The selector switch is a spring return from "gate reset" to "auto permit". When the switch is allowed to return to "auto permit", automatic motion is again permitted. The key can only be removed from the selector switch in the "gate unlock" position.

Each gate key will be numbered, to identify its specific gate. Each zone will have a different type (cut) key. The (3) Zone #1 keys will all be of one type (blue), and the (3) Zone #2 keys will be of a different type (red).

In addition to the three-position selector switch, a green auto permit lamp is located on the pushbutton box. This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur.

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## 10.5 OPERATOR PLATFORM ACCESS GATES

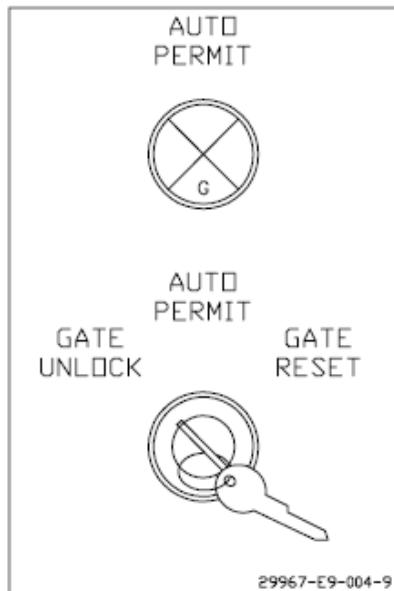
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The Operator Platform has two access gates; one on the aisle side of the platform and the other opening to the machine's floor plate.

For either gate to be unlocked, all machine motion must be stopped.

While either gate is open, all automatic operations are inhibited, including automatic execution of part programs. Manual or maintenance commands are permitted. Functions from the auxiliary pendant are permitted.

Exit from each of the operator platform doors is controlled with an Access Gate Pushbutton Box mounted next to each door.



OPERATOR PLATFORM ACCESS GATE PUSHBUTTON BOX

To open the gate, the key selector switch is moved to the "gate unlock" position. When the controller detects the selector switch in the "gate unlock" position, and logic ensures

the machine is in a safe state to unlock the gate, a solenoid will be energized to open the gate, allowing the operator to leave the platform.

When the solenoid energized to unlock the gate on the aisle side of the platform, all six (6) perimeter gates are also unlocked. This will allow the operator to leave the platform and the machine area.

When the gate is opened, the operator should remove the key and take it with him or her, leaving the selector switch in the "gate unlock" position, thus inhibiting any automatic motions. Manual control of devices for maintenance purposes will still be allowed with the gate open.

When the operator returns to the platform, he or she closes the gate, inserts the key back into the selector switch, and then turns the selector switch to the "gate reset" position. This action will de-energize the solenoid and lock the gate.

The selector switch is a spring return from "gate reset" to "auto permit". When the switch is allowed to return to "auto permit", automatic motion is again permitted. The key can only be removed from the selector switch in the "gate unlock" position.

When the solenoid is de-energized to lock the platform gate on the aisle side, all (6) perimeter gates will also be locked. All (6) gate keys must be located in the master key station, and all must be rotated to the "auto permit" position.

In addition to the three-position selector switch, a green auto permit lamp is located on the pushbutton box. This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur.

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## 10.6 GATE OPERATION EXAMPLES

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### 10.6.1 SETUP PERSON ACCESS

A setup person may need to access the floor plate of the inactive zone to tear down the previous part or set up the next one to be machined. This can occur while a part is being machined in the other zone.

The Setup person will go to Access Gates Master Key Station to get the key for the gate they want to go through, in the non-active zone.

- Key will be turned to the "gate unlock" position.
- When the controller detects the selector switch in the "gate unlock" position, and logic ensures the machine is in a safe state to unlock the gate, a solenoid will be energized to open the gate.
- The green "auto permit" lamp above the key switch will turn off.

- The amber "gate open zone #1" or "gate open zone #2" lamp on the main operator console will turn on for the corresponding zone.
- Setup person will take the key from the master key station for the corresponding gate, leaving the switch in the "gate unlock" position. The key can only be removed in the "gate unlock" position.

The Setup person exits the inside of the perimeter when work is complete, closes the gate, and returns to the Access Gates Master Key Station.

- Key is inserted back into the proper selector switch, and is turned to the "gate reset" position. If the gate is properly closed (as indicated by the limit switch), this action will de-energize the solenoid and lock the gate.
- The selector switch is a spring return from "gate reset" to "auto permit". When the switch is allowed to return to "auto permit", automatic motion is again permitted
- The green "auto permit" lamp above the key switch will turn on.
- The amber "gate open zone #1" or "gate open zone #2" lamp on the main operator console will turn off for the corresponding zone if all gates are closed and reset.

#### 10.6.2 OPERATOR ACCESS

The machine operator may want to access the floor plate to examine a part more closely.

The operator leaves the machine, when his operations are complete, by exiting the operator platform.

- Place machine in feed hold or e-stop.
- Operator platform access gate key will be turned to the "gate unlock" position.
- When the controller detects the selector switch in the "gate unlock" position, and logic ensures the machine is in a safe state to unlock the gate, a solenoid will be energized to open the operator platform gate.
- The green "auto permit" lamp above the key switch will turn off.
- When the solenoid is energized to unlock the gate on the aisle side of the platform, all six (6) perimeter gates are also unlocked. This will allow the operator to leave the platform and the machine area.

The operator returns to the machine, through the unlocked perimeter access gates, and climbs onto the operator platform.

- Operator platform access gate key will be turned to the “gate reset” position. If the gate is properly closed (as indicated by the limit switch), this action will de-energize the solenoid and lock the operator platform gate.
- The green “auto permit” lamp above the key switch will turn on.
- When the solenoid is de-energized to lock the platform gate on the aisle side of the platform, all (6) perimeter gates will also be locked. All (6) gate keys must be located in the master key station, and all must be rotated to the “auto permit” position.

## 10.7 ZONE SWITCHING

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### To enable both zones:

1. Stop any active automatic programs.
2. Switch to MDA mode.
3. In MDA mode, enter and execute a M22 command. With M22 active, X-axis travel limits are re-written to full travel for access to both zones.

### To enable Zone #1:

1. Stop any active automatic programs.
2. Switch to MDA mode.
3. In MDA mode, enter and execute M23 command.
4. If the machine is beyond X-axis plus limit for Zone #1 (i.e. machine is in Zone #2), X-axis inhibit/feedhold is applied and a message is posted indicating machine is not in the proper zone.
5. Operator must switch to Manual mode.
6. With M23 active, in manual mode, X-axis can be jogged in the minus (-) direction, to move it into Zone #1. X-axis cannot be jogged in the plus (+) direction.
7. Once in Zone #1, X-axis travel limits are re-written to Zone #1 limits. X-axis inhibit / feedhold is removed.

### To enable Zone #2:

1. Stop any active automatic programs.
2. Switch to MDA mode.
3. In MDA mode, enter and execute the M24 command.
4. If the machine is beyond X-axis minus limit for Zone #2 (i.e. machine is in Zone #1), X-axis inhibit / feedhold is applied, a message is posted indicating machine is not in proper zone.
5. Operator must switch to Manual mode.
6. With M24 active, in manual mode, X-axis can be jogged in the plus (+) direction, to move it into Zone #2. X-axis cannot be jogged in the minus (-) direction.
7. Once in Zone #2, X-axis travel limits are re-written to Zone #2 limits. X-axis inhibit / feedhold is removed.

### 10.7.1 X-AXIS POSITION & HOMING

The X-axis position is read by logic to determine which zone the machine is in. X-axis position feedback uses a Heidenhain distance coded scale. Only a short distance is traveled (100 mm) to home (reference) X-axis. X-axis does NOT travel to a home switch at one end of travel for homing. X-axis can be homed while in Zone #1 or Zone #2.

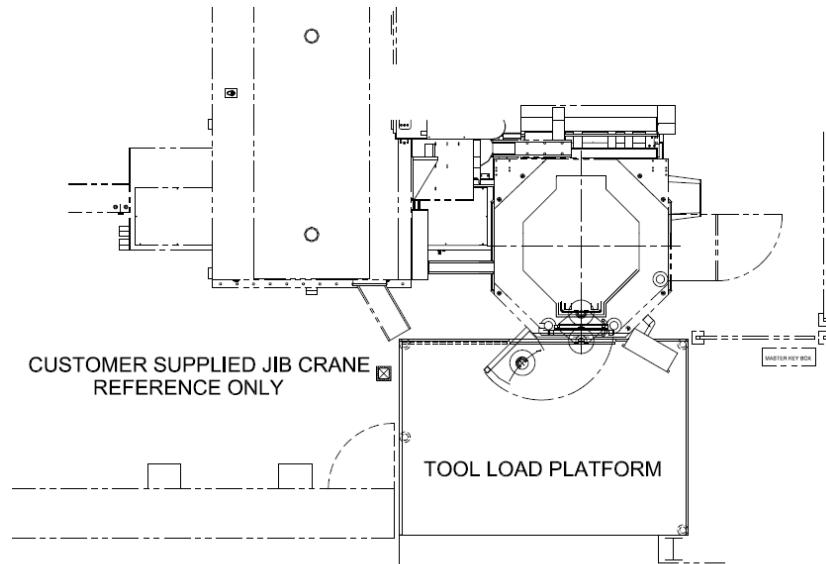
After an X-axis homing cycle is completed, based on the X-axis position, Zone #1 (M23) or Zone #2 (M24) is automatically made active.

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## 10.8 TOOL LOAD PLATFORM ACCESS GATE

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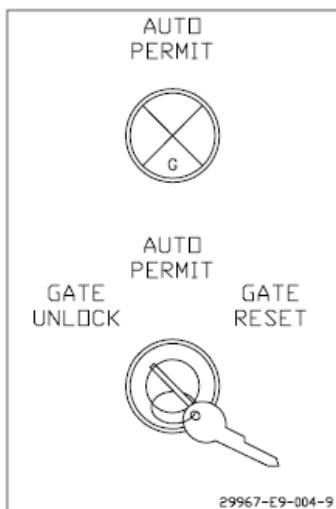
An elevated Tool Load Platform with handrails is provided near the X-axis minus travel limit, to assist the operator in loading and unloading tools from the tool carousel. The tool load platform has one access gate, opening to the tool carousel. A jib crane (provided by the customer) is available to assist in handling heavy tools.



For the gate to be unlocked and opened, the X-axis must be at the tool load position, and all machine motion must be stopped. The X-axis tool load position (range) is stored in a data table entry.

While the gate is open, all automatic operations are inhibited, including automatic execution of part programs, or tool changes. Manual or maintenance commands are permitted. Functions from the auxiliary pendant are permitted. X-axis motion is inhibited.

Access from the platform to the tool carousel, for tool load or tool changer maintenance, is controlled with an Access Gate Pushbutton Box mounted next to each door.



OPERATOR PLATFORM ACCESS GATE PUSHBUTTON BOX

To open the gate, the key selector switch is moved to the "gate unlock" position. When the controller detects the selector switch in the "gate unlock" position, and logic ensures the machine is in a safe state to unlock the gate, a solenoid will be energized to open the gate, allowing access to the tool carousel.

After the tool load platform gate is open, the **Operator** can press the tool load pushbutton on the tool changer check in terminal, and rotates the tool changer load door to the open position. After the desired tool is loaded or unloaded, the operator rotates the tool changer door back to the closed position.

Next, the operator closes the tool load platform gate, and then turns the selector switch to the "gate reset" position. This action will de-energize the solenoid and lock the gate.

The tool load platform gate must be open to allow operation of the tool changer rotary door. The tool magazine travels with the machine, along the X-axis, therefore loading or unloading tools cannot be performed while the machine is running.

If a **Maintenance Person** plans on entering the tool carousel for repair, when the gate is opened, the maintenance person should remove the key and take it with him or her, leaving the selector switch in the "gate unlock" position, thus inhibiting any automatic motions. Manual control of devices for maintenance purposes will still be allowed with the gate open.

When the maintenance person exits the tool carousel, and returns to the platform, he or she closes the gate, inserts the key back into the selector switch, and then turns the selector switch to the "gate reset" position. This action will de-energize the solenoid and lock the gate.

The selector switch is a spring return from "gate reset" to "auto permit". When the switch is allowed to return to "auto permit", automatic motion is again permitted. The key can only be removed from the selector switch in the "gate unlock" position.

In addition to the three-position selector switch, a green auto permit lamp is located on the pushbutton box. This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur.

## 10.9 ACCESS GATES INPUTS/OUTPUTS

ACCESS GATES INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
OPERATOR PLATFORM AISLE SIDE	UNLOCK OPERATOR PLATFORM AISLE DOOR	I093-3	This input comes on when the key switch for the associated access door is in the Gate Unlock position.
	AUTO PERMIT OPERATOR PLATFORM AISLE DOOR	I093-4	This input comes on when the key switch for the associated access door is in the Auto Permit position.
	RESET OPERATOR PLATFORM AISLE DOOR	I093-5	This input comes on when the key switch for the associated access door is in the Gate Reset position.
	OPERATOR PLATFORM AISLE DOOR CLOSED	I093-7	This input is on when the associated access door is Closed.
	UNLOCK OPERATOR PLATFORM AISLE DOOR	Q090-1	Logic will turn this output on to unlock the access door when logic detects the selector switch in the "Gate Unlock" position and logic insures the machine is in a safe state to unlock the door.
	AUTO PERMIT OPERATOR PLATFORM AISLE DOOR	Q090-3	This light will illuminate when the door is closed, and the switch has been moved to "Gate Reset" and then back to "Auto Permit", indicating automatic motion can occur within the restricted area.
OPERATOR PLATFORM FLOOR SIDE	UNLOCK OPERATOR PLATFORM FLOOR PLATE DOOR	I093-0	This input comes on when the key switch for the associated access door is in the Gate Unlock position.
	AUTO PERMIT OPERATOR PLATFORM FLOOR PLATE DOOR	I093-1	This input comes on when the key switch for the associated access door is in the Auto Permit position.
	RESET OPERATOR PLATFORM FLOOR PLATE DOOR	I093-2	This input comes on when the key switch for the associated access door is in the Gate Reset position.

ACCESS GATES INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
OPERATOR PLATE DOOR	OPERATOR PLATFORM FLOOR PLATE DOOR CLOSED	I093-6	This input is on when the associated access door is Closed.
	UNLOCK OPERATOR PLATFORM FLOOR PLATE DOOR	Q090-0	Logic will turn this output on to unlock the access door when logic detects the selector switch in the "Gate Unlock" position and logic insures the machine is in a safe state to unlock the door.
	AUTO PERMIT OPERATOR PLATFORM FLOOR PLATE DOOR	Q090-2	This light will illuminate when the door is closed, and the switch has been moved to "Gate Reset" and then back to "Auto Permit", indicating automatic motion can occur within the restricted area.
PERIMETER GATE #1	UNLOCK PERIMETER GATE #1	I047-0	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #1	I047-1	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #1	I047-2	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
	PERIMETER GATE #1 CLOSED	I047-6	This input is on when the associated access gate is closed.
	UNLOCK PERIMETER GATE #1	Q037-4	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #1	Q037-5	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
PERIMETER GATE #2	UNLOCK PERIMETER GATE #2	I047-3	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #2	I047-4	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #2	I047-5	This input comes on when the key switch for the associated access gate is in the Gate Reset position.

ACCESS GATES INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
<b>PERIMETER GATE #3</b>	PERIMETER GATE #2 CLOSED	I047-7	This input is on when the associated access gate is closed.
	UNLOCK PERIMETER GATE #2	Q037-6	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #2	Q037-7	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
	UNLOCK PERIMETER GATE #3	I050-0	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #3	I050-1	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #3	I050-2	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
<b>PERIMETER GATE #4</b>	PERIMETER GATE #3 CLOSED	I050-6	This input is on when the associated access gate is closed.
	UNLOCK PERIMETER GATE #3	Q050-0	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #3	Q050-1	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
	UNLOCK PERIMETER GATE #4	I050-3	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #4	I050-4	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #4	I050-5	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
	PERIMETER GATE #4 CLOSED	I050-7	This input is on when the associated access gate is closed.

ACCESS GATES INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
	UNLOCK PERIMETER GATE #4	Q050-2	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #4	Q050-3	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
PERIMETER GATE #5	UNLOCK PERIMETER GATE #5	I052-0	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #5	I052-1	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #5	I052-2	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
	PERIMETER GATE #5 CLOSED	I052-6	This input is on when the associated access gate is closed.
	UNLOCK PERIMETER GATE #5	Q051-0	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #5	Q051-1	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
PERIMETER GATE #6	UNLOCK PERIMETER GATE #6	I052-3	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT PERIMETER GATE #6	I052-4	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET PERIMETER GATE #6	I052-5	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
	PERIMETER GATE #6 CLOSED	I052-7	This input is on when the associated access gate is closed.

ACCESS GATES INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
	UNLOCK PERIMETER GATE #6	Q051-2	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT PERIMETER GATE #6	Q051-3	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.
OPERATOR CONSOLE	GATE OPEN IN ZONE #1	Q091-1	This light on the operator console will illuminate when any gate in zone #1 has been opened, and not reset.
	GATE OPEN IN ZONE #2	Q091-2	This light on the operator console will illuminate when any gate in zone #2 has been opened, and not reset.
TOOL LOAD PLATFORM	UNLOCK TOOL LOAD PLATFORM GATE	I051-3	This input comes on when the key switch for the associated access gate is in the Gate Unlock position.
	AUTO PERMIT TOOL LOAD PLATFORM GATE	I051-4	This input comes on when the key switch for the associated access gate is in the Auto Permit position.
	RESET TOOL LOAD PLATFORM GATE	I051-5	This input comes on when the key switch for the associated access gate is in the Gate Reset position.
	TOOL LOAD PLATFORM GATE CLOSED	I051-6	This input is on when the associated access gate is closed. The gate must be closed to allow automatic operations or X-axis motion.
	TOOL LOAD PLATFORM GATE OPENED	I051-7	This input is on when the associated access gate is opened. The gate must be open to allow operation of the tool changer rotary door.
	UNLOCK TOOL LOAD PLATFORM GATE	Q036-6	Logic will turn this output on to unlock the access gate when logic detects the selector switch in the "gate unlock" position and logic insures the machine is in a safe state to unlock the gate.
	AUTO PERMIT TOOL LOAD PLATFORM GATE	Q036-7	This light will illuminate when the gate is closed, and the switch has been moved to "gate reset" and then back to "auto permit", indicating automatic motion can occur within the restricted area.

# **CHAPTER 11 - FLUIDS**



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## 11.1 FLUID SYSTEM PLATFORMS

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This machine is supplied with platforms that hold the hydraulic power unit, the chiller unit, and the lubrication service panel. The pneumatic service panel that distributes some of the pneumatic services for the machine, is also located on one of the platforms. The location of the power unit platforms is provided on the machine plan view layout.

The fluids systems consist of various subsystems that provide hydraulics, lubrication, pneumatics, and heat removal.

For additional information on the Fluids subsystems, refer to the following documents:

- Ingersoll Fluids schematics
- Trabon (Lubriquip) axis lubrication system manual
- Koolant Kooler refrigerated chiller manual
- Mayfran Coolant system manual
- Acumen lubrication system

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## 11.2 HYDRAULICS

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### 11.2.1. MAIN HYDRAULIC SYSTEM

The hydraulic power unit is located on the right column. This hydraulic system is used for the following machine functions:

- Spindle Unit Tool Gripper
- Corner SU Grippers
- C and A Axes Clamps
- A-Axis Worm Preload
- Attachment Lubrication
- Z-Axis Counterbalance

The main hydraulic tank is a 60 gal. tank with a pump and motor. The Hydraulic Pump Motor is started with the Machine On pushbutton. The hydraulic motor is stopped with an e-stop, or when a fault in the hydraulic system is detected (loss of pressure, over temperature, etc).

Any excess oil from the Z-axis counterbalance system drains into the main tank. In addition to capturing leakage oil, this tank is also used for the initial fill of the accumulators and for storing discharge oil during accumulator maintenance.

A level switch in the main tank signals when the oil level in the tank is low. Another level switch indicates when oil in the main tank is at an acceptable high level.

### 11.2.2. SPINDLE UNIT TOOL GRIPPER

Each spindle unit that supports automatic tool changing has a hydraulically activated tool gripper. The pressure required for unclamping the tool gripper varies between spindle units. A proportional valve is used to select the correct pressure. An analog pressure switch is used to monitor the gripper clamped or unclamped state. For more details, refer to the Spindle Unit chapter.

### 11.2.3. CORNER SU GRIPPERS

The gripping of the Spindle Units to the ram is achieved by the use of four hydro-mechanical clamps. The grippers are contained within the ram. Gripping force is provided by a combination of spring force and hydraulic pressure. Hydraulic pressure in the opposite direction is needed to overcome spring tension when unloading the Spindle Units. For more information, refer to the Spindle Unit chapter.

### 11.2.4. C-AXIS CLAMP

C-axis is held in position with eight hydraulic cylinders, which are mechanical spring engaged and hydraulic disengaged. An analog pressure switch is used to monitor the unclamped and clamped pressure.

For more information on the operation of the C-axis clamp, refer to the C-axis section in the Axis Control chapter.

### 11.2.5. A-AXIS CLAMP

Some spindle units are designed with an A-axis, which include integral A-axis clamps. The A-axis uses a hydraulic cylinder to clamp and unclamp the axis. If the spindle unit has a non-motorized spindle, it requires high pressure to activate the clamp, whereas the motorized spindle unit requires a lower pressure. The A-axis unclamp pressure is set by a proportional valve, based on which spindle unit is attached. An analog pressure switch is used to monitor the clamped pressure. The pressure must fall within an acceptable range for the type of SU mounted.

For more information on the operation of the A-axis clamp, refer to the A-axis section in the Axis Control chapter.

Note: This machine does not currently have any spindle units that use this method for A-axis clamps.

### 13.1.1 A-AXIS WORM PRELOAD

The OH-150 spindle unit on this machine is designed with an A-axis that includes a worm drive for the A-axis.

The A-axis uses a hydraulic pre-load on the worm drive. The pre-load pressure on the A-axis worm gear can be switched between two pressures, to provide a low pressure and a high pressure A-axis worm drive pre-load. This optimizes the A-axis stiffness for use in high speed and low rigidity applications, or for low speed and high rigidity applications. The A-axis pre-load pressure is set by a proportional valve based on which

M-code is active. An analog pressure switch is used to monitor the pre-load pressure. The pressure must fall within an acceptable range for the type of SU mounted.

For more information on the operation of the A-axis pre-load, refer to the A-axis section in the Axis Control chapter.

#### 11.2.6. Z-AXIS COUNTERBALANCE

The saddle carries two hydraulic cylinders to act as a counterbalance for the Z-axis ram. Six (6), 57 L (15 gal.), oil accumulators are located on the cross rail to supply pressurized oil to the cylinders. The accumulators are pre-charged with nitrogen gas, to 1100 psi. The pressurized oil counterbalance system acts as a spring with a fixed amount of oil trapped in the cylinder and receiver system.

The Z-axis counterbalance pressure is monitored by the machine controller, through an analog input, from a pressure transducer. If the counterbalance pressure falls below a minimum limit, or rises above a maximum limit, an alarm is posted and the machine goes into a controlled e-stop condition.

Any leakage oil from this system is drained into a collection pan on the crossrail.

A solenoid valve is located at the highest point in the Z-axis counterbalance system to periodically bleed off any air trapped in the system.

<b>WARNING</b> 	<b>Refer to the Fluid Schematics for full details on the Z-axis counterbalance system and safety precautions when charging and discharging the system.</b>
---	--

##### 11.2.6.1 THEORETICAL Z-AXIS COUNTERBALANCE PRESSURES

As the Z-axis ram moves up and down, the counterbalance system will operate between 1350 PSI and 1200 PSI (theoretically). Actual exact pressure values are determined during machine set-up and stored in data registers.

With the head at its lowest point, the oil volume in the counterbalance cylinder is smallest, and the pressure in the system is at maximum (1350 PSI). At this point, the weight of the Z-axis ram is approximately 115% counterbalanced.

With the head up at its highest point, the oil volume in the counterbalance cylinder is greatest, and pressure in the system is at minimum (1200 PSI). The weight of Z-axis ram is approximately 105% counterbalanced at this point.

The counterbalance pressure will vary linearly between these extremes as Z-axis moves through its travel. In other words, the expected counterbalance pressure is a linear function with respect to Z-axis position.

#### 11.2.6.2 Z-AXIS COUNTERBALANCE PRESSURE MONITORING

A pressure transducer is used to monitor the counterbalance cylinder pressure. This transducer inputs a 4-20ma DC signal to the Siemens control, which is proportional to the actual pressure.

The PLC logic will monitor the incoming pressure value and compare this to a theoretical pressure calculated based on the Z-axis position. The logic will post messages if this difference falls outside the range of predefined limits. There are two pressure limits: a warning limit and an alarm limit. These limits are sent in data register values. If the pressure is outside of the warning limit range, an informational message is posted. No machine inhibits occur at this point. If the pressure continues to fall/rise and reaches the alarm limit, then an alarm is posted and the machine goes into a controlled e-stop condition.

Before homing the Z-axis, the pressure must simply be between the high and low extremes.

#### 11.2.6.3 Z-AXIS COUNTERBALANCE PRESSURE RECHARGING

The Z-axis counterbalance circuit will experience some leakage with normal machine usage. Any leakage oil is drained into a collection pan on the crossrail.

The PLC logic will monitor the incoming system pressure value and compare this to a theoretical pressure calculated based on the Z-axis position. The logic turns on the Z-axis Counterbalance Pressure Charging Valve when the pressure difference falls below a predefined limit. This limit is set in a data register value. When the counterbalance system is re-charged, and the pressure returns to the theoretical calculated pressure based on Z-axis position, the valve will be turned off.

If the Z-axis Counterbalance Pressure Charging Valve is on for an excessive amount of time without reaching the desired pressure, the valve is closed and a message is posted. The time limit is set in a data register value. An e-stop is not applied at this time, but a cycle start inhibit is applied. (The counterbalance system pressure monitoring will stop the machine if the counterbalance pressure moves outside the acceptable limits.)

Initial charging (or re-charging after repair) of the Z-axis counterbalance system may require energizing the Z-axis Counterbalance Pressure Charging Valve for a longer time than the limit set in the data register entry.

E-stop will turn off the Z-axis Counterbalance Pressure Charging Valve.

Logic will also monitor the accumulated amount of time that the recharge valve has been on. If the timer reaches a preset limit for the current day, logic forces a machine stop and posts a counterbalance charging valve fault message. Maintenance personnel must perform a manual counterbalance recharging circuit check before machine motion is allowed. The accumulators, bladders, hydraulic pressures, and nitrogen gas pre-charge should be inspected at this time.

<b>WARNING</b>	<b>Accumulators may be charged with hydraulic pressure. Block head before oil discharge and service.</b>
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#### 11.2.6.4 Z-AXIS COUNTERBALANCE AIR BLEED-OFF

A valve is installed at the highest point in the Z-axis counterbalance circuit to bleed off any air that may become trapped in the system. Logic will have an adjustable timer to periodically turn on a solenoid to open this valve and release any trapped air. Another timer in logic will determine how long the valve remains open.

E-stop will turn off the Z-axis Counterbalance Bleed valve.

#### 11.2.6.5 Z-AXIS COUNTERBALANCE DATA

The following data will be stored in registers in the PLC that can be edited by authorized maintenance personnel.

<b>Z-AXIS COUNTERBALANCE DATA</b>	
<b>NAME</b>	<b>DESCRIPTION</b>
Z-AXIS COUNTERBALANCE HIGH PRESSURE ALARM	Differential pressure above theoretical pressure where an alarm is posted and a controlled e-stop is performed.
Z-AXIS COUNTERBALANCE HIGH PRESSURE WARNING	Differential pressure below theoretical pressure where the counterbalance charging valve is turned on.
Z-AXIS COUNTERBALANCE LOW PRESSURE ALARM	Differential pressure below theoretical pressure where an alarm is posted and a controlled e-stop is performed.
Z-AXIS COUNTERBALANCE LOW PRESSURE WARNING	Differential pressure below theoretical pressure where an informational message only is posted.
Z-AXIS COUNTERBALANCE LOW PRESSURE: RE-CHARGE	Differential pressure below theoretical pressure where the oil pump motor is turned on to recharge the accumulators.
Z-AXIS COUNTERBALANCE RECHARGING VALVE EXCESSIVE ON TIME	Time the counterbalance charging valve is allowed energized before an excessive run time message is posted.
Z-AXIS COUNTERBALANCE BLEED CYCLE INTERVAL	The time between activating a counterbalance bleed-off cycle.

Z-AXIS COUNTERBALANCE DATA	
NAME	DESCRIPTION
Z-AXIS COUNTERBALANCE BLEED TIME	The amount of time the counterbalance bleed valve is energized.
Z-AXIS COUNTERBALANCE RECHARGE VALVE ON ACCUMULATED TIME	The accumulated amount of time that the recharge valve has been energized.
Z-AXIS COUNTERBALANCE ALLOWABLE RECHARGE VALVE ON ACCUMULATED TIME	The accumulated amount of time that the recharge valve can be energized, before a manual recharge check is required.

#### 11.2.7. HYDRAULIC INPUTS/OUTPUTS

HYDRAULIC INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
HYDRAULIC POWER UNIT	HYDRAULIC PUMP MOTOR STARTER ENERGIZED	Q034-4	The Hydraulic Pump Motor is started with the Machine On pushbutton as the machine comes out of e-stop. The hydraulic motor is stopped with an e-stop, or when a fault in the hydraulic system is detected (loss of pressure, over temperature, etc).
	NOT HYDRAULIC TANK LOW LEVEL	I091-1	If this signal stays low for a preset period, a message is posted. Cycle start of a new program is inhibited; any active program is unaffected.
	NOT HYDRAULIC TANK CRITICAL LOW LEVEL	I091-6	If this signal stays low for a preset period, a feed hold is issued, then the main hydraulic pump motor is stopped (causing e-stop) and a message is posted.
	NOT HYDRAULIC TANK OVER TEMPERATURE	I091-2	If this signal stays low for a preset period, a message is posted. Cycle start of a new program is inhibited; any active program is unaffected.
	NOT HYDRAULIC TANK CRITICAL OVERTEMPERATURE	I091-7	Loss of signal causes a feed hold, then the main hydraulic pump motor is stopped (causing e-stop), and a message is posted.
	HYDRAULIC PRESSURE OK	I091-3	After the hydraulic pump motor is running, loss of signal causes a feed hold, then the main hydraulic pump motor is stopped (causing e-stop), and a message is posted.
	HYDRAULIC RECIRCULATION PRESSURE OK	I091-0	After the hydraulic pump motor is running, loss of signal causes a feed hold, then the main hydraulic pump motor is stopped (causing e-stop), and a message is posted.

HYDRAULIC INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
	HYDRAULIC FILTER NOT DIRTY	I091-4	Loss of signal causes a message only to be posted. Cycle start is inhibited.
	HYDRAULIC RECIRC. FILTER NOT DIRTY	I091-5	Loss of signal causes a message only to be posted. Cycle start is inhibited.
C-AXIS CLAMP	UNCLAMP C-AXIS	Q103-3	This solenoid is energized when the C-axis is commanded by M-code to unclamp and enable the C-axis.
	C-AXIS UNCLAMPED PRESSURE OK	I100-6	This input is on while the C-axis is unclamped. C-axis motion is inhibited when this signal is low.
A-AXIS CLAMP	CLAMP A-AXIS	Q102-0	M-codes are used to command A-axis to clamp or unclamp. This output is turned on to unclamp the A-axis and turned off to clamp the A-axis. This output is used in conjunction with the A-AXIS PRESSURE SELECT PROPORTIONAL VALVE to deliver proper unclamp pressure.
	A-AXIS CLAMPED/UNCLAMPED PRESSURE	PIW 604	This signal is monitored when a spindle unit with A-axis clamps is attached. Three different acceptable pressure ranges are used: 1. A-axis clamped 2. A-axis unclamped with high pressure 3. A-axis unclamped with low pressure If this signal falls outside of the acceptable pressure range for the type of unit when A-axis is clamped/unclamped, an immediate e-stop occurs.
	A-AXIS CLAMPED PRESSURE OK	PIW 600	This signal is monitored when a spindle unit with A-axis worm drive is attached. Two different acceptable pressure ranges are used: 1. Low A-axis worm drive pre-load 2. High A-axis worm drive pre-load If this signal falls outside of the acceptable pressure range for the commanded A-axis pre-load, an immediate e-stop occurs.
	A-AXIS CLAMP PRESSURE SELECT	Q302	This output is set per spindle unit, to deliver the proper unclamp pressure for the A-axis. This output is also set to obtain the desired pre-load for the A-axis worm drive.

HYDRAULIC INPUTS/OUTPUTS			
DEVICE	NAME	ADDRESS	DESCRIPTION
SPINDLE UNIT TOOL GRIPPER	SPINDLE TOOL GRIPPER CLAMPED/UNCLAMPED PRESSURE	PIW 602	This analog input must be within an acceptable range for the type of spindle unit mounted on the ram when a tool is loaded in the unit. If it falls outside of this range, an immediate feedhold will be issued. This will feedhold any active tool change motion.
	TOOL GRIPPER PRESSURE SELECT	Q300	This output is set to a value based on the spindle unit prior to opening the tool grippers. It remains at the preset value while the tool grippers are open.
	TOOL GRIPPER PRESSURE	PIW 606	This input verifies the proper pressure is set to open the spindle unit tool grippers (based on active spindle unit).
	UNCLAMP TOOL GRIPPER	Q102-1	This output is turned on to release a tool during a tool change. Depending on the type of SU, the <i>Tool Gripper Pressure Select</i> proportional valve output must also be set accordingly.
SU CORNER GRIPPERS	UNCLAMP CORNER GRIPPERS	Q103-1	This output is energized to release the spindle unit from the ram.
	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6	This input is monitored while the SU grippers are open. Loss of this signal causes a feedhold.
	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7	This input is monitored when a spindle unit is mounted on the ram. Loss of this signal will cause an e-stop.
	UNCLAMP CORNER GRIPPERS (REDUNDANT)	Q103-0	This output is energized to release the spindle unit from the ram. This redundant valve assures an accidental manual override is not performed.
Z-AXIS COUNTER-BALANCE	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE MONITOR	PIW 608	This analog input is used to monitor the Z-Axis Counterbalance System Pressure.
	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE CHARGING VALVE ON	Q100-2	This output is energized when the Z-axis counterbalance pressure falls below a preset level. The output is turned off when the pressure rises above another preset level.
	Z-AXIS COUNTERBALANCE BLEED CIRCUIT ON	Q080-0	This solenoid is energized periodically based on a preset timer. The solenoid remains energized for a preset amount of time.

## 11.3 LUBRICATION

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Lubrication of the Ingersoll machine is achieved automatically through the main hydraulic system for some spindle units, and separate subsystems for axes and other spindle unit lube. This machine uses self-contained lubrication systems for X, Y, and Z axis lubrication. The separate subsystems will be described in this section.

The reservoirs and pumps of the lubrication subsystems are located on the Fluids Service Panel located on the Left Column.

The automatic lubrication subsystems include:

- X-axis and Y-axis pinions and linear trucks
- Z-axis ballscrew bearings, linear trucks, and ball nuts
- Spindle lube
- Attachment Lube

### 11.3.1. AXIS LUBRICATION SYSTEM

The X, Y and Z-axis bearing trucks, ball nuts, pinions, and ball screws require lubrication. A Trabon (Lubriquip) series-progressive type system is supplied to provide automatic periodic lubrication. The Trabon system and reservoir is located on the Lubrication Service Panel located on the Right Column. The control and timer of the axis lubrication system is part of the main machine controller.

Lubricant is pumped via a pneumatically driven piston pump that is actuated by an electric solenoid valve. A timer setting in the machine controller determines when the pump operates. Once a lubrication cycle begins, the pump continues to deliver lubricant to the series progressive distribution valves. Lubricant is delivered to each of the trucks and ball nuts. Once all sections of the series progressive distribution valves have cycled, the lubrication cycle switch actuates and indicates to the machine controller. The machine logic will continue the lubrication cycle until the lube cycle switch has toggled three (3) times, indicating that all the feeder valves have cycled enough to apply adequate lubrication to all points on the machine.

The lube cycle control logic verifies that the cycle switch is not tripped (the switch valve has not shifted) at the beginning of the cycle. Installation personnel have set the PLC preset values of counter #1 and #2 for the lube interval time and the lube cycle time, respectively, in units of minutes. At the end of the interval time count, the lube cycle will start, energizing the solenoid in 5-second pulses.

Under normal operation, the lube cycle switch will trip on, indicating that the feeder valves have cycled enough to shift the switch valve that trips the switch. The cycle will continue until enough pulses have occurred to trip the switch off, and then the cycle will be complete and stop.

If the lube cycle counter counts to its preset time, a fault is generated, indicating that one or more of the feeder valves have stuck, or a leak in the system prevents the valves from shifting properly. Other faults are detected from low oil supply level or a block in the system causing a blowout plug to be dislodged. Any of these faults prevent further cycling of the lube system and an operator alarm message to be displayed.

An axis lubrication cycle can be manually initiated using the *Start Axis Lube* pushbutton on the main operator console.

### 11.3.2. SPINDLE BEARING LUBRICATION IN RAM

The spindle supplied with the machine requires lubrication while operating. An Acumen lubricating unit is used to provide a specific amount of lubricating oil and air to the bearings of the spindle. The spindle lube reservoir is located on the Ram. The lube reservoir supplies oil to two (2) injectors located on the back of the ram.

Pressurized air is supplied to the lube reservoir whenever the main machine air is on to help deliver oil from the reservoir. A level switch is used to monitor when the lube requires refilling. This is a manual operation.

The Spindle Lube Air solenoid is on any time the spindle is commanded to run. When the Spindle Lube Air solenoid is turned on, an oil and air mixture will be dispensed through the bifurcated line to the spindle bearings.

A vacuum suction pump and motor is used to remove tramp oil from the spindle bearing lubrication system. Excess lube is returned to a collection tank in the ram box. The small amount of lube recovered in this tank must be periodically drained by manually opening a ball valve at the bottom of the ram.

The machine controller will track the amount of time the spindle is running (M03 or M04 command active). Spindle orient time is not tracked, as it is insignificant compared to spindle run time.

When the spindle run time reaches an amount set in a data variable, the Spindle Lube solenoid is turned on to refill the injectors. The Spindle Lube solenoid will be energized for an interval specified in another data variable.

Two (2) oil pressure transducers and two (2) air pressure transducers are used to monitor the lube system. Each transducer returns a 4-20 ma analog signal to the CNC.

The air pressure from all air transducers is monitored whenever the Spindle Lube Air solenoid is on. The current air pressure is compared to a low air pressure limit (set in a data table) for each air transducer. Low air pressure indicates a broken line. The air pressure is also compared to a high air pressure limit (data table entry) for each air transducer. High air pressure indicates a blocked line.

The oil pressure from all oil transducers is monitored to verify that the pressure does not rise excessively. When the Spindle Lube solenoid is off, the current oil pressure is

compared to the maximum oil pressure limit (data table entry) for each oil transducer. High oil pressure indicates a blocked line. To avoid unnecessary errors, the pressure is not monitored while the Spindle Lube solenoid is on. The oil pressure transducers are monitored to verify that the pressure drops back to starting pressure after the lube cycle, but does fall excessively. During all portions of the cycle, the current oil pressure is compared to the minimum oil pressure limit (data table entry) for each oil transducer. Low oil pressure indicates a broken line.

Before starting a lube cycle, logic will verify the oil pressure is okay. When the Spindle Lube solenoid is turned on, the oil pressure should rapidly spike, and then drop back to the starting base pressure. The highest oil pressure is recorded from all oil transducers. The differential or peak pressure (data table entry) is compared to the required peak pressure at the end of each pump on dwell time for each nozzle. When the spindle lube solenoid is turned off, the oil pressure should already be back at the starting base pressure.

A fault reported by the spindle lubrication package will cause an end of block stop, followed by a spindle stop. A spindle start inhibit will be enforced until the fault is corrected and the alarm is reset.

The Spindle Lube button on the main operator console will flash if a spindle lube fault is present.

After a lube cycle is completed without a fault, or after faults are reset, all recorded transducer pressure values are cleared.

### 11.3.3. SPINDLE UNIT LUBRICATION

Different types of lubrication are required for the various types of spindle units. Some spindle units are greased packed and do not require any other lubrication. Other spindle units require a grease injection system, while still other spindle units require recirculating lubrication. The type of lubrication required for each spindle unit must be identified in the SU data table.

The Orthogonal Spindle Unit OH150 (Offset Swivel #14) used on this machine has grease packed spindle bearings and uses recirculating oil for the gears and other bearings.

#### 11.3.3.1 RECYCLING LUBE INSIDE SU

This section applies to spindle units that require a recirculating lubrication system totally contained within the spindle unit, such as the OH150 (Offset Swivel #14).

This method of SU lubrication provides for a continuous flow of lubricant, with the oil recirculating system totally contained within the SU attachment. The main hydraulic pump supplies oil to the head. A valve located on the ram is used to direct the flow of a higher pressure (300 psi) lubricating oil to the head. This oil is used to power a hydraulic pump inside the spindle unit. The pump delivers oil to the spindle gear sets and A-axis

bearings, from the small oil collection tank inside the SU. A heat exchanger is included in the oil recirculating circuit.

After a SU requiring recirculating lube is attached to the ram, the Turn On Attachment Hydraulic Motor solenoid valve is energized. The Spindle Lubrication Scavenge Pump Motor and the Spindle Lubrication Pump Priming solenoid valve are not used (remain turned off), since this is a closed system.

Upon entering an E-stop, the spindle unit lubrication will be turned off. The Turn On Hydraulic Motor solenoid valve is de-energized.

#### 11.3.4. LUBRICATION INPUTS / OUTPUTS

DEVICE	NAME	ADDRESS	DESCRIPTION
AXIS LUBE	AXIS LUBRICATION CYCLE SWITCH	I101-2	This input must toggle (3) times to complete a full lube cycle.
	AXIS LUBRICANT LEVEL LOW	I101-0	When this signal goes high, a message is posted with no machine inhibits.
	AXIS LUBRICATION PRESSURE BLOW-OUT	I101-1	This signal coming on will cause lube pump operations to be stopped and an alarm to be posted. Logic will issue a feedhold and spindle stop. Cycle start is inhibited.
	AXIS LUBRICATION PUMP ON	Q100-0	Logic energized this output to start an axis lube cycle. This output remains energized until the cycle switch comes on or until a lube fault occurs.
SPINDLE BEARING LUBE	SPINDLE BEARING LUBRICATION LEVEL OK	I101-4	Loss of this signal indicates the oil level in the reservoir tank is low. A fault reported by the spindle lubrication package will cause an end of block stop, followed by a spindle stop. A spindle start inhibit will be enforced until the fault is corrected and the alarm is reset.
	SPINDLE BEARING LUBE SCAVENGE TANK OIL LEVEL NOT HIGH	I090-5	Loss of this signal indicates the oil level in the Scavenge Tank is High. A fault reported by the spindle lubrication package will cause an end of block stop, followed by a spindle stop. A spindle start inhibit will be enforced until the fault is corrected and the alarm is reset.
	AIR ON TO SPINDLE BEARING LUBE	Q104-3	Spindle lube air solenoid is "on" any time spindle is commanded to run Spindle lube air solenoid is turned "off" when spindle is stopped AND the active lube cycle is completed.
	SPINDLE BEARING LUBE SCAVENGE PUMP MOTOR STARTER	Q034-7	This pump motor is energized whenever the Air On To Spindle Bearing Lube solenoid is active. It remains running approximately 1 minute after the Air On To Spindle Bearing Lube solenoid is de-energized. E-stop will turn off these pump motors.
	SPINDLE LUBRICATION	Q080-1	The spindle lube oil solenoid is turned on to refill the injectors. This solenoid is cycled based on the lube interval time and the pump dwell time.

DEVICE	NAME	ADDRESS	DESCRIPTION
ATTACHMENT LUBE	FRONT BEARING LUBE OIL TRANSDUCER #1	PIW 432	These analog inputs for oil and air pressures are monitored during the C-Axis / Spindle Lube cycle as described above in the C-Axis / Spindle Lube section.
	FRONT BEARING LUBE OIL TRANSDUCER #2	PIW 436	
	FRONT BEARING LUBE AIR TRANSDUCER #1	PIW 434	
	FRONT BEARING LUBE AIR TRANSDUCER #2	PIW 438	
ATTACHMENT LUBE	TURN ON ATTACHMENT LUBE OIL	Q102-3	This output is energized when a spindle unit requiring SU recirculating lube (40 psi) is mounted on the ram. It is turned off when the spindle unit is programmed to be removed.
	TURN ON ATTACHMENT HYDRAULIC MOTOR	Q105-0	This output is energized when a spindle unit requiring SU recirculating lube (300 psi) is mounted on the ram, where the system contained entirely inside the SU. It is turned off when the spindle unit is removed.
	ATTACHMENT LUBE OIL PRESSURE OK	I100-0	This switch is monitored only when a spindle unit requiring SU recirculating lube is mounted on the ram.  Once the spindle unit is attached, and the attachment lube oil or attachment hydraulic motor oil output is energized, the pressure switch is monitored. If corresponding pressure is lost, the attachment oil output is de-energized, a feed hold is issued, and a fault message is displayed on the CRT.
	SPINDLE LUBE SCAVENGE PUMP MOTOR STARTER ENERGIZED	Q034-6	This output is energized when a spindle unit requiring SU recirculating lube (40 psi) is mounted on the ram. It is turned off when the spindle unit is removed.
	SPINDLE LUBE PUMP PRIMING ON	Q080-2	This output is energized when the scavenge pump is started. It remains on for approximately 10 second, until the pump is primed, and then is turned off.
	SU GREASE LUBE LOW LEVEL	I081-5	This input is monitored when a su with a grease injection lube system is mounted. If this input turns on, logic posts a message for the operator to manually refill the lube cylinder. Logic will inhibit any future cycle start, until this input turns off.
ATTACHMENT LUBE	ACTIVATE SU GREASE LUBE	Q081-0	This output is energized periodically to lube a spindle unit that has a grease injection system. This solenoid is turned on after a preset amount of time, for a preset interval. The interval and duration is settable per spindle unit.

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## 11.4 COOLANT

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A Coolant Delivery and Filter System is provided with the machine.

Pressurized internal coolant is pumped from a clean tank, and pressurized external coolant is pumped from the main coolant tank, routed through the machine sections and power tracks, coupled through the spindle units, and delivered to work piece with integral coolant nozzles in the spindle units.

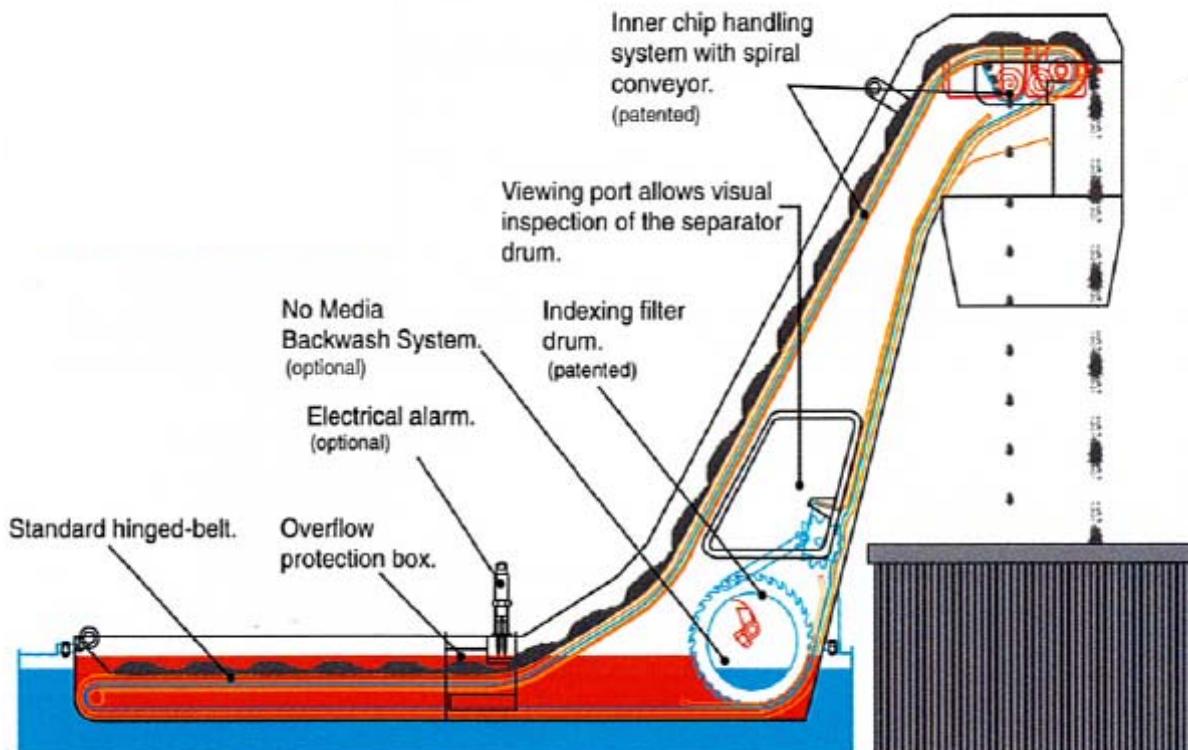
Used coolant is recovered as it flows into the chip conveyors. The coolant is routed to the filter system.

The filter system is designed to automatically clean and remove chips from dirty machine tool coolant. Dirty coolant and chips enter the coolant system, where a steel belt conveyor moves the large chips and swarf up the filter's incline, and dumps them into a chip tote. The coolant and fine particles fall through the steel belt conveyor, into the main coolant tank.

A "no media" backwash system is used to separate the fine particles from the coolant. The fines are transported up the filter's incline with the backwash conveyor, and dumped into the chip tote. The clean coolant is contained in a separate tank from the main tank, and is used for internal coolant.

A disc-type oil skimmer is provided with the filtration system.

The coolant system is a stand-alone system built by Mayfran. See the Installation, Operating, and Maintenance Instructions from Mayfran for full detail on the coolant system.



Coolant System Drawing

#### 11.4.1. COOLANT SYSTEM DETAILS

The coolant system includes:

- Main Coolant Tank (800 gal)
- Clean Coolant Tank (50 gal)
- Low Pressure Coolant Pump - External Coolant (10 gpm @ 45 psi)
- High Pressure Coolant Pump - Internal Coolant (5 gpm @ 220 psi)
- Coolant Filtration System
- Steel Belt Conveyor (removes large chips and swarf)
- Backwash Filter Drum
- Backwash Conveyor (removes fines)
- 3 Chip Conveyors: 2 side (branch) conveyors, and 1 cross (drag) conveyor
- Oil Skimmer
- External Cutting Coolant solenoid valve
- Internal Cutting Coolant solenoid valve

#### 11.4.2. COOLANT SYSTEM ENABLE

The coolant system is enabled as the machine comes out of e-stop, with the Machine On pushbutton.

The coolant filtration system control starts and stops the internal coolant and external coolant motor starters for the coolant pumps based commands from the Ingersoll PLC. The coolant filtration system control monitors for motor overloads, and reports errors to the Ingersoll PLC.

The chip conveyors are started and stopped by the coolant filtration system through commands from buttons on the main operator console.

Manual control of the coolant filtration system and chip conveyors can be performed at the coolant filtration system. The control panel at the coolant filtration system includes a manual / auto selector switch.

With the switch in the manual position, maintenance can start and stop the coolant pumps, and jog the chip conveyors forward or reverse (to un-jam chips), with pushbuttons on the control panel at the coolant filtration system. With the switch in the auto mode, the Ingersoll PLC will remotely start and stop the coolant filtration system and the chip conveyors.

A hard-wired E-stop circuit will turn off the coolant filtration system and chip conveyors with an e-stop.

#### 11.4.3. CHIP CONVEYORS

Three (3) chip conveyors are included on this machine for chip removal.

Two chip conveyors run parallel to the X-axis of the machine, one on each side of the floor plate. The third chip conveyor is a cross conveyor, which connects the two parallel conveyors to the coolant filtration system. These conveyors deliver the chips and used coolant to the coolant filtration system.

Pushbuttons on the Operator Console allow the operator to start and stop the chip conveyors.

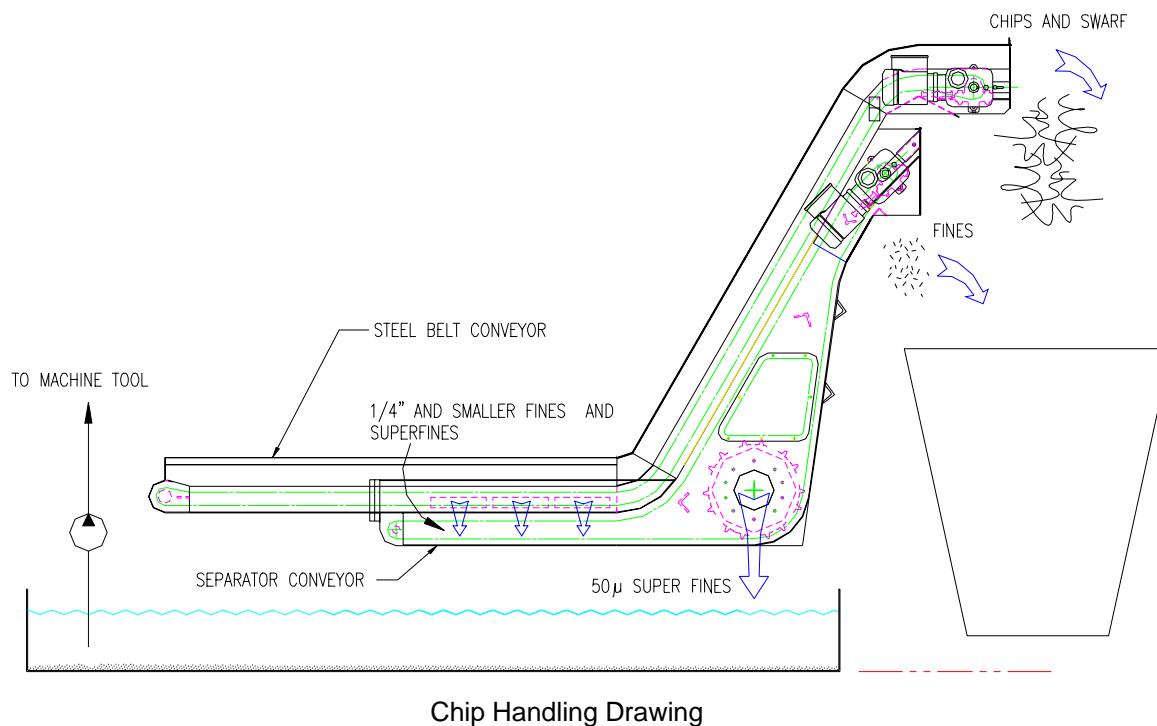
- When the Chip Conveyor Start pushbutton is pressed, the chip conveyors will start. When the button is released, the chip conveyor will continue running in the forward direction.
- Pressing the Chip Conveyor Stop pushbutton will stop the chip conveyor.
- Manual control of the chip conveyors can be performed by maintenance at coolant filtration system local panel.

Any e-stop will stop the chip conveyor. Feed hold or Reset will not stop the chip conveyor.

If an automatic program is started and the chip conveyor is not running, a feedhold is issued and a message is posted. The operator can press cycle start to continue the program without the chip conveyor running.

Two (2) additional conveyors are integral to the coolant filtration system.

The Steel Belt Conveyor removes large chips and swarf from the coolant, and the Backwash Conveyor removes fines from the coolant. These conveyors are controlled automatically by the coolant filtration system.



#### 11.4.4. EXTERNAL CUTTING COOLANT

The external coolant system consists of an entry point located on the saddle, pneumatically-activated valve, and input air supply.

The external coolant is supplied from the main reservoir tank to an entry point located on the saddle. From here, the coolant is piped to the top of the ram, through the rotary union (inside the head), through a quick disconnect to the spindle unit, then the coolant is piped to a hose and nozzle mounted to the side of the spindle unit.

- External coolant is activated by commanding a M10 code.

When the external coolant is enabled, from the pushbutton on operator console or from an M10 programmed command, the Coolant Pump Motor is energized, and the External

Cutting Coolant solenoid valve is energized. The external coolant will flow through the rotary union to the coolant nozzle on the spindle unit.

The external coolant flow is interrupted when M00 (program stop), M05 (spindle stop), M09 (coolant off), M07-M12 (Lube, coolant, and air codes), M30 (program end), Reset, or E-stop are executed.

#### **11.4.5. INTERNAL CUTTING COOLANT**

The internal coolant is used to remove chips from the work piece while machining. This coolant is taken from the clean tank, piped to the saddle, through the rotary union, through the tool holder and tool, and finally to the work piece.

- Internal coolant is activated by commanding a M12 code.

When the Internal coolant is enabled (pushbutton on operator console) or an M12 programmed command, the Coolant Pump Motor is energized, and the Internal Cutting Coolant solenoid valve is energized. The internal coolant will flow through the rotary union to the coolant nozzle in the spindle unit.

The internal coolant flow is interrupted when M00 (program stop), M05 (spindle stop), M09 (coolant off), M07-M12 (Lube, coolant, and air codes), M30 (program end), Reset, or E-stop are executed.

After the internal cutting coolant solenoid valve is energized, an analog signal is monitored to confirm proper coolant flow. Automatic operations are allowed to continue after proper flow is established (value set in data register).

If this signal drops below the defined level, logic will generate a feed hold, followed by a spindle stop. A message will be posted.

#### **11.4.6. OIL SKIMMER**

A disk-type oil skimmer is provided with the filtration system to remove oil from the coolant. The oil skimmer motor is turned on when the coolant system is enabled, and is controlled automatically by the coolant filtration system.

#### **11.4.7. COOLANT SYSTEM INTERFACE**

The coolant system is started remotely by control signals from the Ingersoll CNC/PLC. The coolant system can also be started locally at the coolant system control panel for maintenance purposes. Diagnostic lights are included on the coolant system's local control panel for trouble-shooting.

#### **11.4.8. COOLANT SYSTEM INPUTS / OUTPUTS**

The outputs in this list are outputs from the Ingersoll CNC/PLC to the Cutting Coolant System. Inputs are from Cutting Coolant System to Ingersoll CNC/PLC.

NAME	ADDRESS	DESCRIPTION
COOLANT FILTRATION SYSTEM RUNNING (NO FAULTS)	I053-0	This input is on after the cutting coolant system is started (remote or local), both tank levels are at proper levels, internal conveyors are not overloaded, and the backwash conveyor is running. Loss of this signal causes an immediate stop to all coolant system pump motors, the conveyor motors, and turns off the Coolant Filtration System Remote Start. Diagnostic lights are included on the coolant system's local control panel for troubleshooting.
COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP RUNNING – INTERNAL COOLANT	I053-1	This input is on when the Coolant High Pressure Pump motor starter is energized, providing internal cutting coolant. Loss of this signal causes the Coolant High Pressure Pump motor to stop (the Start Coolant Filtration System High Pressure Pump is turned off), and a message is posted. Loss of this signal with internal cutting coolant active, additionally forces a feed hold and a message is posted.
COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP RUNNING – EXTERNAL COOLANT	I053-2	This input is on when the Coolant Low Pressure Pump motor starter is energized, providing external cutting coolant. Loss of this signal causes the Coolant Low Pressure Pump motor to stop (the Start Coolant Filtration System Low Pressure Pump is turned off), and a message is posted. Loss of this signal with external cutting coolant active, additionally forces a feed hold and a message is posted.
CHIP CONVEYORS RUNNING	I053-3	This input is on when the machine Chip Conveyors motor starters are energized (side conveyors and cross conveyor). With loss of this signal, a message only is posted. Loss of this signal does not turn off the Coolant Filtration System (e-stop), does not stop the Coolant System High Pressure Pump or Low Pressure Pump. Loss of this signal does not turn off the Start Coolant Filtration System Chip Conveyors. The coolant filtration system controller shuts off the faulted conveyor and the non-faulted conveyors continue to run.
MAIN CONTROL NOT E-STOP	3910 CR	This relay is turned on to enable the coolant filtration system. This relay output is energized after the machine is brought out of e-stop, and is turned off with an e-stop. The relay is controlled with both logic and a hard wired e-stop circuit. This output is not turned off with reset, chip conveyor running fault, high pressure coolant pump motor running fault, or low pressure coolant pump motor running fault.
START COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP – INTERNAL CUTTING COOLANT	Q050-5	This output is turned on to start the internal cutting coolant. This output is energized when internal coolant is activated with an M-code or from the pushbutton on the operator console. This output is turned off 2 minutes after the internal coolant request is cancelled (the time is stored in a data register to allow for adjustment). This process will prevent the pump motor from short-cycling if another coolant request is pending. This will also prevent the pump from experiencing extended periods with a dead-head pressure. This output is turned off with an e-stop, coolant filtration system ready fault, or high-pressure process coolant pump running fault. This output is not turned off with reset or chip conveyor running fault.

NAME	ADDRESS	DESCRIPTION
START COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP – EXTERNAL CUTTING COOLANT	Q050-6	<p>This output is turned on to start the external cutting coolant. This output is energized when external coolant is activated with an M-code or from the pushbutton on the operator console.</p> <p>This output is turned off 2 minutes after the external coolant request is cancelled (the time is stored in a data register to allow for adjustment). This process will prevent the pump motor from short-cycling if another coolant request is pending. This will also prevent the pump from experiencing extended periods with a dead-head pressure.</p> <p>This output is turned off with an e-stop, coolant filtration system ready fault, or low-pressure process coolant pump running fault. This output is not turned off with reset or chip conveyor running fault.</p>
START CHIP CONVEYORS	Q050-7	<p>This output is energized to start the chip conveyors.</p> <p>This output is turned on with the “chip conv start” button on the main operator console.</p> <p>This output is turned off with the “chip conv stop” button on the main operator console or with an e-stop.</p> <p>A chip conveyor fault or a coolant filtration system running fault, will not turn off the Start Coolant Filtration System Chip Conveyors. The coolant filtration system controller shuts off the faulted conveyor and the non-faulted conveyors continue to run.</p>
EXTERNAL CUTTING COOLANT ON	Q061-0	<p>This solenoid valve is energized when external cutting coolant is requested from the pushbutton on operator console or from an M10 programmed command.</p> <p>The external coolant flow is interrupted when M00 (program stop), M05 (spindle stop), M09 (coolant off), M10-M12 (coolant and air codes), M30 (program end), Reset, or E-stop are executed.</p>
INTERNAL CUTTING COOLANT ON	Q061-1	<p>This solenoid valve is energized when internal cutting coolant is requested from the pushbutton on operator console or from an M12 programmed command.</p> <p>The internal coolant flow is interrupted when M00 (program stop), M05 (spindle stop), M09 (coolant off), M10-M12 (coolant and air codes), M30 (program end), Reset, or E-stop are executed.</p>
INTERNAL CUTTING COOLANT FLOW	PIW 408	<p>After the internal cutting coolant solenoid valve is energized, this analog signal is monitored. Automatic operations continue after flow is established.</p> <p>If this signal drops below a defined level, logic will generate a feed hold, followed by a spindle stop. A message will be posted.</p>

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## 11.5 PNEUMATICS

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The main air drop to the machine comes from a central system supplied by the customer. A supply of clean, dry, pressurized air is necessary for proper operation of the machine. To help achieve optimum performance of this equipment, it is important that the air supply provided meets the following conditions:

Pressure: 1416 NL/M at 6.2 bar (50 SCFM at 90 PSI) +/- 10%  
Filtration: 40 microns maximum and oil-free  
Dew point: -40°C +/- 1°C at 6.9 bar (-40°F +/- 2°F at 100 PSI)

There is a solenoid valve on floor service panel that turns on the main air to the machine. This solenoid is hard-wired controlled and is energized when power is applied to the machine. A lockout valve on the Service Panel overrides the Air On solenoid allowing the pneumatic system to be disabled for maintenance.

For full details on air requirements and proper pressure setting throughout the machine, refer to the pneumatic schematics.

The following machine functions require air:

- X, Y, and Z-axes Heidenhain air pressurization
- Air supply to Trabon lubrication sub-systems
- Coolant valves pilot
- Spindle seal pressurization
- Ram face blow off
- Spindle tool taper blow off
- Spindle unit air
- Spindle bearing lubrication
- Tool Probe
- Tool Changer

### 11.5.1. X, Y, AND Z AXES HEIDENHAIN AIR PRESSURIZATION

The X, Y, and Z -axis Heidenhain scales provide positional feedback of the individual axis to the machine controller. The glass and metal scale and read head of each Heidenhain scale must be purged with clean compressed air in order keep contaminants from entering.

### 11.5.2. AIR FOR AXIS LUBRICATION SYSTEMS

Air is supplied to the axis Trabon lubrication system. Refer to the lubrication section for details.

### **11.5.3. COOLANT VALVES PILOT**

Air is used to operate the pilot ports on the coolant valves.

### **11.5.4. SPINDLE SEAL AIR PRESSURIZATION**

The spindle front seal is purged with clean compressed air in order keep contaminants from entering. Spindle front seal pressurization is monitored with a pressure switch.

### **11.5.5. RAM FACE BLOW OFF**

Air is used to blow contaminants away from the ram face during a spindle unit change. Refer to the spindle unit change chapter for full details.

### **11.5.6. SPINDLE TOOL TAPER AIR BLOW OFF**

This is used whenever the spindle gripper is opened in an automatic manner (i.e. during a tool change) to keep debris from entering the spindle. Additionally, there is an M11 code that is used by the part programmer to force air through the spindle.

### **11.5.7. SPINDLE UNIT AIR**

Some spindle unit attachments require positive pressure air. These attachments must be identified in the spindle unit data table. When one of these attachments is mounted on the head, logic will turn on air to the attachment and monitor the air pressure.

### **11.5.8. AIR TO SPINDLE BEARING LUBE**

Some spindle units require spindle bearing lubrication. With these spindle units, the spindle lube air solenoid is "on" any time spindle is commanded to run. Spindle lube air solenoid is turned "off" when spindle is stopped AND the active lube cycle is completed.

### **11.5.9. TOOL PROBE AIR**

A constant stream of air is supplied to the laser tool probe to keep it clear of chips and contaminants. A pressure switch is monitored to check this line.

### **11.5.10. TOOL CHANGER AIR**

Pressurized air is supplied to the Tool Changer Carousel to operate the pneumatic cylinders for the robot grippers

### 11.5.11. PNEUMATIC INPUTS / OUTPUTS

DEVICE	NAME	ADDRESS	DESCRIPTION
MACHINE AIR	MACHINE AIR ON	4030 SOL	This solenoid valve turns on the air service to the entire machine. This solenoid is energized when power is applied to the machine.
	MACHINE AIR PRESSURE OK	I051-2	Loss of this signal causes an immediate e-stop.
MISC.	AIR TO ATTACHMENT AIR PRESSURE OK	I100-1	This input is on to confirm proper air pressure for spindle lubrication of motorized spindle units. Loss of signal while the spindle bearing lubrication pump motor is running causes an end of block stop, followed by a spindle stop. The pump motor is stopped, and a message is posted.
	AIR ON TO ATTACHMENTS	Q100-1	This output is turned on whenever a spindle unit requiring air is mounted. This output remains energized during e-stop.
	RAM FACE BLOW OFF	Q104-0	This output is energized during a spindle unit drop and pick cycle to keep debris away from the ram face.
	AIR BLAST RETENTION KNOB (SPINDLE TAPER BLOW-OFF)	Q104-2	This is used whenever the spindle gripper is opened for a tool change.
	AIR ON TO SPINDLE BEARING LUBE	Q104-3	This output is energized when a spindle unit requiring spindle bearing lubrication is mounted on the head. It is turned off when the spindle unit is removed.
SPINDLE SEAL	SPINDLE FRONT SEAL PRESSURIZATION AIR PRESSURE OK	I083-1	A constant pressure is maintained across the spindle front seal to keep the seal clear of contaminants. Loss of air pressure signal causes a message only to be posted.
HEIDENHAIN SCALES	X-AXIS LEFT HEIDENHAIN AIR PRESSURE OK	I051-0	A constant pressure is maintained across the axes scales to keep the Heidenhain scales clear of contaminants. Loss of air pressure signal causes a message only to be posted.
	X-AXIS RIGHT HEIDENHAIN AIR PRESSURE OK	I051-1	
	Y-AXIS HEIDENHAIN AIR PRESSURE OK	I100-2	
	Z-AXIS HEIDENHAIN AIR PRESSURE OK	I100-4	

## 11.6 MOTOR COOLING

Heat removal is supplied by a refrigerated Koolant Kooler unit with air-cooled condenser located on the Chiller Platform. The stand alone, self-monitoring system contains a reservoir and one pump supplying water-glycol to various areas on the machine including spindle, X, Xg, Xt, Xgt, Y, Yt, C, and A axes motors. A flow meter is installed in each branch in the circuit return lines to provide visual and electrical indication of correct cooling water flow.

The spindle motor cooling circuit has two temperature sensors installed, one to monitor the temperature of the incoming water temperature and another to monitor the outgoing water temperature. These temperature sensors are connected to analog inputs to the CNC. The logic will store these temperatures in data registers.

In addition to supporting remote start and stop signals from the Ingersoll controller, the chiller also has a local panel that allows start and stop and temperature control for ease of maintenance.

The chiller is equipped with a diagnostics panel to display status of the chiller on a light panel and any alarms associated with the chiller. A valve on the supply line allows the circuit to be shut off for maintenance.

### 11.6.1. MOTOR COOLING INPUTS / OUTPUTS

NAME	ADDRESS	DESCRIPTION
REMOTE START CHILLER	Q061-4	The Chiller is started with the Machine On pushbutton as the machine comes out of e-stop. The chiller is stopped with an e-stop, or when a fault in the chiller system is detected.
MOTOR CHILLER HIGH/LOW TEMP ALARM	I061-0	After the chiller is started, it responds with this signal. Loss of signal causes a feed hold, followed by a spindle stop, and then an e-stop, and a message is posted.
AXIS MOTOR RETURN COOLING BALL VALVE OPEN	I061-1	If this signal is high, an alarm message is posted and an e-stop is generated.
X-AXIS COOLING WATER FLOW OK	PIW 300	After the cooling water pump is started and water flow is established, these analog signals are monitored.
XT-AXIS COOLING WATER FLOW OK	PIW 302	
XG-AXIS COOLING WATER FLOW OK	PIW 600	If any of these signals drops below a defined level, logic will generate a feed hold, followed by a spindle stop, and then an e-stop. A message will be posted.
XGT-AXIS COOLING WATER FLOW OK	PIW 502	
Y-AXIS COOLING WATER FLOW OK	PIW 412	
YT-AXIS COOLING WATER FLOW OK	PIW 414	
C-AXIS MOTOR COOLING WATER FLOW OK	PIW 410	
A-AXIS MOTOR COOLING WATER FLOW OK	PIW 426	

NAME	ADDRESS	DESCRIPTION
SPINDLE MOTOR COOLING WATER FLOW OK	PIW 424	
SPINDLE COOLING WATER INLET TEMPERATURE	PIW 416	The temperature of the water going into the spindle motor is monitored and displayed.
SPINDLE COOLING WATER OUTLET TEMPERATURE	PIW 418	The temperature of the water flowing out of the spindle motor is monitored and displayed.

**INGERSOLL**

**Machine Tools**

## **CHAPTER 12 - CNC SCREENS**



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## 12.1 INTRODUCTION

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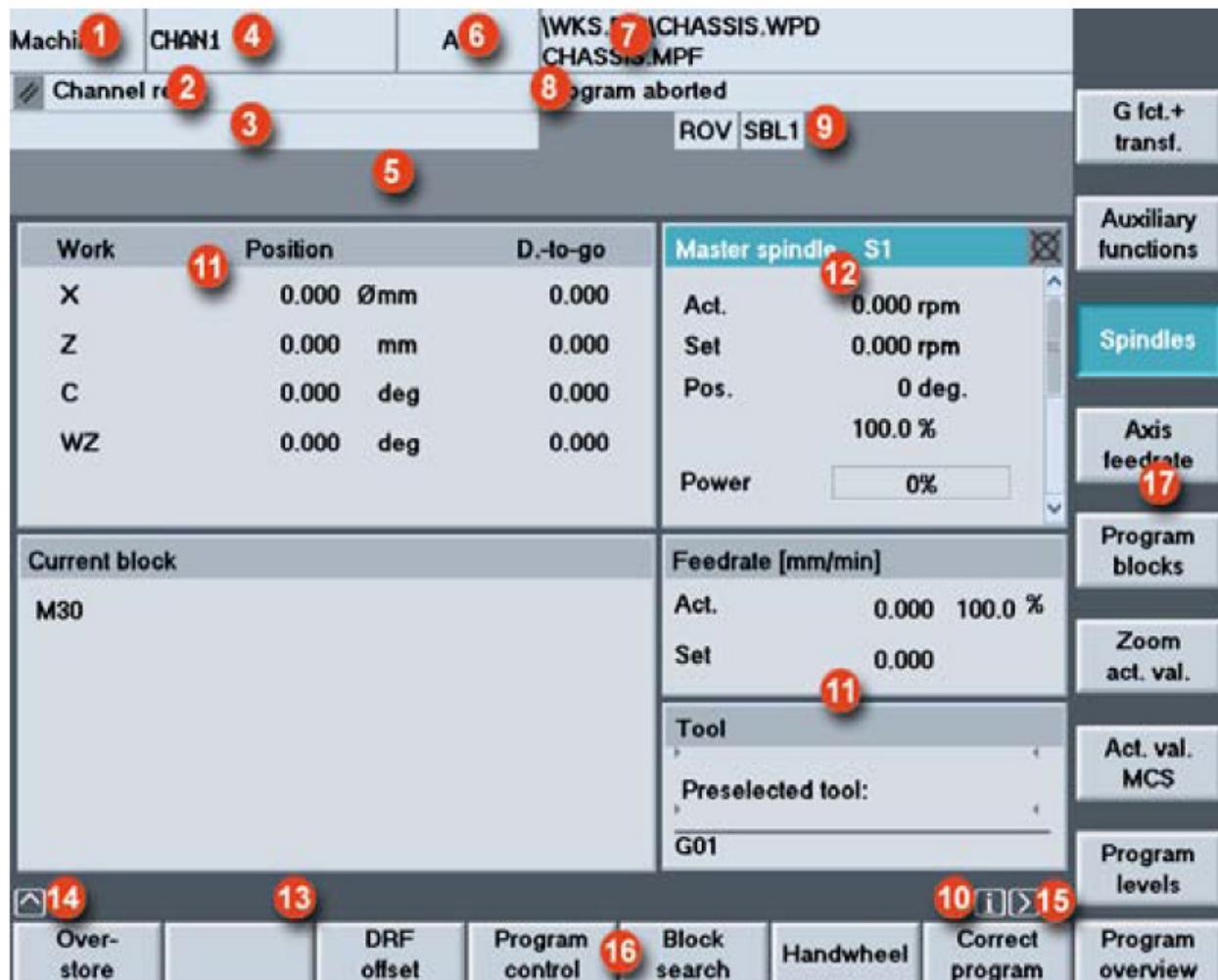
The CNC screens are used by the operator for manual operations and to display status during automatic operation of part programs. These are the standard CNC screens provided by Siemens.

This section is intended to briefly describe the CNC screens typically used by an operator. For more information on the CNC screens, see the Siemens 840D Operator's Manual.

Ingersoll develops a few custom CNC screens for machine-specific operations and to display machine status. These are also described in this chapter.

## 12.2 GRAPHICAL USER INTERFACE

This section describes the interface display and operator interaction.



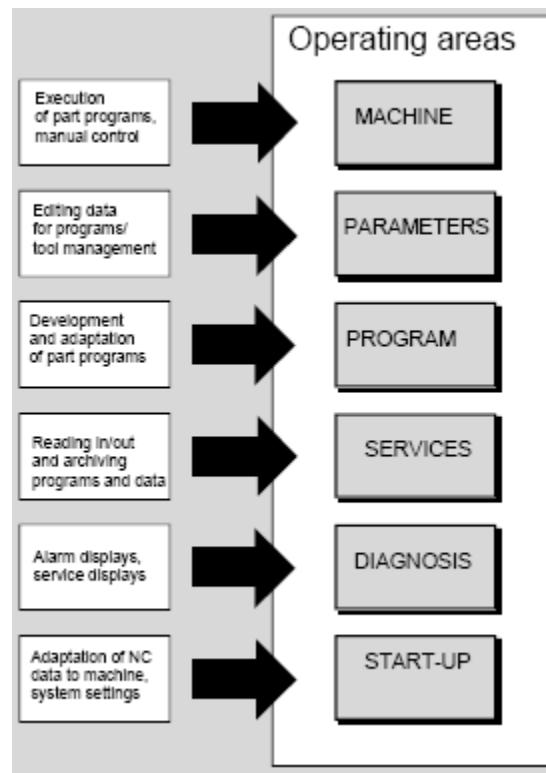
- |   |                              |    |                                      |
|---|------------------------------|----|--------------------------------------|
| 1 | Operating area               | 10 | Information relating to the menu bar |
| 2 | Channel status               | 11 | Work windows and NC displays         |
| 3 | Program status               | 12 | Dialog line with notes for operator  |
| 4 | Channel and mode group       | 13 | Focus                                |
| 5 | Alarm and message line       | 14 | Menu Back                            |
| 6 | Mode                         | 15 | Menu Forward                         |
| 7 | Program name                 | 16 | Horizontal softkey bar               |
| 8 | Channel operational messages | 17 | Vertical softkey bar                 |
| 9 | Channel status display       |    |                                      |

### 12.2.1 OPERATING AREAS

The standard functions in the control are organized into the following operating areas:

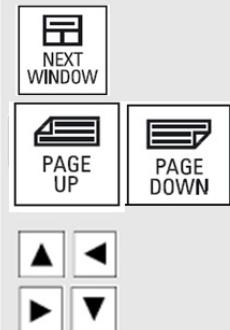


When you press the Menu Select key, the operating areas in the main menu appear in the horizontal softkey bar. Use this key to switch from any menu to the main menu.



### 12.2.2 OPERATING PRINCIPLE

#### Navigation in the menu window:



**Change menu windows:**  
Change the focus to the selected menu window.

**Scroll in the menu window:**  
Scroll one screen page down or up.

**Position cursor in the menu window:**  
Position the cursor at the desired point in the menu window.

#### Operation with the mouse:

If you have installed a mouse, operation is facilitated as follows:

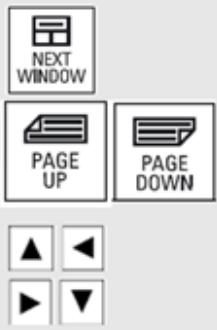
##### 1 "click"

- 1 click means:
  - Activate the menu window.
  - Position the cursor on the desired input field.
  - Select directory.
  - Activate softkey.
  - Activate/deactivate radio button/check box.
  - Activate input field.
  - Open selection list.

##### 2 "clicks"

- 2 clicks mean:
  - Accept value/input.
  - Open directory.

<b>Navigation in the directory tree:</b>	
	<b>Select directory/file:</b> Position the cursor on the desired directory/file.
	<b>Open/close directory:</b> Open or close the selected directory.
	<b>Close directory:</b> Close selected directory.
	<b>Open file:</b> Open the desired file, e.g. if you want to edit the file in the ASCII editor (in this case the editor is opened automatically).
	<b>Select file (HMI Advanced):</b> Select the desired file.
	<b>Select several files (HMI Advanced):</b> Hold down the "Shift" and "Cursor Down" keys.
	<b>Select start of block:</b>
	Neighboring files are selected when you hold down the "Cursor Up" or "Cursor Down" keys.
	You can use the "Toggle" key to select one of several default values.
	<b>3. Selection list (HMI Advanced):</b> Display the preselection of possible values.
	Open selection list
	Position the cursor on the desired values.
	Always confirm your input with the "Input" key. The value is accepted.
	Switch to the next value in the selection list without displaying the entire list.
	Deselect selected files.
	Cancel all selections.
<b>Edit inputs/values:</b>	
	If you want to edit inputs/values, the corresponding key is always displayed automatically on the right of the input field. The following input fields are available:
	<ol style="list-style-type: none"> <li><b>Option fields (radio buttons or check boxes):</b> Activate or deactivate the option field.</li> <li><b>Input fields:</b> Switch to input mode.</li> </ol>
	Enter the value or word (e.g. file name, type, etc.) on the numeric keypad.
	You automatically switch to input mode if you first position the cursor on the input field.
	Always confirm your input with the "Input" key. The value is accepted.
<b>Confirm/cancel input:</b>	
	<b>Confirm input:</b> Save the inputs and exit the current menu (you automatically return to the calling menu).
	<b>Cancel input:</b> Reject the inputs and quit the current menu (you automatically return to the calling menu).
	Reject the inputs and quit the current menu (you automatically move up one level).
	Clear the current input but remain in the current menu.

<p><b>Navigation in the menu window:</b></p>  <p><b>Change menu windows:</b> Change the focus to the selected menu window.</p> <p><b>Scroll in the menu window:</b> Scroll one screen page down or up.</p> <p><b>Position cursor in the menu window:</b> Position the cursor at the desired point in the menu window.</p>	<p><b>Operation with the mouse:</b></p> <p>If you have installed a mouse, operation is facilitated as follows:</p> <p><b>1 "click"</b></p> <ul style="list-style-type: none"> <li>• Activate the menu window.</li> <li>• Position the cursor on the desired input field.</li> <li>• Select directory.</li> <li>• Activate softkey.</li> <li>• Activate/deactivate radio button/check box.</li> <li>• Activate input field.</li> <li>• Open selection list.</li> </ul> <p><b>2 "clicks"</b></p> <ul style="list-style-type: none"> <li>• Accept value/input.</li> <li>• Open directory.</li> </ul>
--	---

## 12.3 ALARMS

Any e-stop or interlock condition will generate an alarm. The CNC and PLC can also generate other alarm conditions that may or may not stop operations.

The CNC monitors the machine axes and generates alarms associated with axis control, part programs, and other CNC functions. The PLC logic monitors the input and outputs on the machine, controls most of the devices on the machine, and issues appropriate alarms when required.

### 12.3.1 CNC ALARM SCREEN

A full screen display of all active alarms can be viewed on the CNC Alarm Screen. The CNC alarm screen displays all active CNC and PLC generated alarms with alarm numbers, date, clearance criteria and descriptions. To access this screen:

1. Press the MENU SELECT key  to get the main menu of horizontal soft keys displayed.
2. Select the DIAGNOSIS softkey.
3. Select the ALARMS softkey.

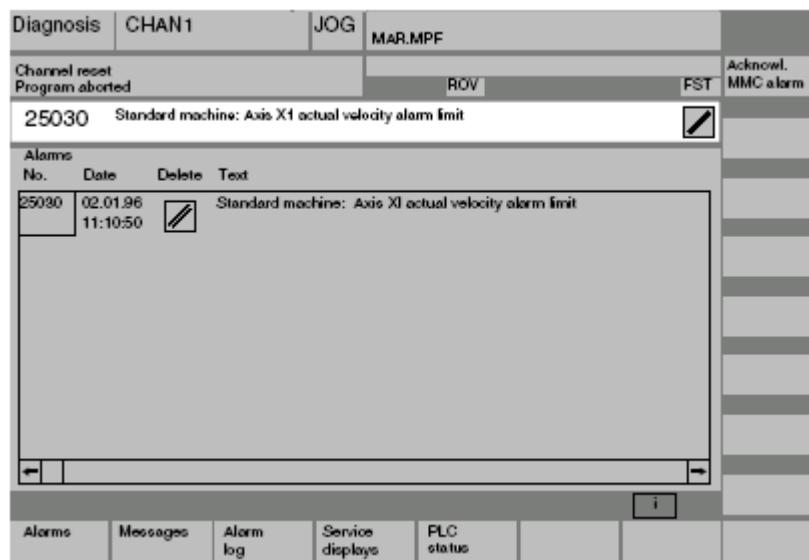
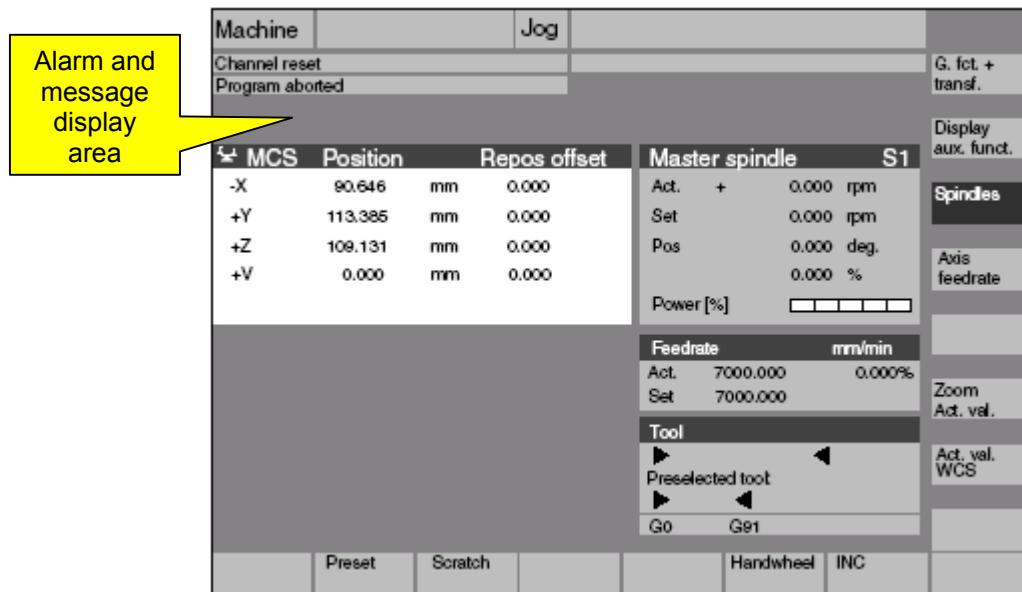
For some CNC generated alarms, additional help can be obtained by pressing the "Help" key.

All alarms generated by the CNC and PLC are reported to the CNC. The operator can view all alarms on the CNC alarm screen and respond to them if required. For more information on the CNC alarm display, see the Siemens 840D Operator Manual.

Depending on the severity of an alarm, logic may do one or more actions:

- display a message
- flash a light
- sound the beeper
- cause a feedhold (or other inhibit) at the end of the current block
- cause an immediate feedhold
- cause an e-stop

When a CNC or PLC-generated alarm occurs or a message is generated, the alarm or message is displayed on the top of the CNC screen as shown below.



CNC Alarm Screen

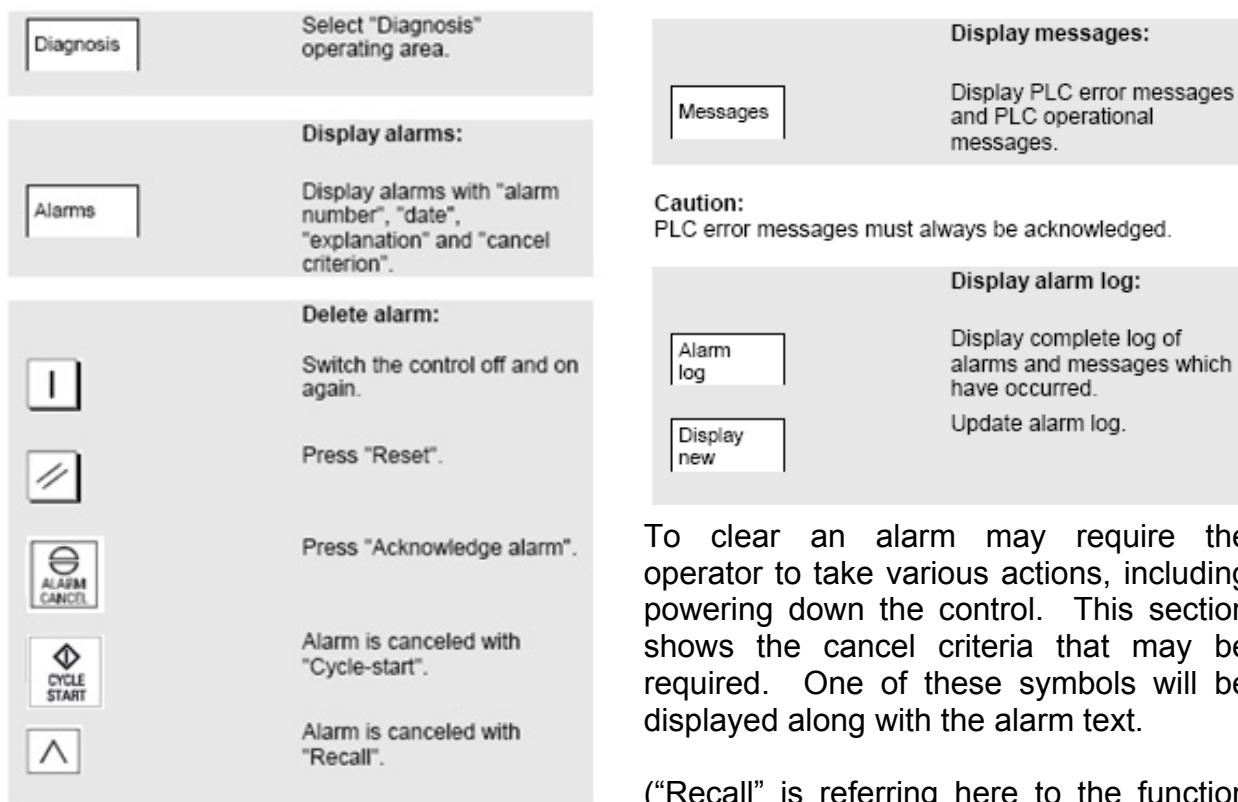
The following fields are displayed on the Alarm screen:

- Number = The alarm number is output under "Alarm No.". The alarms are output in chronological order.
- Date = The date and time at which the alarm occurred is displayed with the date in day,month,year format and hours, min, sec.
- Delete = The criterion for clearing the alarm. The symbol denoting the alarm abort key is displayed for every alarm.
- Text = The alarm text is displayed under "Text".

The alarm screen can also be accessed by pressing the ALARMS softkey as detailed below.

### 12.3.2 ALARMS/MESSAGES

The majority of operator alarms will display on the CNC screens. All CNC and PLC generated alarms will be displayed and acknowledged at the CNC.



To clear an alarm may require the operator to take various actions, including powering down the control. This section shows the cancel criteria that may be required. One of these symbols will be displayed along with the alarm text.

("Recall" is referring here to the function performed by the Menu Back key ^ )

### 12.3.3 MESSAGES

This softkey available under the DIAGNOSIS function will display operational messages that do not have to be acknowledged.

#### 12.3.4 ALARM LOG

This softkey available under the DIAGNOSIS function displays a log screen containing the alarms and messages that have occurred, including those that have already been acknowledged. 150 alarms/messages can be logged as standard. The alarms cannot be acknowledged here.

#### 12.3.5 INFORMATION KEY

Whenever the symbol "i" appears in the dialog line, this means that additional information can be called via the information key. A comment appears in the dialog line. Pressing the information key will display explanatory text and information relating to the current operating status (e.g. interactive programming, diagnosis, PLC, alarms). i

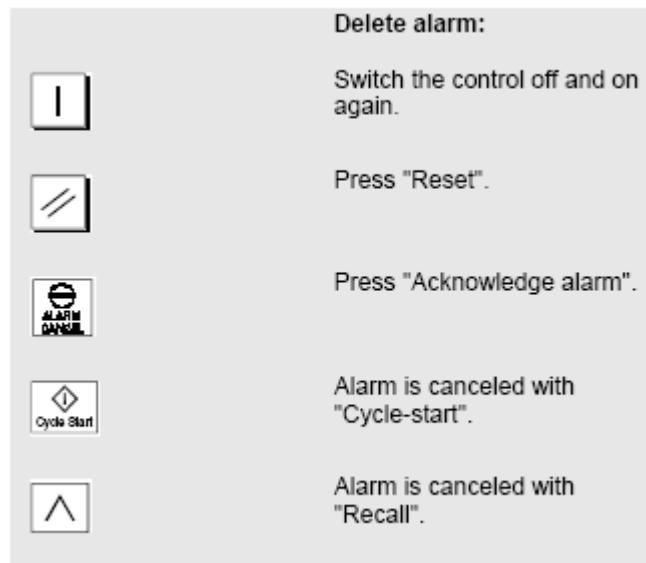
#### 12.3.6 PLC DIAGNOSTIC MESSAGES

Additional PLC diagnostic messages can be displayed on the CNC alarm screen by pressing and holding the Emergency Stop Reset pushbutton for more than five (5) seconds. The E-stop Reset button is located at the control console, just above the Emergency Stop pushbutton. The PLC will generate alarm messages for any e-stop or inhibit that is currently active.

#### 12.3.7 CLEAR ACTIVE ALARM

To clear an alarm may require the operator to take various actions, including powering down the control. The symbol displayed next to the alarm text on the CNC shows the cancel criterion that may be required. The various cancel criterion symbols are shown:

Those alarms whose conditions remain active, will not clear. These alarms will remain in affect until the actual fault conditions are resolved (then the operator may clear the fault).



## 12.4 CUSTOMIZED CNC SCREENS

---

The customized CNC screens allow Ingersoll to present machine specific data to machine operators in a user-friendly format. Ingersoll's implementation of these screens employs a hierarchy of menus, each leading to a specific area of control and information.

**WARNING**

**EXTREME CARE MUST BE TAKEN WHEN CHANGING DATA ON CUSTOM CNC SCREENS. SETTING DATA INCORRECTLY WILL CAUSE IMPROPER MACHINE OPERATION OR MACHINE DAMAGE!**

The actual menus shown on a machine are dependent on the operator's privilege level, the machine type, the number of axes, and options supplied for the machine. A password may be required to access some screens.

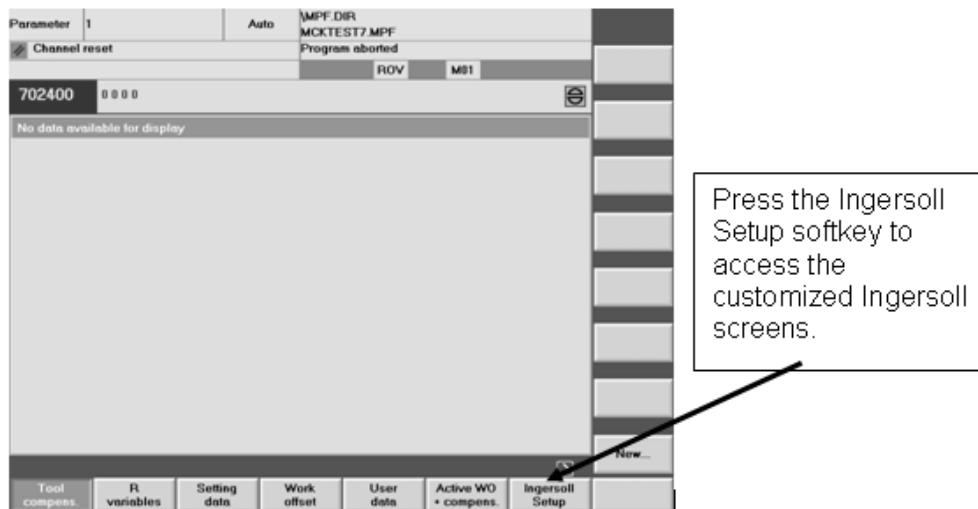
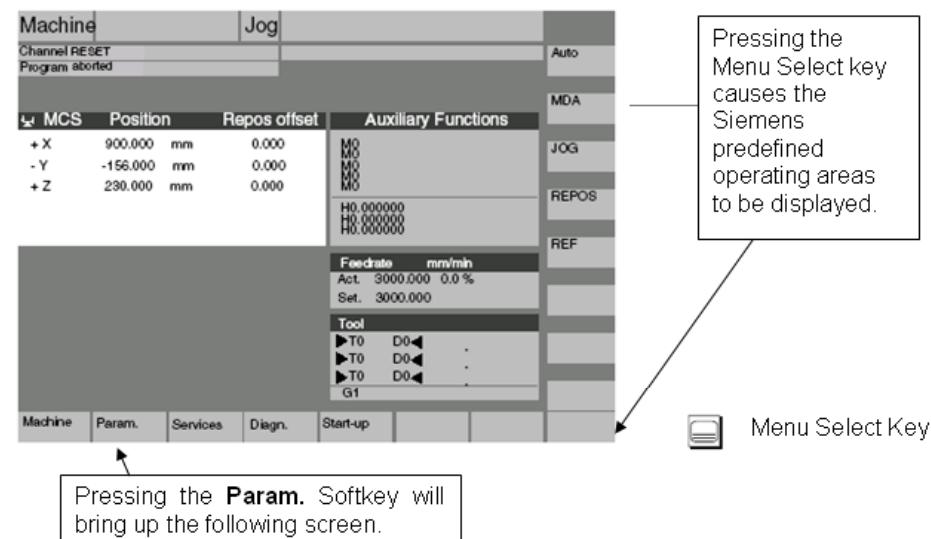
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**NOTE:** Some data shown on the screens in this document may be different for your specific machine. This is especially true of information relating to axes positions, number of axes, feedrates, and clamps.

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### 12.4.1 ACCESSING CUSTOMIZED CNC SCREENS

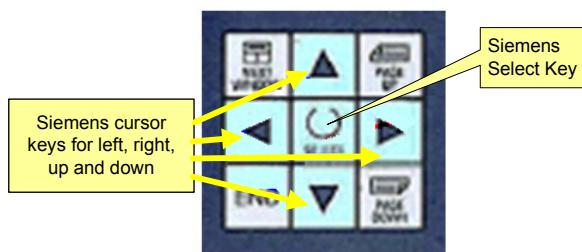
The Ingersoll customized CNC screens can be accessed by pressing the **Menu Select** key on the CNC console. Pressing the Menu Select key causes the softkeys on the bottom of the screen to revert to the Siemens predefined operating areas. Pressing the **Param.** Softkey will cause the softkeys to change and then pressing the Ingersoll Setup softkey will take the user to the Ingersoll customized CNC screens. Screens shown below are examples only.



### 12.4.2 NAVIGATING SCREENS

On each of the available Ingersoll screens, there is a softkey on the side labeled **BACK**, which is used to back out one level of screens. The other softkeys below and to the right side of the display are used to access the various levels of Ingersoll screens.

On the Ingersoll customized screens, a white box around a value signifies where the operator is allowed to change values. The Siemens cursor keys can be used to position the cursor to the value to be changed. The operator can then toggle the value by pressing the **SELECT** key or enter a new value, depending on the type of input required.



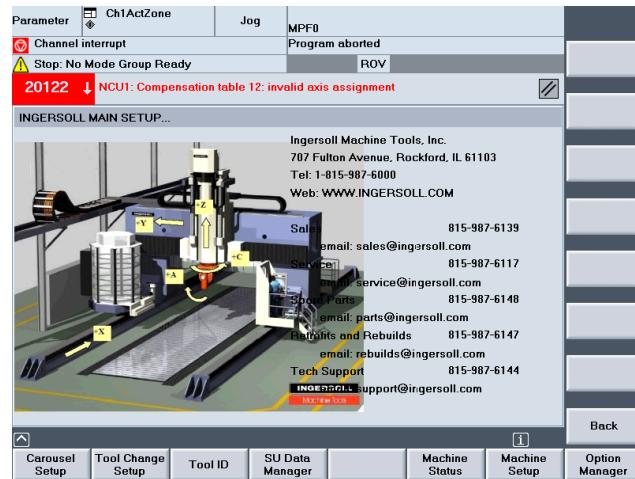
## 12.5 INGERSOLL MAIN SETUP SCREEN

The first screen displayed in the customized CNC section is the Ingersoll Main Setup screen.

This screen displays information for contacting Ingersoll and provides function key access to the custom Ingersoll CNC screens which are grouped in the following manner:

### ❖ MAIN SETUP INTERFACE

- Carousel Setup
- Tool Change Setup
  - Carousel
  - Manual
- Tool ID
- SU Data Manager (Main)
  - SU Data
    - Additional Axis
    - Fluids
    - Tool Gripper
  - SU Nest Data
    - Nest Exchange
  - NC DBB[#] Data
  - View Filter
- Machine Setup
  - Cooling Flows Data
  - Spindle/Axis Lube Data
  - Counterbalance Data
  - Spindle Misc. Data
  - SP Voltage Protection
- Machine Status
  - Cooling Flow Status
  - Spindle/SU Lube Status
  - Counterbalance Data
  - Spindle Sensors
- Option Manager

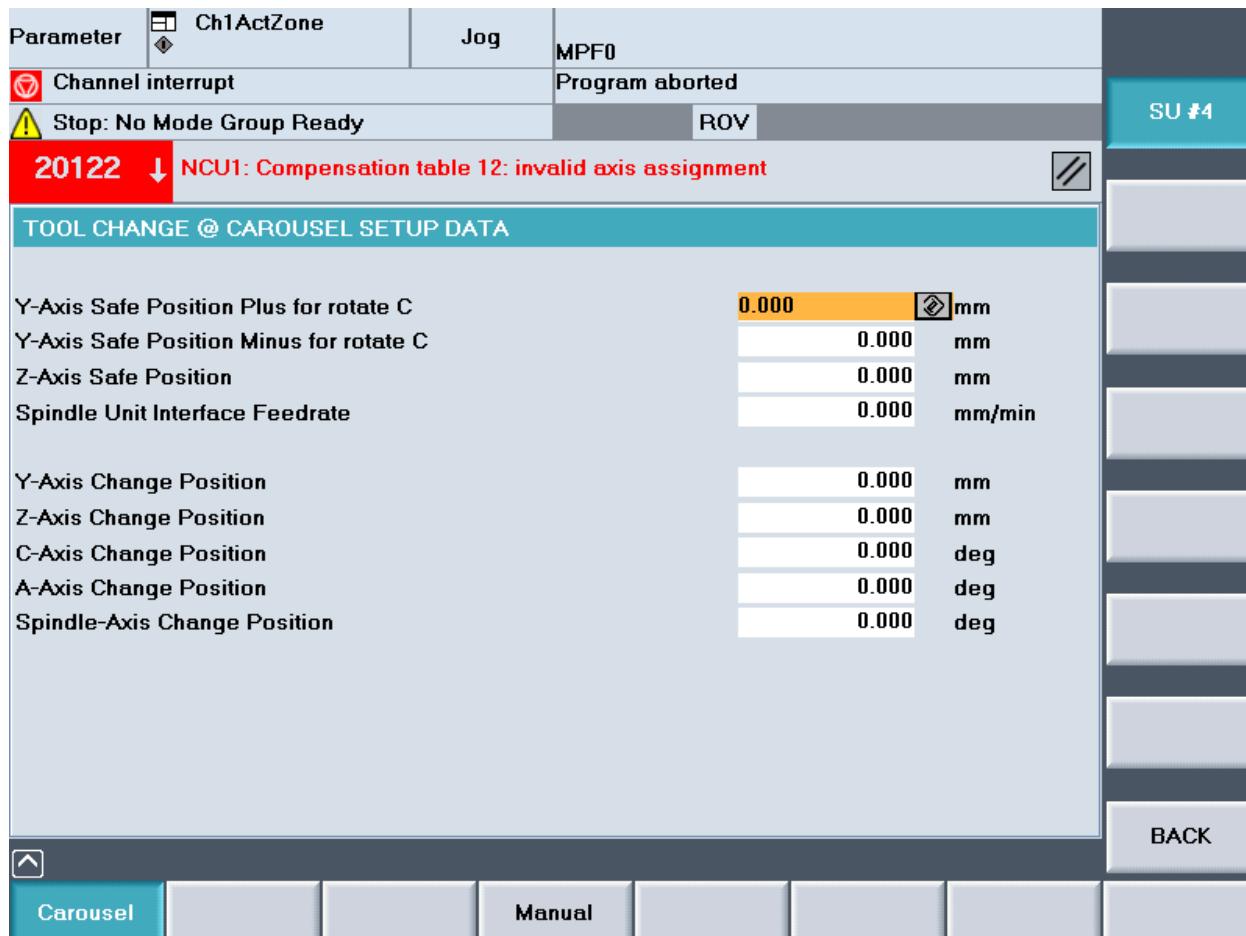


## 12.6 CAROUSEL SETUP

The Tool Carousel Setup screens are explained in the Maintenance Manual in the chapter on Tool Management.

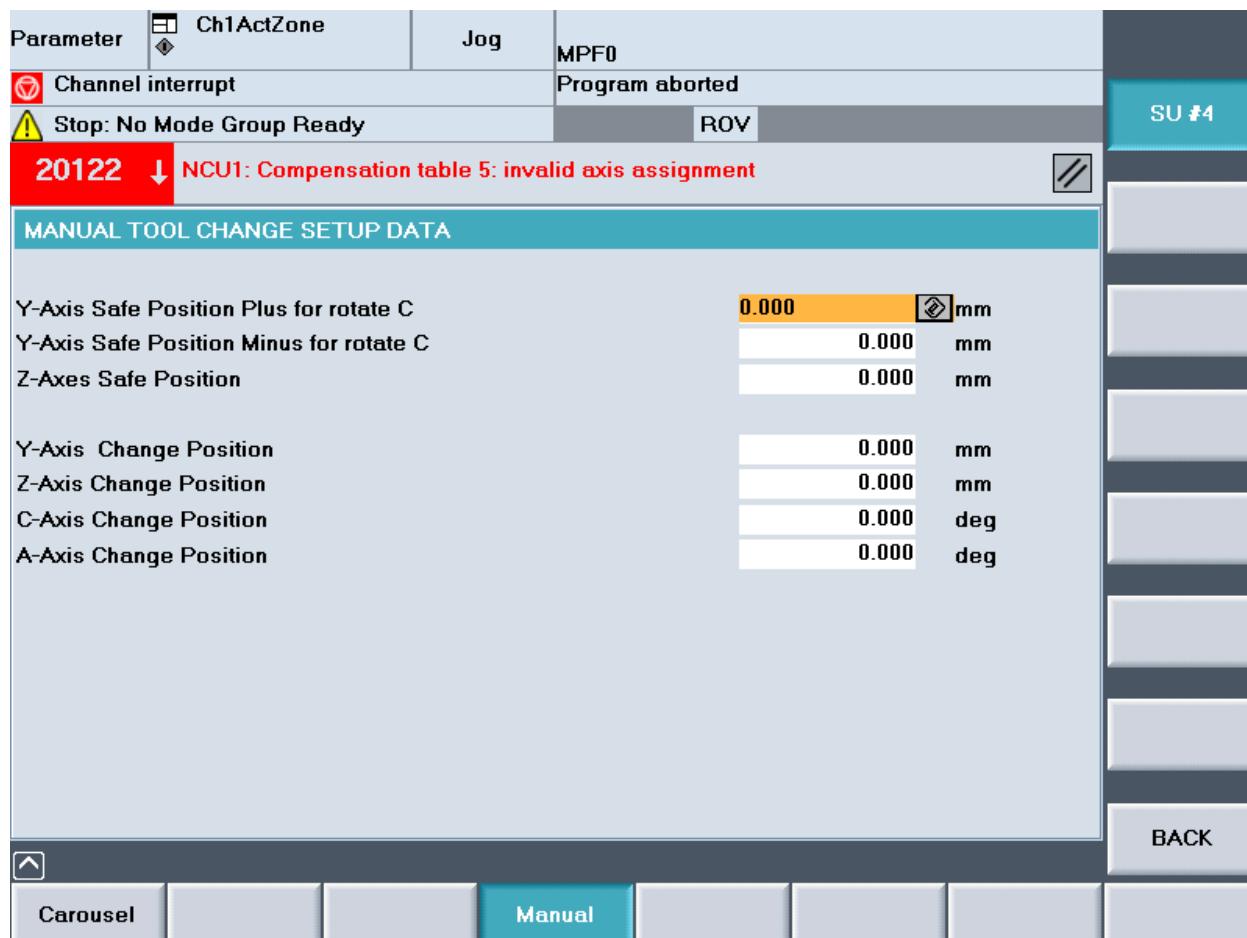
## 12.7 TOOL CHANGE SETUP

The Tool Change Setup screen displays the positions and data values used by software to do automatic tool changes from the tool carousel. An authorized user can modify this data.



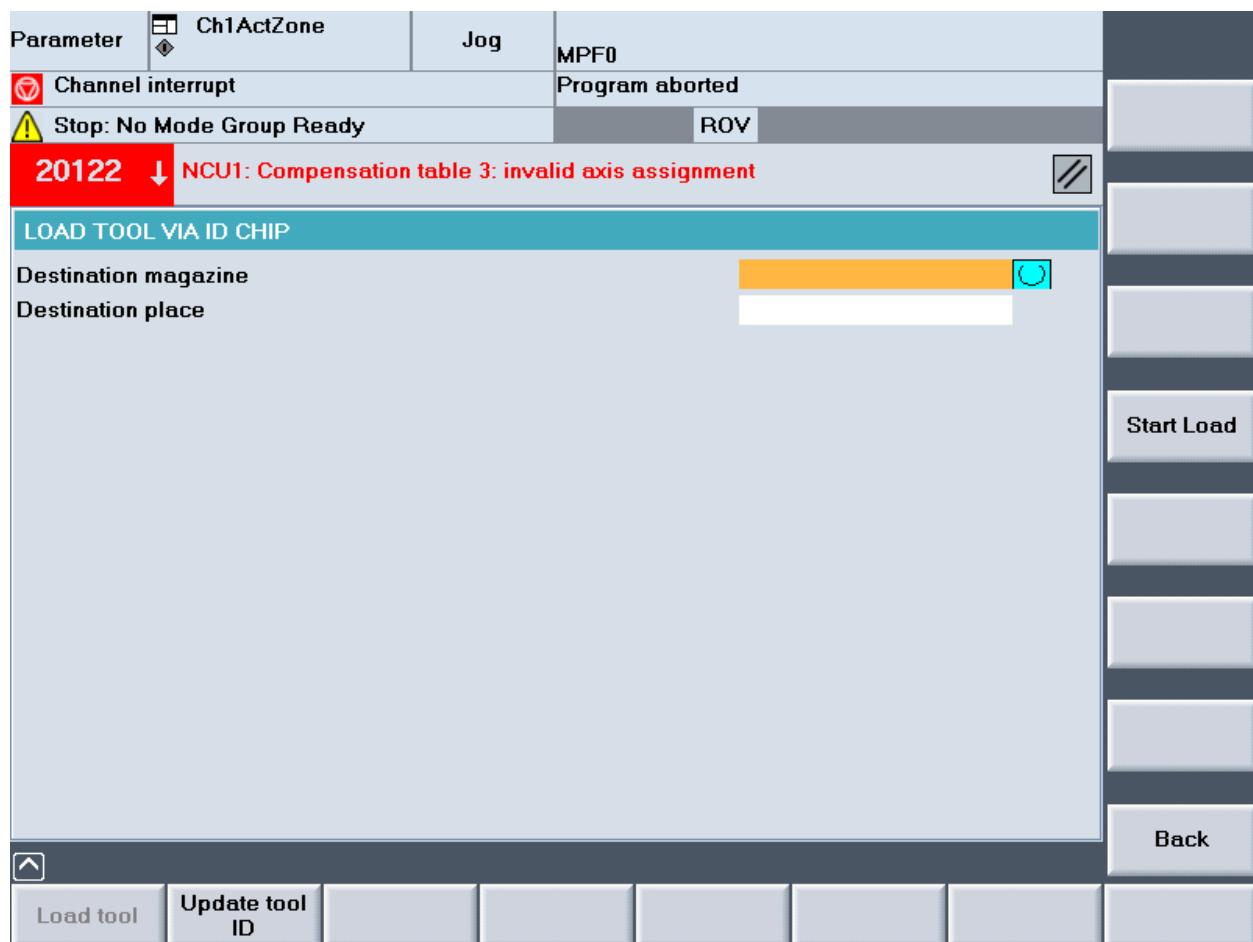
### 12.7.1 MANUAL TOOL CHANGE

The Manual Tool Change Setup screen displays the positions and data values used by software to do manual tool changes. An authorized user can modify this data. The vertical function keys along the right-hand side of the screen allow the user to select the spindle unit whose tool change positions are being shown on the screen. The tool change positions must be set separately for each spindle unit capable of tool changing.



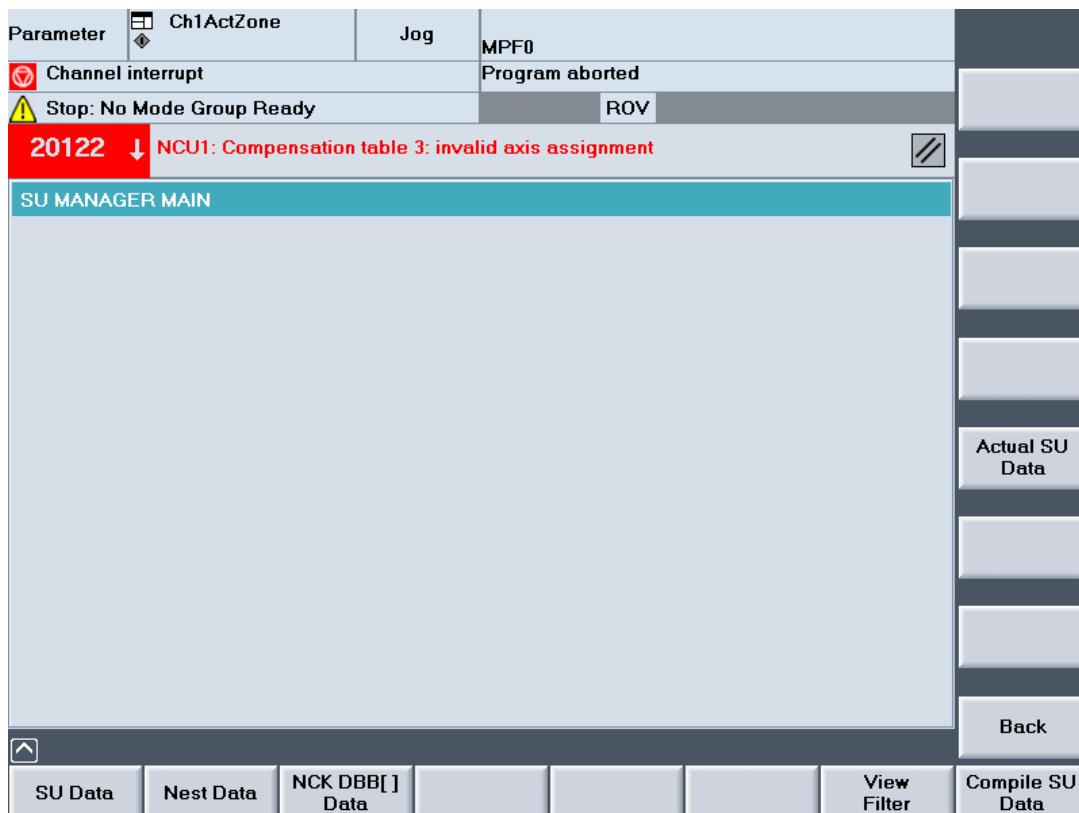
## 12.8 TOOL ID

The Tool ID screen is used to set up which magazine and pocket the tool id chip is read at.



## 12.9 SU MANAGER MAIN

The Spindle Unit Data Manager screen allows the user to access subscreens to configure which spindle units are installed on this machine, what the characteristics of each spindle unit are, information on nest locations for these spindle units, and parameters for spindle unit change cycles.



The **SU Data** horizontal function key brings up another set of screens that allows the user to enter the characteristics of each spindle unit.

The **Nest Data** function key brings up screens for entering nest locations.

The **NCK DBB[ ] Data** function key allows the operator to view system variables that contain SU data.

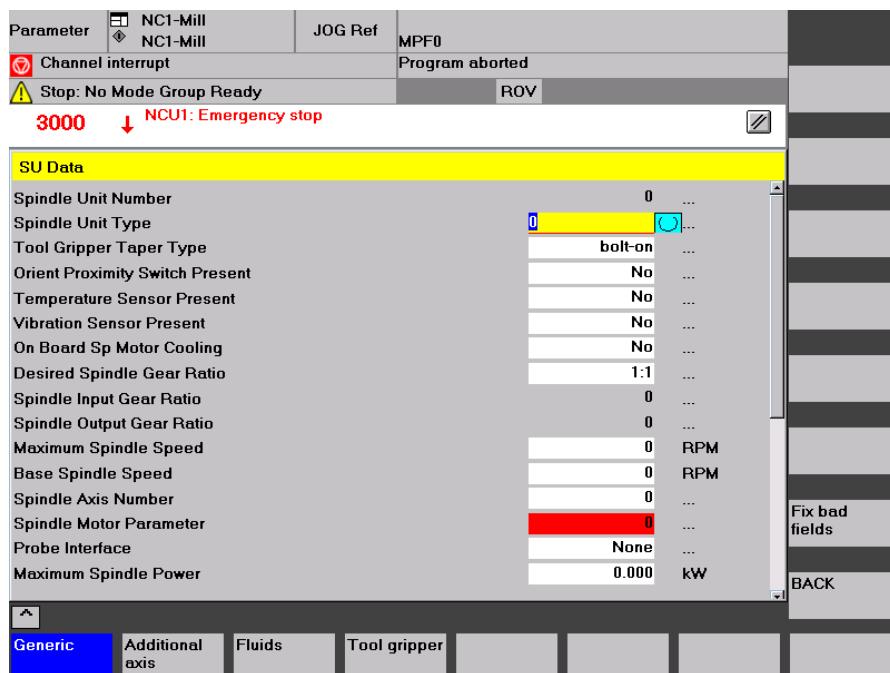
The **View Filter** key allows the user to select which spindle units are present on the machine.

The Compile SU data is used to regenerate SU screens when a major change has been made to the spindle unit data. This should only be used by Ingersoll personnel.

The Actual SU Data vertical function key displays the spindle unit data for the unit currently mounted on the ram.

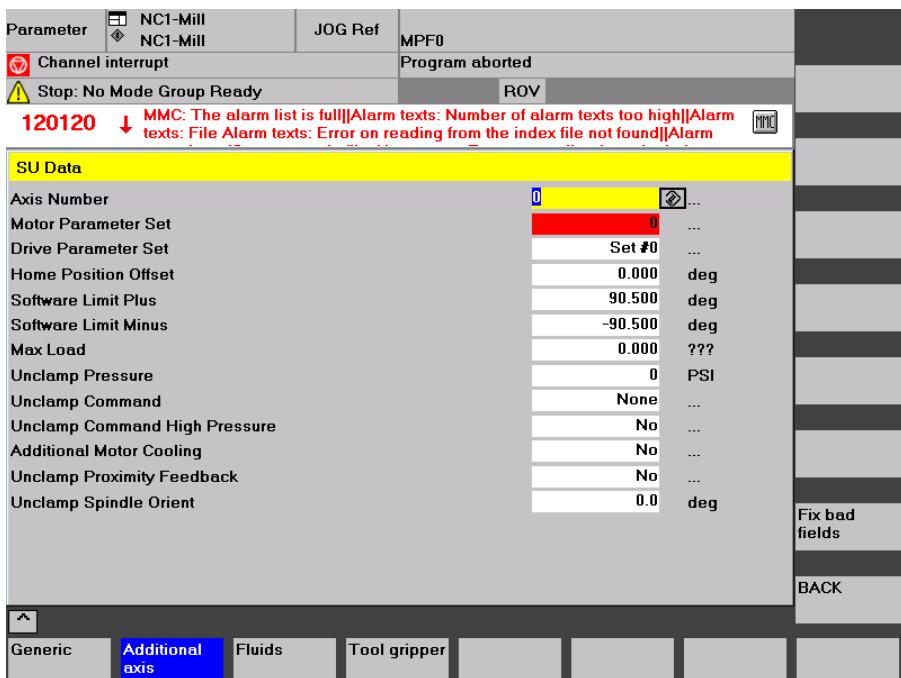
### 12.9.1 SU DATA

The **Generic** screen is used to configure miscellaneous information on each spindle unit.



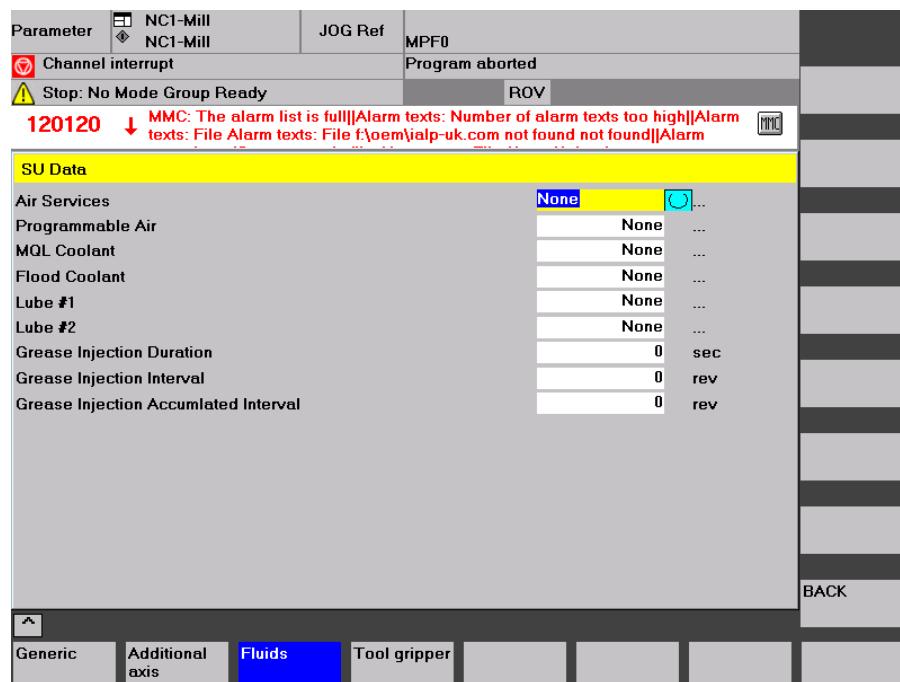
#### 12.9.1.1 ADDITIONAL AXIS

The Additional Axis subscreen under SU Data is used to configure information about any additional axis within a spindle unit.



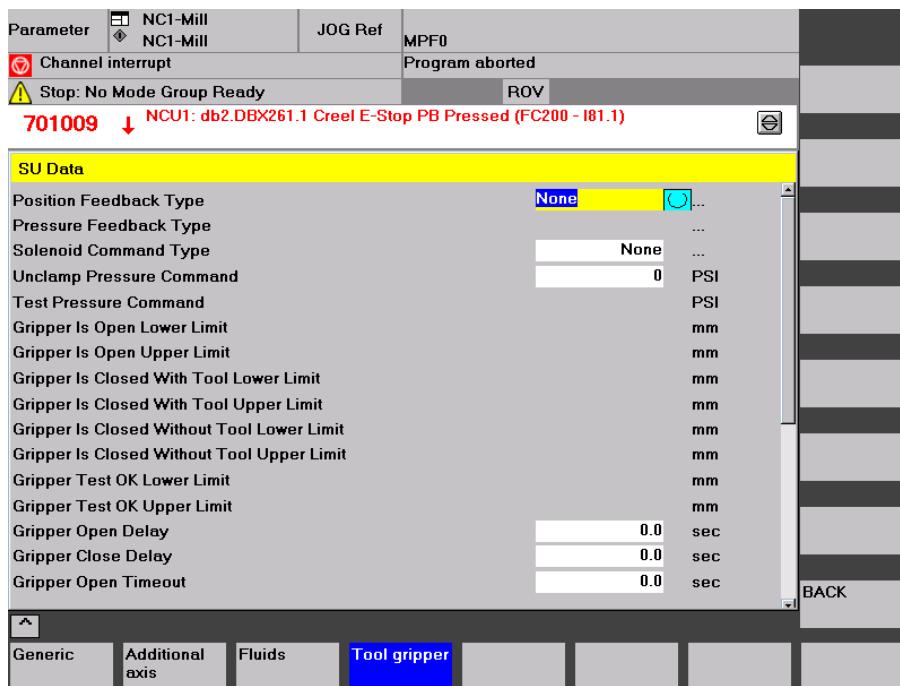
### 12.9.1.2 FLUIDS

The SU Fluids Data screen is used to configure fluids related information on the displayed spindle unit.



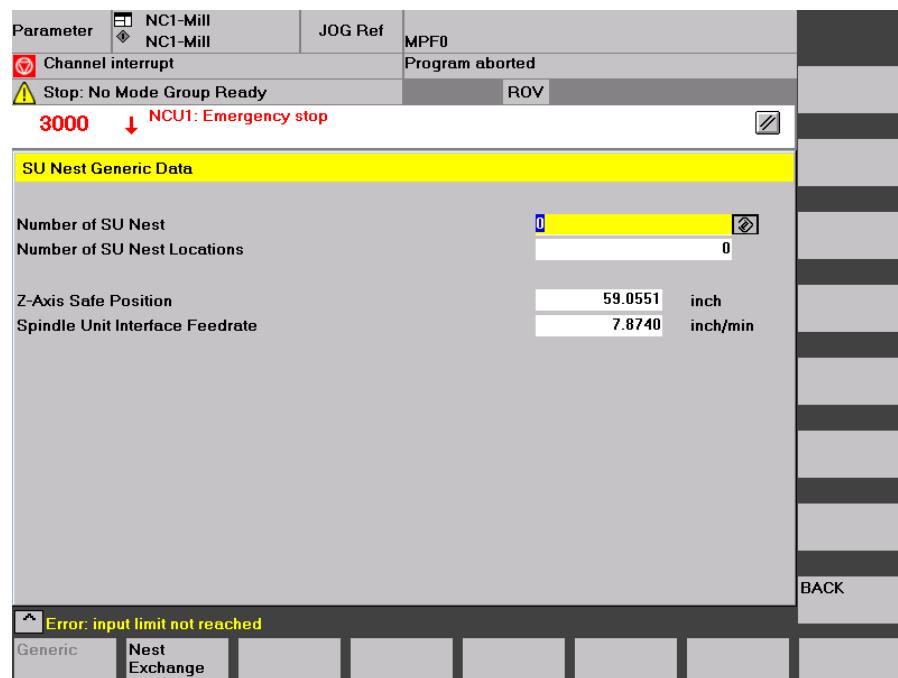
### 12.9.1.3 TOOL GRIPPER

The SU Tool Gripper Data screen is used to configure information about the tool gripper within each spindle unit.



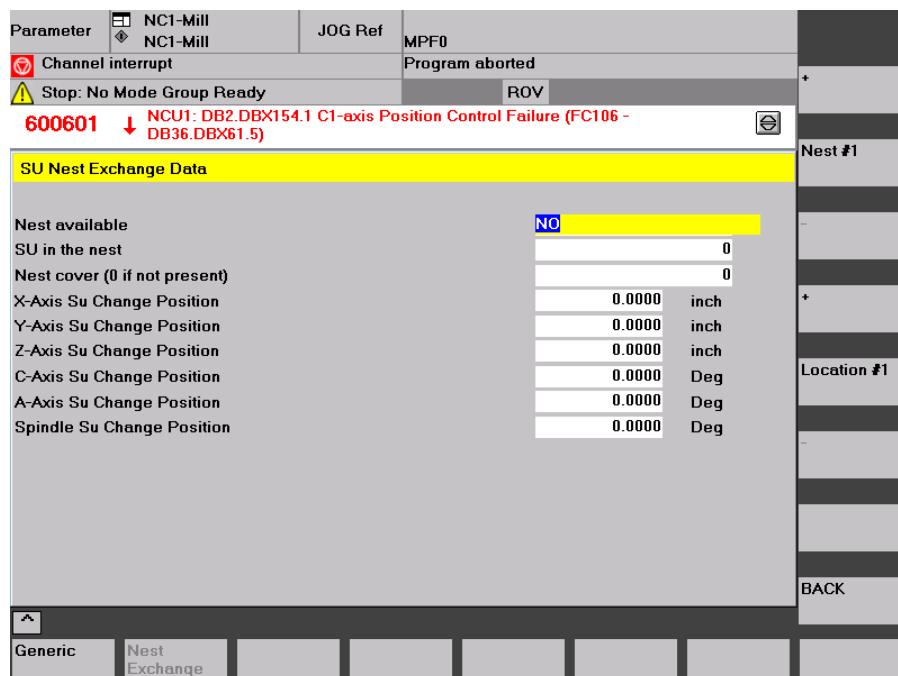
## 12.9.2 SU NEST DATA

The **Generic** screen is used to configure the number of spindle unit nests on the machine, the number of locations around the machine where nests can be located, and other generic data for a spindle unit change cycle.



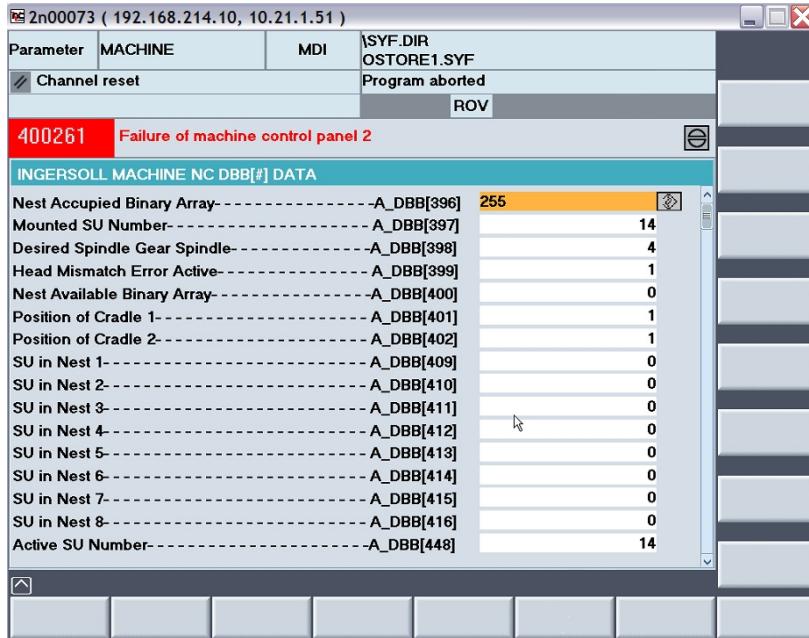
### 12.9.2.1 NEST EXCHANGE

The SU Nest Exchange Data screen is used to set the spindle unit change position for each nest on the machine. Using the vertical function keys, the user selects which nest's data is displayed. The SU change position must be set for each nest and for every location that the nest can be moved to.



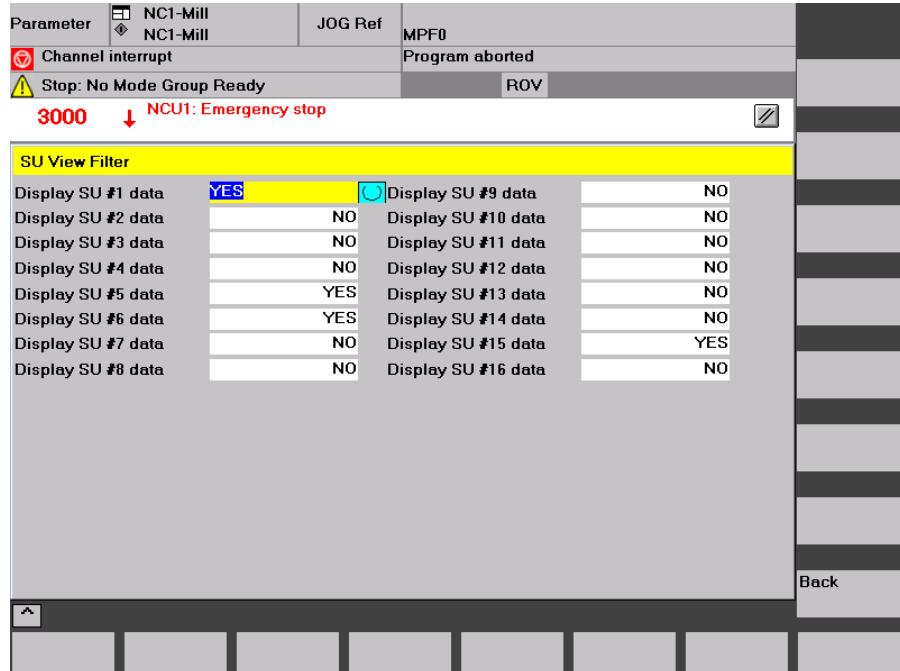
### 12.9.3 NC DBB[#] DATA

The NC DBB[#] Data screen displays the current SU data in CNC system variables. These variables can be used by the part programs. A knowledgeable user can modify this data.



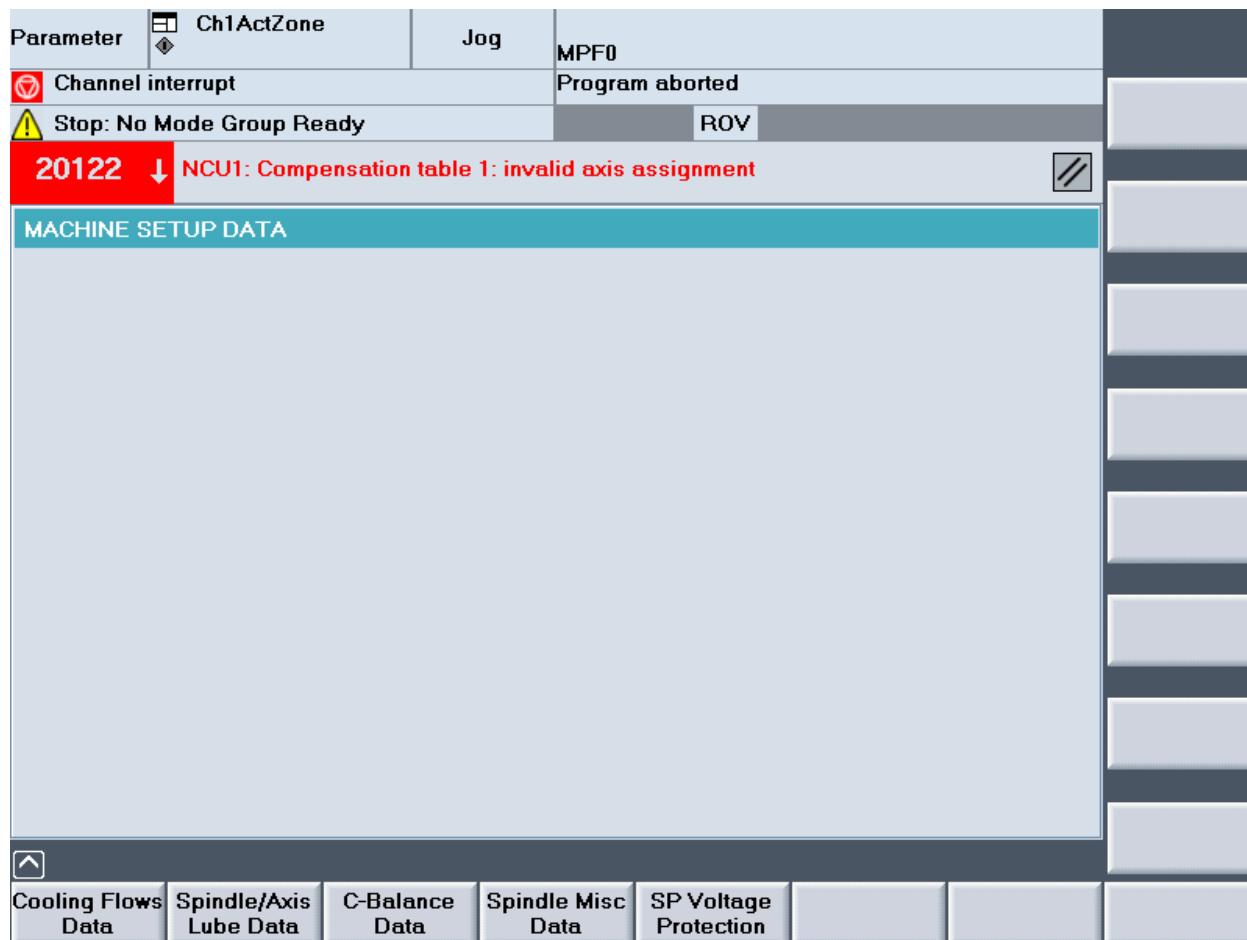
### 12.9.4 VIEW FILTER

The SU View Filter screen is used to select which spindle units are currently active on the machine.



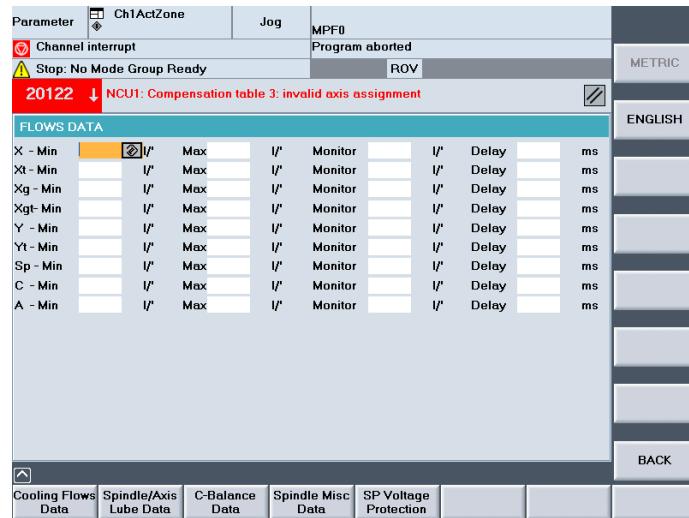
## 12.10 MACHINE SETUP DATA

The Machine Setup Data Screen is used to change parameters for axis motor cooling, spindle and axis lube cycles, counterbalance data, miscellaneous spindle data, and the spindle voltage protection system.



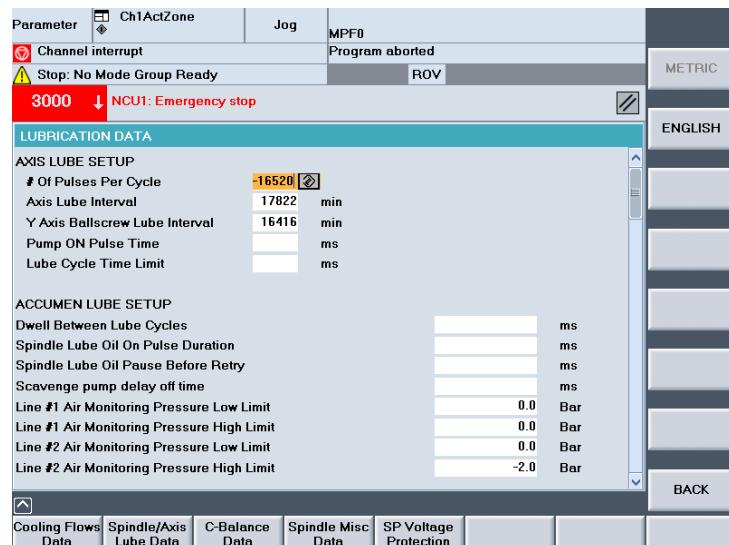
### 12.10.1 COOLING FLOWS DATA

The Axis Cooling Flows screen allows a knowledgeable user to set the motor cooling water flow parameters for the X, Y, C, A, and SP motors. The data can be entered in Metric or English units by selecting the appropriate vertical function key.



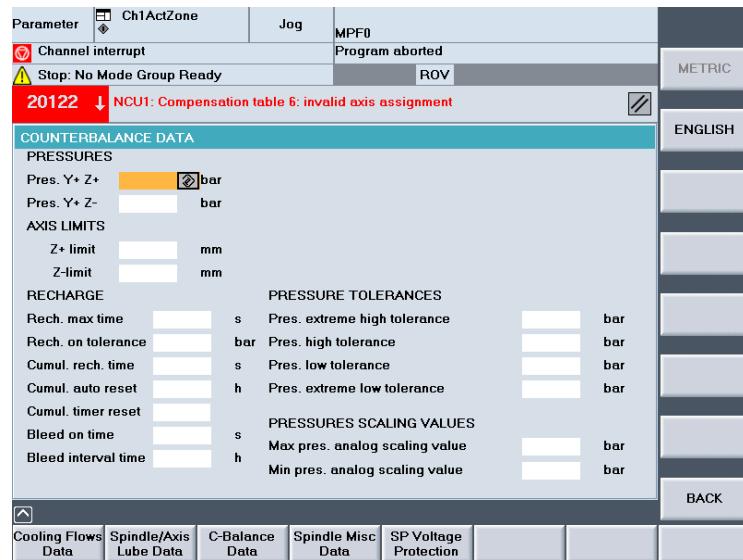
### 12.10.2 SPINDLE/AXIS LUBE DATA

The Lubrication Data screen allows a knowledgeable user to setup the axis lube cycles and the Acumen lube system for the spindle. The data can be entered in Metric or English units by selecting the appropriate vertical function key.



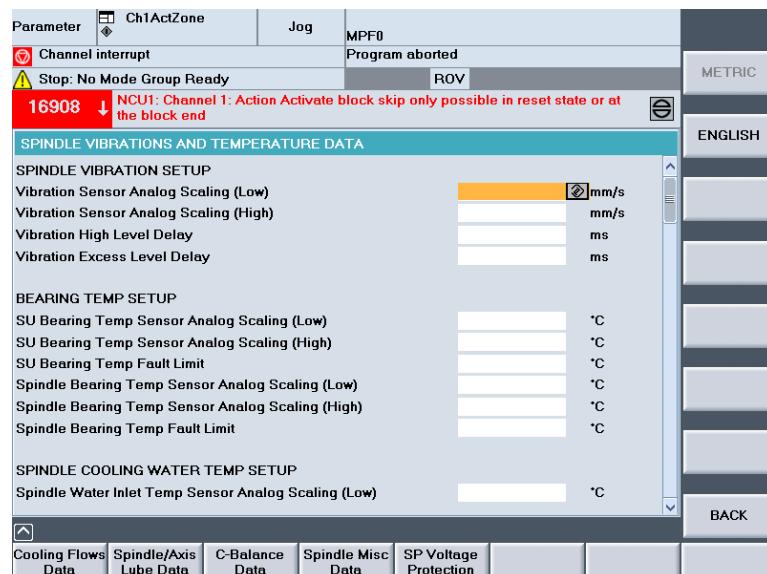
### 12.10.3 COUNTERBALANCE DATA

The Counterbalance Data screen allows a knowledgeable user to set parameters affecting the operation of the Z-axis counterbalance system. The data can be entered in Metric or English units by selecting the appropriate vertical function key.



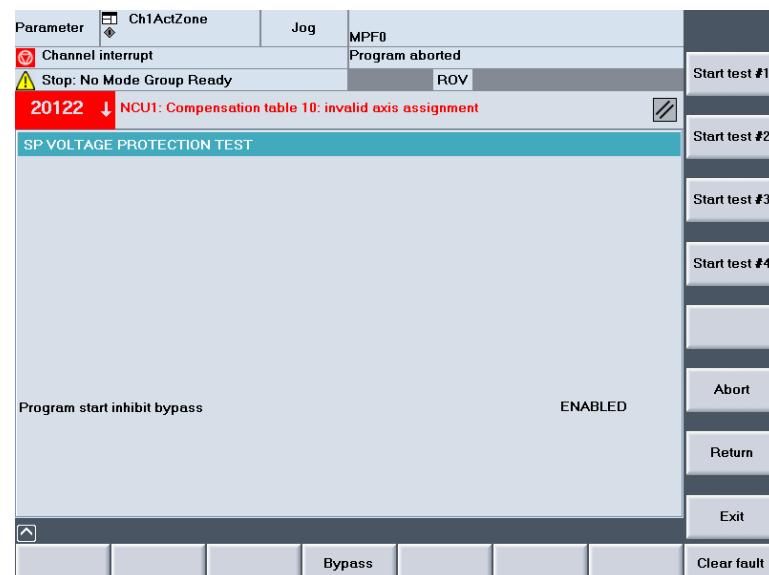
### 12.10.4 SPINDLE MISC. DATA

The Spindle Vibrations and Temperature Data screen allows a knowledgeable user to set up the spindle vibration monitoring, the bearing temperature systems, and the spindle cooling water monitoring. The data can be entered in Metric or English units by selecting the appropriate vertical function key.



### 12.10.5 SPINDLE VOLTAGE PROTECTION

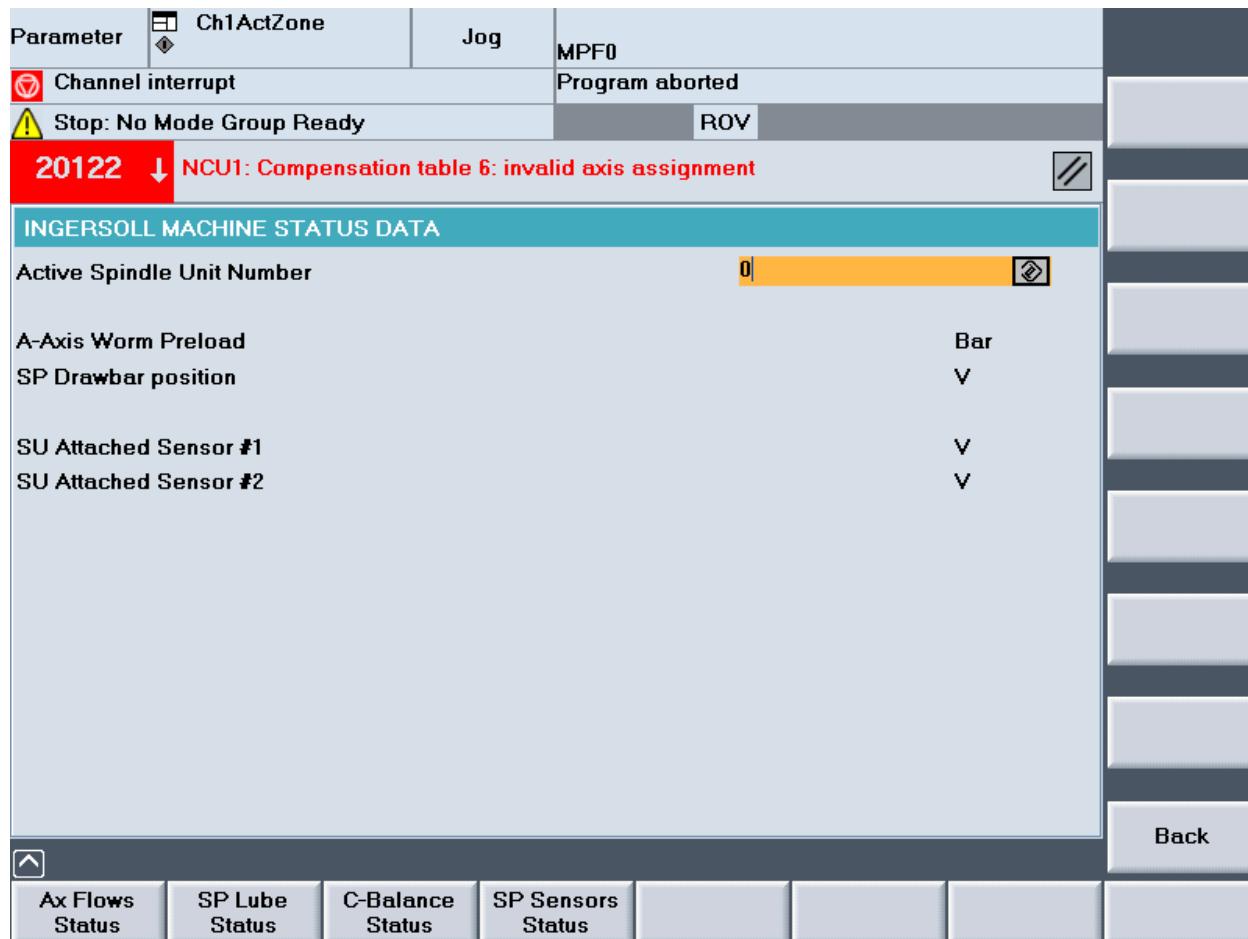
The Spindle Voltage Protection Test screen allows a knowledgeable user to conduct a spindle voltage protection test. An alarm message will be displayed notifying the operator when a protection test is required. The user then comes to this screen and follows instructions on the screen. See Spindle chapter in Maintenance manaul for more information.



## 12.11 MACHINE STATUS DATA

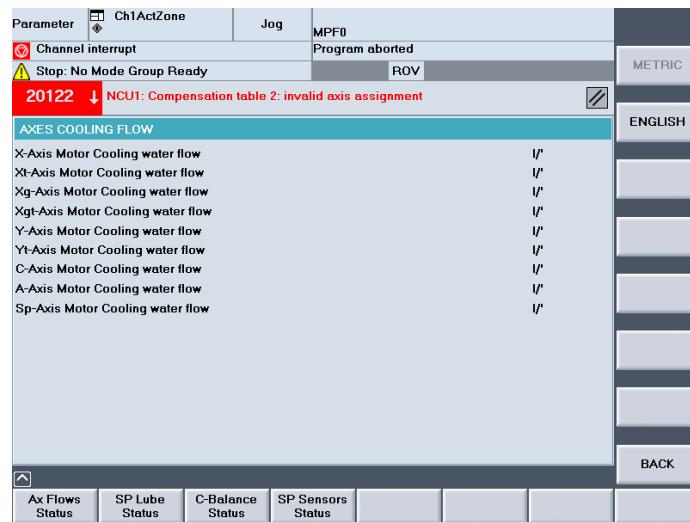
The Machine Status Data screen can be used by an operator to display the currently active machine status. The active spindle unit number is the SU that the PLC logic believes is currently mounted on the ram. This number should only be changed by a knowledgeable maintenance person to recover from a spindle unit change problem. All other data on this screen and the sub-screens are view only.

The horizontal function keys along the bottom of the screen are used to view the status of various subsystems on the machine.



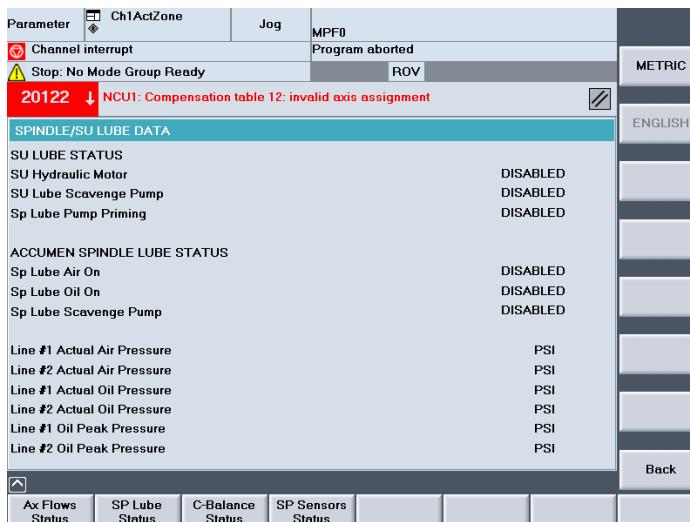
### 12.11.1 AXIS COOLING FLOW STATUS

The Axis Cooling Flows screen displays the status of the motor cooling water flow for the X, Y, C, A, and SP motors. The data can be displayed in Metric or English units by selecting the appropriate vertical function key.



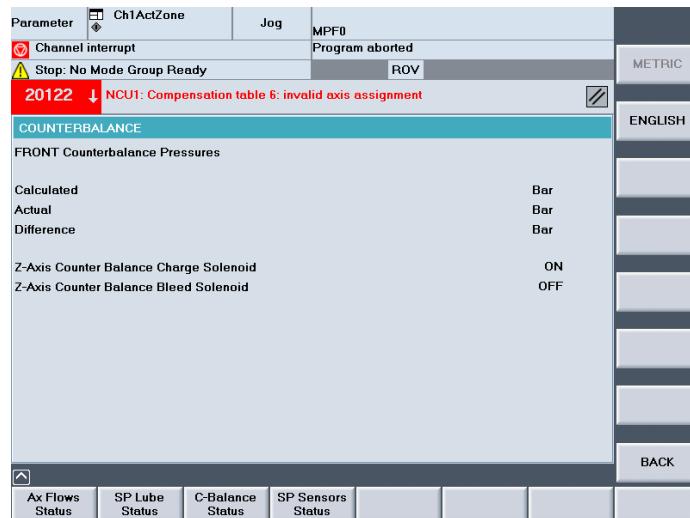
### 12.11.2 SPINDLE/SU LUBE STATUS SENSORS

The Spindle/SU Lube Data screen displays the status of the SU Lube motor and pumps, and the Acumen Spindle Lube system. The data can be displayed in Metric or English units by selecting the appropriate vertical function key.



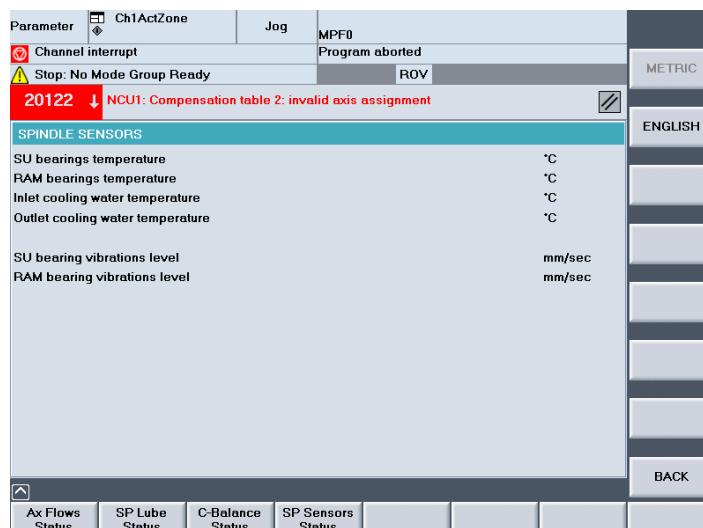
### 12.11.3 COUNTERBALANCE DATA

The Counterbalance Data screen displays the status of the counterbalance system for Z-axis. The data can be displayed in Metric or English units by selecting the appropriate vertical function key.



### 12.11.4 SPINDLE SENSORS

The Spindle Sensor Data screen displays the status of the spindle and ram bearing temperatures and spindle vibration sensors. The temperature sensors for the spindle cooling water are also displayed. The data can be displayed in Metric or English units by selecting the appropriate vertical function key.



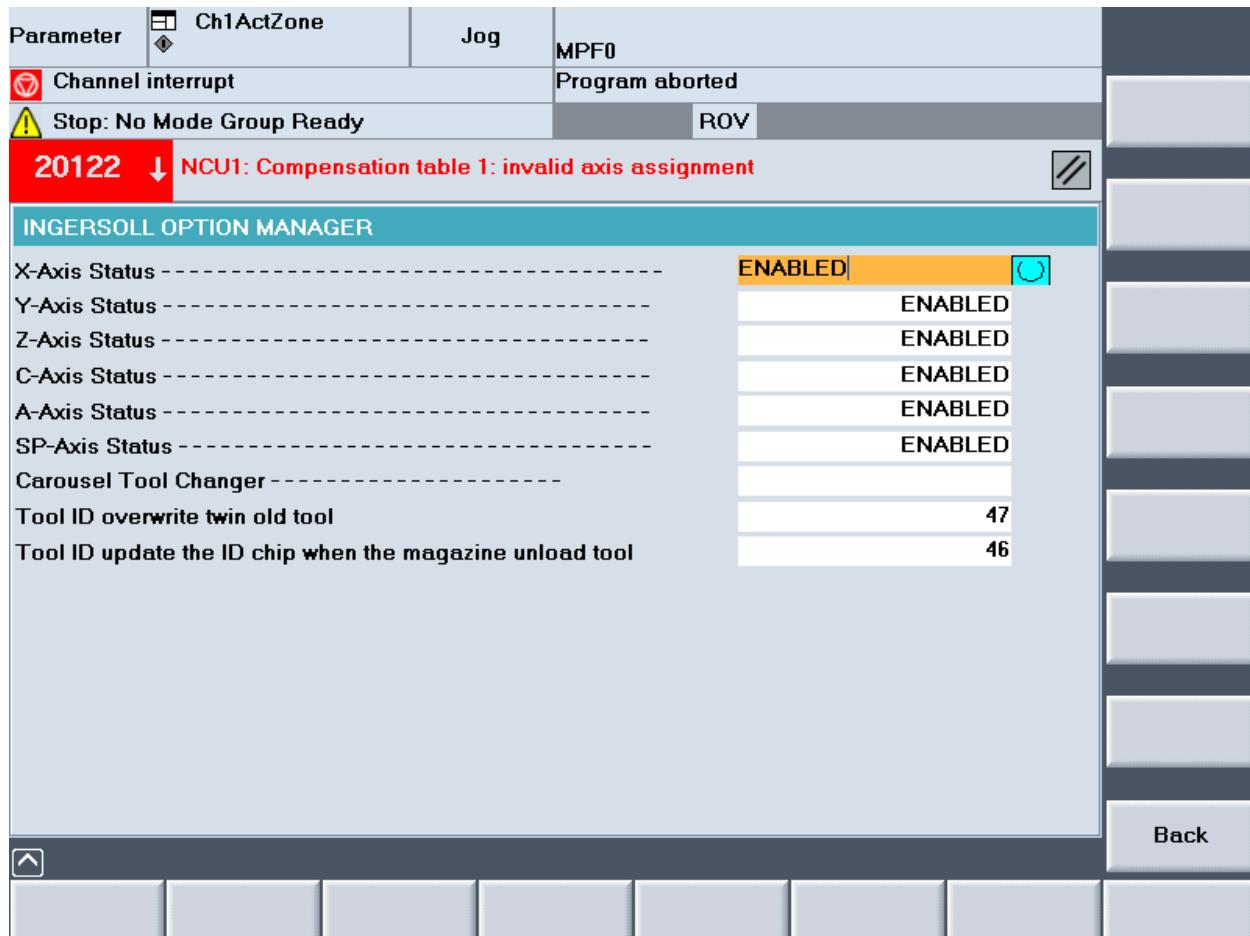
## 12.12OPTION MANAGER SCREEN

The Options Manager Screen is used by Ingersoll personnel to turn software options on and off for this machine. The options that are turned on are shown as ENABLED.

This screen allows any of the major machine axes to be enabled or disabled. If an axis is disabled, all commands to that axis will be ignored. The axis will not move when programmed.

If the Carousel Tool Changer is disabled, all tool changes must be done manually. The machine logic will not try to pick any tools from the tool magazine.

User the Back or ^ softkey to return to the previous screen or main menu respectively.



# **CHAPTER 13 - PROGRAMMING CODES**



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## **CHAPTER 13 - PROGRAMMING CODES**

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## 13.1 INTRODUCTION

The chapter is intended to list the programming codes used on this machine. For details on what each code does, please refer to the Operator's manual.

## 13.2 PROGRAM BLOCK FORMAT

Listed below are the formats for the words used in this control:

**NOTE: NOTE** A (+/-) sign preceding a number indicates the following value can either be a positive or a negative number. If no (-) negative sign is programmed, the control assumes the number is positive. The plus sign (+) does not need to be programmed. The numbers to the left and right of a decimal point represents the number of places available to the left and right of the decimal point for that code.

PROGRAM BLOCK FORMAT			
Letter	Inch	Metric	Description
x	$\pm 4.4$	$\pm 5.3$	Gantry Travel (Horizontal)
y	$\pm 4.4$	$\pm 5.3$	Head Saddle Travel (Horizontal)
z	$\pm 4.4$	$\pm 5.3$	Ram Travel (Vertical)
c	$\pm 3.3$	$\pm 3.3$	Head Rotation Travel (Rotary)
a	$\pm 3.3$	$\pm 3.3$	Spindle Unit Twist/Swivel Head Tilting (Rotary)
f	4.4	5.3	Feedrate
g	3	3	Preparatory Function
h	2	2	Auxiliary Function
i	$\pm 4.4$	$\pm 5.3$	X Axis Arc Center
j	$\pm 4.4$	$\pm 5.3$	Y Axis Arc Center
k	$\pm 4.4$	$\pm 5.3$	Z Axis Arc Center
l	4	4	Subprogram Repeat Count
m	3	3	Miscellaneous Code
n	5	5	Block Number
	24	24	Program Number (15 character name)
p	8	8	Number of Program Passes
s	4	4	Spindle Speed
t	8	8	Tool Number
/n			Optional Block Skip (/n: n=1-9)

### 13.3 PREPARATORY (G) CODES

Below is the list of preparatory codes for your machine. Please refer to the Siemens Programming Guide for additional details on formats and fundamentals of programming these G-codes.

**NOTE:** Group 00 indicates non-modal G-codes; all others are modal. An asterisk (\*) before the G-code value indicates the initial G-code. These G-codes are set active when the control is powered up or reset.

G-Code	Group	Function
G00	01	Rapid Traverse
* G01	01	Linear Interpolation
G02	01	Clockwise Circular Interpolation
G03	01	Counter-Clockwise Circular Interpolation
G04	00	Predefined Dwell Time
G09	11	Exact Stop
* G17	06	Plane Selection XY
G18	06	Plane Selection ZX
G19	06	Plane Selection YZ
G33	01	Thread Cutting with Constant Lead
G331	01	Tapping (rigid)
G332	01	Retraction (tapping)
* G40	07	No Tool Radius Compensation
G41	07	Tool Radius Compensation to Left of Contour
G42	07	Tool Radius Compensation to Right of Contour
G53	09	Suppression of current Zero Offset Frame
SUPA	09	Suppress all Offsets
G500	08	Deactivate all Settable G54-G57
G54	08	#1 Settable Zero Offset Frame
G55	08	#2 Settable Zero Offset Frame
G56	08	#3 Settable Zero Offset Frame
G57	08	#4 Settable Zero Offset Frame
G505-G599	08	#5-#99 Settable Zero Offset Frame
G60	10	Deceleration, Exact Stop Mode
* G64	10	Continuous Path Mode
G641	10	Continuous Path Mode with Programmable Approximate Distance
G601	12	Block Change On Exact Stop Fine
G602	12	Block Change On Exact Stop Coarse
G603	12	Block Change On IPO – End Of Block
G63	00	Tapping Without Synchronization
* G70	13	Input System Inch Mode (lengths)
G71	13	Input System Metric Mode (lengths)
* G700	13	Input System Inch Mode
G710	13	Input System Metric Mode

G-Code	Group	Function
G74	00	Reference Point Return
* G90	14	Absolute Dimensions
G91	14	Incremental Dimensions
G93	15	Inverse Time Feedrate
* G94	15	Linear Feedrate, Feed per Minute
G95	15	Revolutional Feedrate, Feed per Rotation
BRISK	21	Brisk (Linear) Path Acceleration
SOFT	21	Soft (Bell) Path Acceleration
DRIVE	21	Velocity Dependant Path Acceleration
TRANS	03	Programmable Translation
ATRANS	03	Additive Programmable Translation
ROT	03	Programmable Rotation
AROT	03	Additive Programmable Rotation
SCALE	03	Programmable Scale
ASCALE	03	Additive Programmable Scale
TRAORI	04	5 Axis Orientation Transformation
TRAFOOF	04	Switch Off Transformation
CUT3DC	22	3D Cutter Compensation - Circumference Milling
CUT3DCC	22	3D Cutter Comp. - Circumference Milling With Limit Surfaces
CUT3DCCD	22	3D Cutter Comp.-Circumference Milling With Limit Surfaces With Differential Tool
CUT3DF	22	3D Cutter Compensation - Face Milling
CUT3DFF	22	3D Cutter Comp. - Face Milling With Constant Tool Orientation
CUT3DFS	22	3D Cutter Comp. - Face Milling With Constant Tool Orientation Independent Of The Current Frame

## 13.4 MISCELLANEOUS CODES (M)

Group numbers indicate modal groups of M-codes and group 00 indicates non-modal M-codes.

**NOTE:** An asterisk (\*) before the M-Code value indicates the initial M-Code. These M-Codes are set active when the control is powered up or reset. A pound sign (#) before the M-Code value indicates the M-Code is used internally in the control or for manual operation.

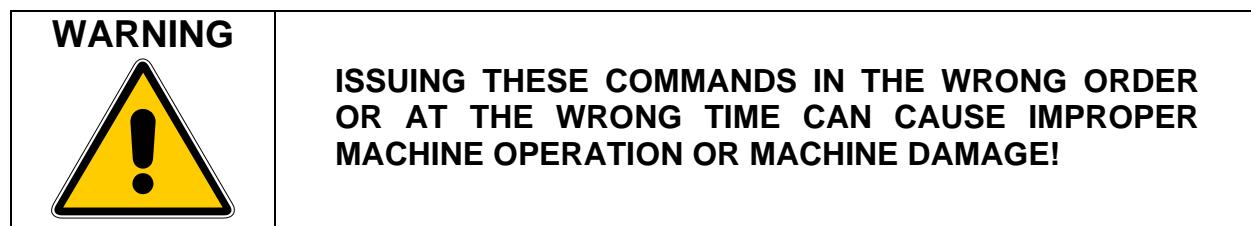
M-Code	Group	Function
M00		Program Stop, Unconditional
M01	01	Program Stop, Optional
* M02		Program End
M03		Start Spindle Clockwise
M04	02	Start Spindle Counter-clockwise
* M05		Stop Spindle
M06	00	Tool Change
* M09		Coolant Off
M10	03	External Coolant On
M11		Air Through Spindle
M12		Internal Coolant On
M17	00	End of Subprogram
SPOS (angle)	00	Spindle Orient
M30	01	End of Program
* M48	06	Cancel Feedrate Override Bypass
M49		Feedrate Override Bypass
M70	00	Activate Spindle Axis Mode
M72	07	Probe Enable (Probe Protect Off)
M73		Probe Disable (Probe Protect On)
M86	15	Clamp C-Axis
M87		Unclamp C-Axis
M88	16	Clamp A-Axis
M89		Unclamp A-Axis
M92 (#)	00	Recall Spindle Unit Data

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## 13.5 MAINTENANCE M AND H CODES

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Maintenance M and H codes are used to command auxiliary functions for tool changing, spindle unit changing, etc. These commands are not required for normal operations, but are used for recovery or maintenance operations.



H-CODE	FUNCTION
H15	Close Spindle Tool Gripper With Or Without Tool
H16	Open Spindle Tool Gripper
H17	Close Spindle Tool Gripper With Tool
H18	Close Spindle Tool Gripper Without Tool
H66	Open Ram SU Grippers
H67	Close Ram SU Grippers
M78	Detach A-Axis Drive
M79	Attach A-Axis Drive
M92(#)	Recall SU Data

CODE	NAME	DESCRIPTION
H15	CLOSE SPINDLE TOOL GRIPPER QUICKLY	This H code will cause the spindle tool grippers to close quickly, without expecting a tool in the spindle. If the sensors report a tool in the spindle, an alarm will be generated. This code only functions if an H36 Enable Tool Change Functions is active.
H16	CLOSE SPINDLE TOOL GRIPPER WITHOUT TOOL	This H code will cause the spindle tool grippers to close at a normal rate, without expecting a tool in the spindle. If the sensors report a tool in the spindle, an alarm will be generated. This code only functions if an H36 Enable Tool Change Functions is active.
H17	OPEN SPINDLE TOOL GRIPPER	This H code will cause the spindle tool grippers to open and release any tool they are holding. The user should be holding the tool before issuing this code. This code only functions if an H36 Enable Tool Change Functions is active.
H18	CLOSE SPINDLE TOOL GRIPPER WITH TOOL	This H code will cause the spindle tool grippers to close and expect a tool. If the sensors report no tool in the spindle, an alarm will be generated. This code only functions if an H36 Enable Tool Change Functions is active.
H66	OPEN RAM SU GRIPPERS	This H code will cause the spindle unit grippers in the ram to open and any spindle unit attached to the ram will come off. <b>This code should be issued with extreme caution!</b>
H67	CLOSE RAM SU GRIPPERS	This M code will close the spindle unit grippers in the ram.
M78	DETACH A-AXIS DRIVE	This code is used internally by Ingersoll logic to remove the A-axis drive from the control system. With this code active, no A-axis motion can occur. This code is output during a spindle unit change cycle for spindle units that have an A-axis.
M79	ATTACH A-AXIS DRIVE	This code is used internally by Ingersoll logic to attach the A-axis drive to the control system. This code is output during a spindle unit change cycle for spindle units that have an A-axis.
M92(#)	RECALL SU DATA	This code allows the operator to recall spindle unit data for the spindle unit that is permanently mounted on the ram. The spindle unit characteristics can be manually modified in the custom spindle unit screens on the CNC and then the data can be activated using a M92(#), where # is the spindle unit number as entered in the CNC spindle unit table.

## 13.6 SUBROUTINES

Ingersoll supplies custom subroutines for your machine. Subroutines (also called subprograms or macros) contain sequences of operations that are to be performed many times. A subroutine has the same structure as a part program.

These subroutines are stored in the Siemens CNC's part program memory. Ingersoll subroutines should not be deleted, as the machine will not function properly without them. The customer should maintain a backup of these subroutines in case of CNC memory loss.

Ingersoll supplies the following subroutines with this machine within the three folders shown below.

\CST = Standard canned cycles and measuring cycles

\CUS = user cycles for tool laser and part probe

\CMA = Ingersoll machine specific cycles (non-programmable cycles)

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
\CST	CYC3D81.SPF	Drilling Cycle	Ingersoll 3D canned cycles. See previous section for details.
	CYC3D82.SPF	Drill/Counter Bore Canned Cycle	
	CYC3D83.SPF	Peck Drill Canned Cycle	
	CYC3D84.SPF	Rigid Tap Canned Cycle	
	CYC3D840.SPF	Floating Tap Cycle	
	CYC3D85.SPF	Bore Canned Cycle (no spindle stop, no dwell, feed return)	
	CYC3D86.SPF	Bore Canned Cycle (spindle stop, no dwell, rapid return)	
	CYC3D87.SPF	Bore Canned Cycle (spindle stop, no dwell, manual return)	
	CYC3D88.SPF	Bore Canned Cycle (spindle stop, dwell, manual return)	
	CYC3D89.SPF	Bore Canned Cycle (no spindle stop, dwell, feed return)	
CYC3D90.SPF	Thread Milling		
CYCLE100.SPF	Log ON	Siemens measuring cycles. Refer to Siemens 840D Measuring Cycles Programming Manual for details.	
CYCLE101.SPF	Log OFF		
CYCLE102.SPF	Measurement result display selection		
CYCLE103.SPF	Pre-assignment of input data		
CYCLE104.SPF	Internal subroutine: Measuring cycle interface		
CYCLE105.SPF	Generate log contents: Log		
CYCLE106.SPF	Logging the sequential controller Log		
CYCLE109.SPF	Internal subroutine: Data transfer		

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
	CYCLE110.SPF	Internal subroutine: Plausibility checks	
	CYCLE111.SPF	Internal subroutine: Measuring functions	
	CYCLE112.SPF	Internal subroutine: Measuring functions	
	CYCLE113.SPF	Read system date and time Log	
	CYCLE114.SPF	Internal subroutine (tool offset)	
	CYCLE115.SPF	Internal subroutine (Z0 compensation)	
	CYCLE116.SPF	Calculation of center point and radius of a circle	
	CYCLE117.SPF	Internal subroutine: Measuring functions	
	CYCLE118.SPF	Format real values: Log	
	CYCLE119.SPF	Arithmetic cycle for determining position in space	
	CYCLE60.SPF	Engraving Cycle	
	CYCLE81.SPF	Drilling Cycle	
	CYCLE82.SPF	Drill/Counter Bore Canned Cycle	
	CYCLE83.SPF	Peck Drill Canned Cycle	
	CYCLE832.SPF	High Speed Settings	
	CYCLE84.SPF	Rigid Tap Canned Cycle	
	CYCLE840.SPF	Floating Tap Cycle	
	CYCLE85.SPF	Bore Canned Cycle (no spindle stop, no dwell, feed return)	Siemens standard cycles
	CYCLE86.SPF	Bore Canned Cycle (spindle stop, no dwell, rapid return)	
	CYCLE87.SPF	Bore Canned Cycle (spindle stop, no dwell, manual return)	
	CYCLE90.SPF	Thread Milling	
	CYCLE961.SPF	Workpiece: Setup inside and outside corner	
	CYCLE971.SPF	Tool measurement for milling tools, calibrate tool probe	Siemens measuring cycles. Refer to Siemens 840D Measuring Cycles Programming Manual for details.
	CYCLE976.SPF	Calibrate workpiece probe in a hole or on a surface	
	CYCLE977.SPF	Workpiece: Paraxial measurement of hole, shaft, groove, web or Z0 calculation	
	CYCLE978.SPF	Workpiece: 1-point measurement or Z0 determination on surface	
	CYCLE979.SPF	Workpiece: Measurement of hole, shaft, groove, web, or Z0 determination at an angle	
	CYCLE996.SPF	Workpiece: Measure kinematics (from measuring cycles	

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
	CYCLE997.SPF	Workpiece: Measuring spheres or Z0 determination	
	CYCLE998.SPF	Workpiece: Angle measurement (Z0 determination only)	
	CYC_JM.SPF	Auxiliary cycle for measuring	
	CYC_JMA.SPF	Aux. cycle for activation	
	CYC_JMC.SPF	Aux. cycle for calculation	
	E_MS_CAL.SPF	For calibrating a workpiece measuring probe	
	E_MS_CAN.SPF	To measure a corner	
	E_MS_HOL.SPF	To measure a hole	
	E_MS_PIN.SPF	To measure a spigot/shaft	
	E_MS_POC.SPF	To measure a rectangular pocket	
	E_MS_SPI.SPF	To measure a rectangular spigot	
	E_MT_CAL.SPF	For calibrating a tool measuring probe	
	E_MT_LEN.SPF	For length measurement of a tool	
	E_MT_RAD.SPF	For radius measurement of a tool	
	FINISH_3.SPF	3-axis Floor finishing	Ingersoll cycles
	FINISH_5.SPF	Side finishing	
	HCOFF.SPF	Head Compensation Off	
	HCON.SPF	Head Compensation On	
	LONGHOLE.SPF	Milling pattern of elongated holes on a circle	Siemens Milling cycles.
	POCKET1.SPF	Rectangular pocket milling (with face cutter)	
	POCKET2.SPF	Circular pocket milling (with face cutter)	
	POCKET3.SPF	Rectangular pocket milling (with any milling tool)	
	POCKET4.SPF	Circular pocket milling (with any milling tool)	
\CUS	BEAM_ALIGN.SPF	This tool setting calibration program checks the alignment of beam and updates R1, R2, R3. This program requires Manual position of Head close to the beam.	Ingersoll supplied routines that call Renishaw tool laser cycles.
\CUS	BRK_LEN.SPF	This tool setting cycle checks for a broken tool or long tool.	
\CUS	BRK_RAD.SPF	This program checks current tool length in the spindle and stops program if broken tool is detected.	
\CUS	CALIB_RG.SPF	Calibration in X and Y on a ring gauge. Must call traori and activate a work offset.	

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
	CALIB_TOOL.SPF	This tool setting calibration program calibrates a tool with known length. Calls REN_SU_CAL to save calibration data for a head.	
	CALIB_Z.SPF	Calibrate in the Z probe direction on a known surface. Must call traori and activate a work offset.	
	CHK_EDGE.SPF	This tool setting cycle checks for missing edge.	
	CHK_LEN.SPF	This tool setting cycle modifies the length of a tool.	
	CHK_LIN_PRF.SPF	This tool setting cycle checks the linear profile of a cutter.	
	CHK_RAD.SPF	This tool setting cycle modifies the radius of a tool.	
	CHK_RAD_PRF.SPF	This tool setting cycle checks the radius profile of a cutter.	
	HOLE.SPF	This routine probe the diameter of a hole.	
	L9700.SPF	General Renishaw error message	
	L9701.SPF	Error message in English	
	L9760.SPF	This tool setting internal subroutine is a Renishaw routine modified to read Laser setting data from REN_SU_SETUP to define the laser directions & defaults for a machine.	
	L9761.SPF	Used for start-up functions.	
	L9762.SPF	Measure move subroutine	
	L9763.SPF	Used for the MEAS (G31) routine	
	L9764.SPF	Used for the G0/G1 routine.	
	L9765.SPF	Used for the G2/G3 routine.	
	L9766.SPF	Used for radial scanning	
	L9767.SPF	Used for MEAS (G31) moves in subroutine L9766.	
	L9768.SPF	Used for RPM check	
	L9769.SPF	Used for error messages	
	L9800.SPF	Clears the global 'R' parameters used for subroutine input data	
	L9860.SPF	Aligning the beam	
	L9861.SPF	Calibrating the system	
	L9862.SPF	Tool length setting	
	L9863.SPF	Broken tool detection	
	L9864.SPF	Broken tool radial	
	L9865.SPF	Cutter radius and linear profile checking	
	L9866.SPF	Broken tool detection for solid tools	
	PRB_Z_NEG.SPF	Probes a point in the -Z direction.	Ingersoll supplied

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
	REN_STRT.SPF	Internal routine to define initial motion for SU before starting any Renishaw tool probe cycle	routines that call Renishaw tool laser cycles.
	REN_SU_CAL.SPF	This tool setting internal subroutine creates REN_SU_CAL_SU#, which stores the calibration data for any head. (ActiveSUNum).	
	REN_SU_CAL_1.SPF	Stores the calibration data for head #1.	
	REN_SU_SETUP.SPF	This tool setting internal subroutine retrieves Renishaw GUD data and is internally called before calling any measuring cycle. The “*” in the file name will be replaced by a head number, and there will one subprogram for each head that has been calibrated for tool setting.	
	SHAFT.SPF	Probe shaft for diameter at a given depth.	
\CMA	8_24_10_R_VARS.SPF	Example output of subroutine PinrtRVars.	Ingersoll developed routines. Non-programmable (MDA use only).
	CLAMPA.SPF	This routine clamps A-axis.	
	DISABLE_DRYRUN.SPF	This routine disables dry run mode.	
	ENABLE_DRYRUN.SPF	This routine enable dry run mode.	
	MOVEZANDW.SPF	Used internally to move Z-axis during tool change.	
	ORI_INIT.SPF	Used to initialize spindle orient.	
	ORI_SPDUP.SPF	This routine is used to speed up spindle orient.	
	PRINTRVARS.SPF	Writes a file with every R variable from R1 to R999 with a file name of for example: 8_24_10_R_VARS.SPF	
	PROG_EVENT.SPF	This subroutine will run on power-up, program start, program end, and reset to initialize system variables.	
	RESTOREGEAR.SPF	This routine restores the active spindle unit gear ratio.	
	RETARM.SPF	This routine is used to move the tool changer arm back to the magazine.	
	RETMACH.SPF	This routine allows the machine to move away from tool change position.	

FOLDER	SUBROUTINE	DESCRIPTION	INFORMATION
	RETMAG.SPF	This routine is used to move the tool changer arm back to the magazine and leave the arm disabled.	
	SPDL_TEST.SPF	This routine is used to periodically test the Spindle Voltage Protection Modules.	
	SUCMAIN.SPF	This routine determines the need for requesting spindle unit data and for performing any spindle unit change operations.	
	TCCAROUSEL.SPF	This routine does an automatic tool change from the tool carousel.	
	TCMAIN.SPF	This routine determines the need for requesting tool data and for performing any tool change operations on the machine.	
	TCMANUAL.SPF	This routine does a manual tool change.	
	TMAGEEXEC.SPF	This routine is used internally by the tool change cycles to execute individual tool magazine functions.	
	TMAGMFUNCT.SPF	This routine can be used by Maintenance to issue an individual tool magazine arm and gripper functions.	
	TOOLMAGAZINE HEADMATCH.SPF	Check if the spindle can exchange tool with a particular magazine.	
	TOOLSHANK HEADMATCH.SPF	Check if the spindle can accept a particular tool shank.	
	TOOL_SEARCH.SPF	Allows an operator to search for a tool and display its pocket number in the machine by entering the tool number and duplo number. Example: Tool_search("123456", 1)	
	UNCLAMPA.SPF	This routine is used to unclamp A-axis.	

# **CHAPTER 14 - PLC LOGIC**



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## CHAPTER 14 - PLC LOGIC

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## 14.1 INTRODUCTION

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The *PLC (Programmable Logic Control)* is a Siemens Simatic 317 CPU running Step 7 software to control all the devices on the machine. The PLC communicates to the CNC and the customer's plant system.

With Step 7 programming, software can be created using Ladder Logic (LAD), Statement List (STL), or Function Block Diagram (FBD) languages. Ingersoll typically uses Ladder Logic, although the end user can select the other types if desired.

Ingersoll provides the machine's Step 7 logic on a CD for the customer's reference. The Step 7 software includes a Symbol List that lists all the symbols used, the PLC addresses, their data type, and their descriptions. The addresses are listed in alphabetical order.

Material discussed in this section is intended to briefly explain some of the PLC features, instruction sets, addressing and communication to the CNC. The electrical circuitry or the PLC logic may not match your schematics. For more information, please refer to the Siemens manuals on Simatic Step 7 and Maintenance of the 840D CNC. When troubleshooting machine problems, always refer to your electrical schematics and the latest version of the PLC logic loaded into your Siemens control.

## 14.2 PLC ADDRESSES

Listed below are the addresses used in the PLC ladder logic.

Address ID	Parameter Ranges	Description
<b>Q</b>	0.0 to 2047.7	Output bit
<b>QB</b>	0 to 2047	Output byte
<b>QW</b>	0 to 2046	Output word
<b>QD</b>	0 to 2044	Output double word
<b>B</b>	—	Byte with general register-indirect addressing
<b>W</b>	—	Word with general register-indirect addressing
<b>D</b>	—	Double word with general register-indirect addressing
<b>DBX</b>	0.0 to 65533.7	Data bit in data block
<b>DB</b>	0 to 2047	Data block
<b>DBB</b>	0 to 65533	Data byte in DB
<b>DBW</b>	0 to 65532	Data word in DB
<b>DBD</b>	0 to 65530	Data double word in DB
<b>DIX</b>	0.0 to 65533.7	Data bit in instance DB
<b>DI</b>	1 to 2047	Instance data block
<b>DIB</b>	0 to 65533	Data byte in instance DB
<b>DIW</b>	0 to 65532	Data word in instance DB
<b>DID</b>	0 to 65530	Data double word in instance DB
<b>I</b>	0.0 to 2047.7	Input bit
<b>IB</b>	0 to 2047	Input byte
<b>IW</b>	0 to 2046	Input word
<b>ID</b>	0 to 2044	Input double word
<b>L</b>	0.0 to 8191.7	Local data bit
<b>LB</b>	0 to 8191	Local data byte
<b>LW</b>	0 to 8190	Local data word
<b>LD</b>	0 to 8188	Local data double word
<b>M</b>	0.0 to 1023.0	Bit memory bit
<b>MB</b>	0 to 1023	Bit memory byte
<b>MW</b>	0 to 1022	Bit memory word
<b>MD</b>	0 to 1020	Bit memory double word
<b>PQB</b>	0 to 8191	Peripheral output byte (direct I/O access)
<b>PQW</b>	0 to 8190	Peripheral output word (direct I/O access)
<b>PQD</b>	0 to 8188	Peripheral output double word (direct I/O access)
<b>PIB</b>	0 to 8191	Peripheral input byte (direct I/O access)
<b>PIW</b>	0 to 8190	Peripheral input word (direct I/O access)
<b>PID</b>	0 to 8188	Peripheral input (direct I/O access)
<b>T</b>	0 to 511	Timer
<b>Z</b>	0 to 511	Counter
<b>B#16# W#16# DW#16#</b>		Instruction addressed via parameter
<b>D#</b>		Byte Word Double word hexadecimal
<b>L#</b>		32-bit integer constant
<b>P#</b>		Pointer constant
<b>S5T#</b>		S5 time constant (16 bits) for loading of S5 timers
<b>T#</b>	1	Time constant (16/32 bits)
<b>TOD#</b>		IEC time constant
<b>C#</b>		Counter constant (BCD-coding)
<b>2#</b>		Binary constant
<b>B (b1,b2) B (b1,b2,b3,b4)</b>		Constant, 2 or 4 Byte

### 14.2.1 SIEMENS ADDRESS FORMAT

The Siemens control uses the following format to specify an input and output address and bit.



Example: Q70.1

### 14.2.2 EIGHT BITS PER ADDRESS LETTER

Each address listed in the previous paragraph has eight bits (7 - 0). Shown in the table below are the eight bits for sample address Q27 and I82. It can be noticed that bits 7, 3, 1 and 0 are TRUE (1), all other bits are FALSE (0) in address Q27. Bits 6, 5, 4, and 0 in address I82 are TRUE.

PLC ADDRESSES vs BINARY BITS								
ADDRESS	BINARY BITS							
	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
	7	6	5	4	3	2	1	0
Q27	1	0	0	0	1	0	1	1
I82	0	1	1	1	0	0	0	1

The bits can be applied to the following Siemens format:

#### ADDRESS Q27

Q27.0 = 1
Q27.1 = 1
Q27.2 = 0
Q27.3 = 1
Q27.4 = 0
Q27.5 = 0
Q27.6 = 0
Q27.7 = 1

#### ADDRESS I82

I14.0 = 1
I14.1 = 0
I14.2 = 0
I14.3 = 0
I14.4 = 1
I14.5 = 1
I14.6 = 1
I14.7 = 0

## 14.3 PLC ADDRESS DISPLAY

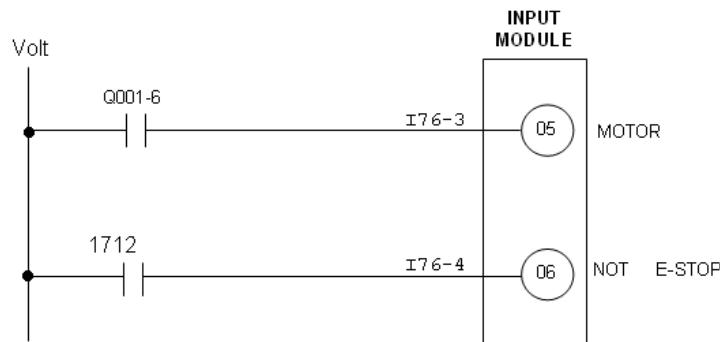
To display the status of any PLC address on the Siemens CNC, the PLC Diagnostic screen can be viewed. To display this screen:

1. On the Siemens CNC monitor, press the “*Menu Select*” key 
2. Select the horizontal softkey “*Diagnosis*”.
3. Select the menu headed “*PLC Status*”.
4. Enter the desired address to display.

### 14.3.1 INPUT ADDRESSES (I0 – I2047)

The state of the machine's input devices (limit, pushbutton, selector, proximity, float, and thermal switches etc.) are transferred to the Siemens CNC through addresses I0 – I2047 with bit numbers 0 to 7. Refer to the Ingersoll electrical schematics.

#### ELECTRICAL DIAGRAM:



#### PLC LOGIC DIAGRAM:



TYPICAL ELECTRICAL & PLC LOGIC

The previous image shows a typical electrical (top) and PLC logic diagram. If either contact Q001-6 or 1712 CRM is closed, voltage is applied to the two Siemens input module terminals. In the PLC logic diagram above, if either of the instructions I76.3 or I76.4 detect that voltage is applied, the PLC will open a path to their respective output (M8.1 and M8.7) to prevent an alarm message from being generated.

However, should one of these electrical contacts (Q001.6 N or 1712 CRM) open, inputs

I76.3 or I76.4 in the PLC circuit will detect a fault condition and in turn will set the respective alarm message.

The *NOT E-STOP REQ* description beside input I76.4 means if voltage is applied to this input, the machine hardware has not set an emergency stop.

#### 14.3.2 OUTPUT ADDRESSES (Q0 - Q2047)

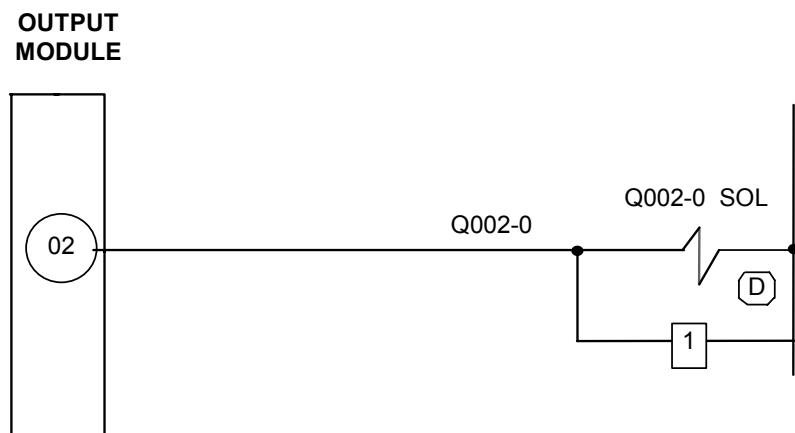
There are 2048 outputs (with bits 0 - 7) available to provide voltage to the machine magnetics. Siemens CNC uses addresses Q0 – Q2047. Refer to the Ingersoll Electrical Schematics and Interconnect Drawings for this machine to determine which outputs are being used on this machine.

The general PLC diagram (shown below) will energize output Q002.0 in order to start the flood coolant. If the all the input elements are *WHITE*, a continuous path is provided to output Q002.0. The output is set on the next I/O up date sequence.

#### PLC LOGIC DIAGRAM:

CLT_MMC M4.5	M08 M21.0	M09 M21.2	CLTON -----( )-----	Q0002.0
----]	[-----]	[-----]	/ [-----	-----]

#### ELECTRICAL DIAGRAM:



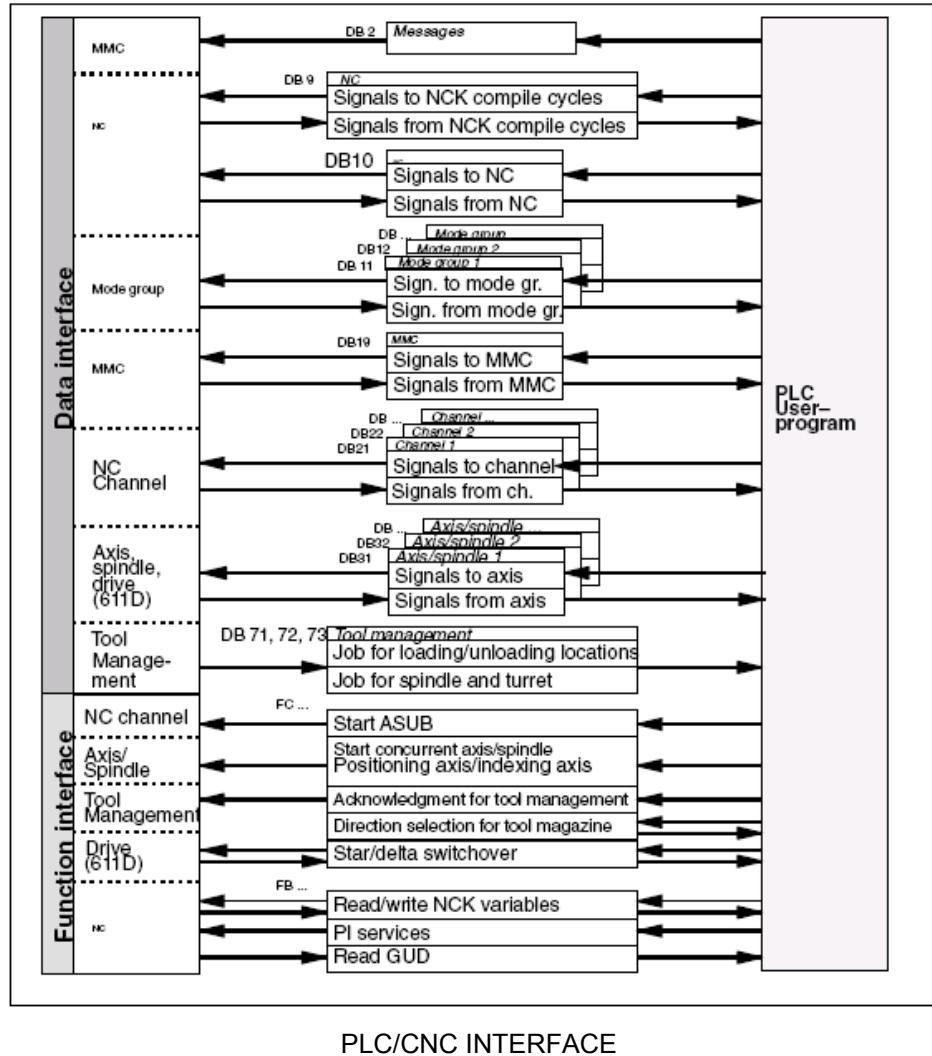
FLOOD COOLANT ON

The previous electrical diagram shows output Q002.0 to energize Q002-0 solenoid valve. When the output is set, the solenoid valve will provide flood coolant to the machine.

## 14.4 COMMUNICATION BETWEEN CNC AND PLC

The CNC and PLC are two individual computers that work independently from one another to monitor and control the machine. The CNC computer is used to handle the axes servo systems, part program execution, MDA program blocks, display machine position, just to mention a few of its functions. The PLC handles the logic.

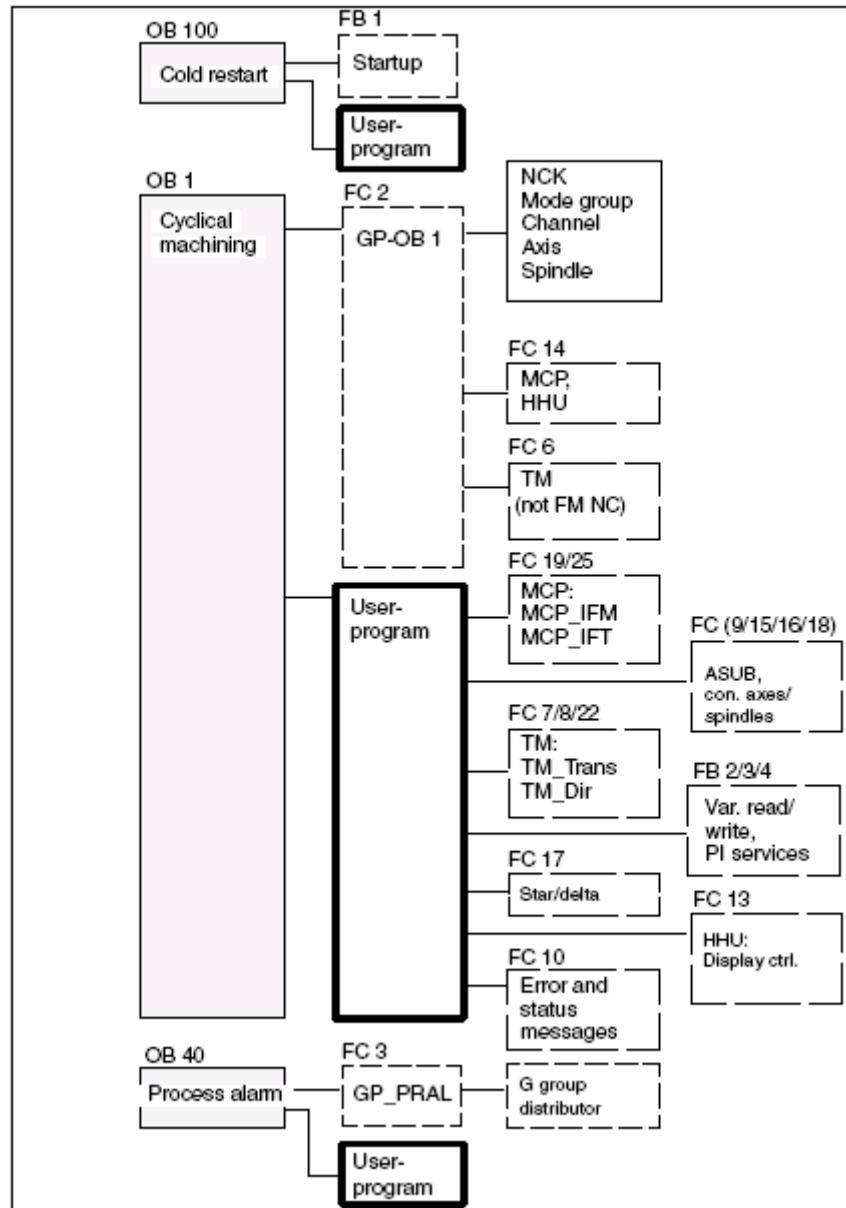
The CNC and PLC must be able to pass data to each other to jointly control the machine. The Siemens controller has provided a data interface and a function interface to transfer communication signals between the CNC and the PLC (refer to the figure below).



## 14.5 PLC LOGIC STRUCTURE

The logic program is modular in design, consisting of organization blocks (OB), function blocks (FB), functions (FC) and other modules. In the operating system, a distinction is made between the following levels of execution:

- Startup and synchronization (OB 100)
- Cyclical mode (OB 1)
- Process interrupt handling (OB 40)



PLC LOGIC STRUCTURE

#### 14.5.1 STARTUP AND SYNCHRONIZATION (OB 100)

The synchronization of the CNC and PLC is performed during startup. The system and user data blocks are checked for integrity and the most important basic program parameters are verified for plausibility. In cases of error, the basic program outputs an error identifier to the diagnostics buffer and switches the PLC to STOP.

A warm restart is not provided, i.e. following system initialization, the operating system runs organization block OB 100 and always commences cyclical execution at the start of OB 1.

#### 14.5.2 CYCLICAL MACHINING (OB 1)

The following functions are performed in the cyclical part of the basic program:

- Transmission of the control/status signals
- Distribution of the auxiliary and G functions
- M decoding (M00-99)
- M, S, F distribution
- Transmission of the machine control panel signals via the CNC
- Acquisition and conditioning of the user errors and operating messages

#### 14.5.3 PROCESS ALARM PROCESSING (OB 40)

A process alarm OB 40 (interrupt) can, for example, be triggered by appropriate configure I/Os or by certain NC functions. Due to the different origin of the interrupt, the PLC user program must first interpret the cause of the interrupt in OB 40. The cause of the interrupt is included in the local data of OB 40.

## **CHAPTER 15 - E-STOP, INTERLOCKS, AND ALARMS**



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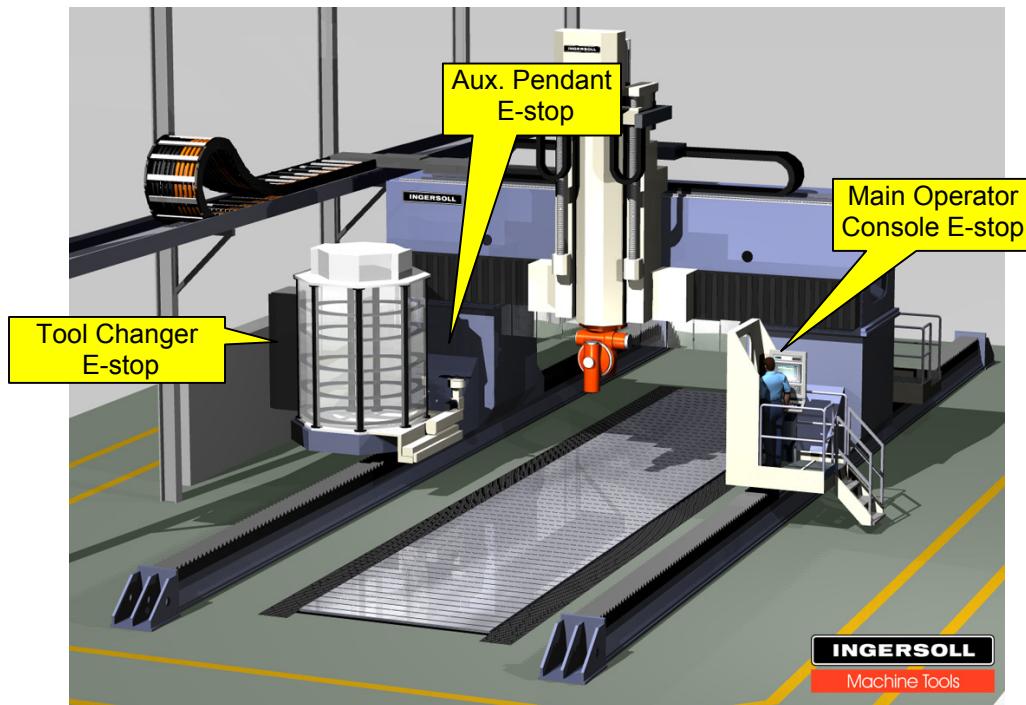


## 15.1 EMERGENCY STOP

Emergency stop (E-Stop) can be activated by either hardware or logic. Hardware is a physical device that can range from an axis overtravel limit switch to a component in the Siemens control. Instead of having hard-wired relays detecting E-Stops, PLC logic monitors counters, timers, switches and indicator lights. When hardware or software detects a fault, an alarm is displayed and the machine can be stopped. Siemens logic sends an E-Stop Request to the CNC when one of these pushbuttons is pressed, and the CNC stops all axes motion and exits the active part program.

### 15.1.1 E-STOP DEVICE LOCATION

Typical E-stop pushbutton locations are at the main operator console, auxiliary pendant(s) and the tool load/unload station. The figure below shows emergency stop pushbutton locations. Siemens logic sends an E-Stop Request to the CNC when one of these pushbuttons is pressed, and the CNC stops all axes motion and exits the active part program.



E-STOP DEVICE LOCATIONS

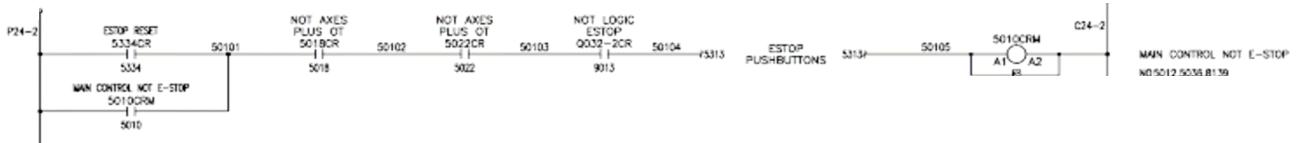
### 15.1.2 PUSHBUTTONS

All of the emergency stop pushbuttons are red in color with a mushroom-style head and a light within. Once pressed, the emergency stop condition is locked in at that location,

preventing it from being reset at another location, until that button is manually twisted counter-clockwise and pulled out (some buttons may spring-out instead of having to be pulled out once turned counter-clockwise).

### 15.1.3 HARDWARE E-STOP

There is one **Main Control Estop String** found in the Ingersoll Electrical Schematics, controlling a relay CRM.



TYPICAL ESTOP STRING

When the CRM is energized an output voltage feeds through the E-Stop String to the main control relay. The control relay CRM will de-energize if:

- One of the machine axes has moved past its plus or minus over-travel.
- An emergency stop push-button is depressed.
- The PLC has activated an e-stop request.

### 15.1.4 LOGIC E-STOP

One of the contacts in the Main Control E-Stop String is controlled by the logic in the PLC. If the software detects an E-stop, the PLC sends a signal to energize the control relay and open the Not CNC E-Stop contact in the E-stop string. When the CR is de-energized, the CRM contact opens, power is removed from the input and the input signal going to the PLC logic is active. This input is an *ACTIVE LOW* bit where voltage to the input must be applied to prevent an E-Stop.

### 15.1.5 AXIS OVER TRAVELS

The main axes on this machine are equipped with over-travel switches at each end of their motions.

The intention of the axis over-travel limit switches is to provide protection for the machine, part, and personnel from problems that can occur when an axis travels beyond its established limits. For this reason, these switches are connected to the emergency stop string. If any of these switches are tripped, the machine enters an emergency stop in which all axis motion ceases, preventing the offending axis from moving further past its limit. This axis must then be manually jogged out of the over travel position (temporarily bypassing emergency stop) before the emergency stop can be reset.

### 15.1.6 DEVICES AFFECTED BY EMERGENCY STOP

Most devices on the machine are disabled as a direct result of an emergency stop. All devices that generate movement on the machine are immediately stopped. The following list shows the devices disabled by an emergency stop.

- All Servo Drives
- Most Siemens controller outputs

Servo drives are disabled in a controlled fashion, keeping the drives active to allow regenerative braking to occur then engaging the mechanical brakes of the system.

### 15.1.7 DEVICES BYPASSING EMERGENCY STOP

Ideally all devices would be disabled as a result of an emergency stop but this is not practical because some devices must continue operation for safety or functional requirements. Listed below are all of the devices on this machine **not** affected by emergency stop with an explanation for the exceptions that accompany each device.

#### 15.1.7.1 CABINET LIGHTS

All lights in the electrical cabinets remain active during an emergency stop. These lights present no danger to the machine or to personnel, and are useful when investigating the cause of the emergency stop.

#### 15.1.7.2 INDICATION LIGHTS

All indication lights on the various operator stations remain active during an emergency stop. These lights present no danger to the machine or to personnel, and the information displayed may prove useful when investigating the cause of the emergency stop.

#### 15.1.7.3 SIEMENS MACHINE CONTROLLER

The Siemens controller remains active during an emergency stop, processing the machine's I/O but suspending execution of the automatic part program. This maintains a controlled state of the machine and generates fault messages when diagnosing machine problems.

#### 15.1.7.4 CABINET AIR CONDITIONERS AND AXIS MOTOR FANS/CHILLER

The cooling devices, such as the air conditioners for the control cabinets and the axis motor fans remain on during e-stop to help cool the systems. Motor or cabinet overheating can generate an e-stop condition and leaving the cooling devices on will help dissipate any heat build-up.

#### 15.1.7.5 HYDRAULIC PUMP MOTOR AND SPINDLE LUBE CONTROLLER

During e-stop, power remains applied to the spindle lubrication controller and hydraulic pump motor.

### 15.1.8 ESTOP INPUTS & OUTPUTS

ESTOP INPUTS/OUTPUTS	
NAME	ADDRESS
MAIN CONTROL NOT E-STOP	I043-2
TOOL CHANGER E-STOP PRESSED	I061-4
AUXILIARY PENDANT NOT E-STOP	I061-7
E-STOP RESET	I090-2
OPERATORS CONSOLE E-STOP PRESSED	I090-4
NOT CNC E-STOP REQUEST	Q034-0

## 15.2 PLC INTERLOCKS

The PLC logic will monitor inputs from the machine axes, air supply, and other systems and activate interlocks, if required. These interlock signals are passed to the CNC, which inhibits or e-stops the machine axes. In addition to setting the appropriate inhibit bit, the PLC will generate an alarm message.

These are the inhibit bits set in the PLC and transferred to the CNC to execute the appropriate interlock software:

- **DB2.DBX0 - DB2.DBX179** ..... PREDEFINED SIEMENS MESSAGES AND INTERLOCKS
- **DB200.DBX8.5** ..... CUT FREE E-STOP
- **DB200.DBX8.6** ..... IMMEDIATE E-STOP
- **DB201.DBX40.0** ..... CUT FREE CYCLE STOP
- **DB201.DBX40.1** ..... IMMEDIATE CYCLE STOP
- **DB201.DBX40.2** ..... END OF BLOCK STOP
- **DB201.DBX40.3** ..... CYCLE START INHIBIT
- **DB201.DBX40.4** ..... FEEDHOLD
- **DB201.DBX40.5** ..... AUTO INTERLOCK
- **DB201.DBX40.6** ..... BLOCK START INHIBIT
- **DB201.DBX40.7** ..... CUTTING BLOCK START INHIBIT
- **DB201.DBX41.0** ..... SPINDLE STOP

More information on the predefined Siemens CNC messages and interlocks from DB2.DBX0 – DB2.DBX179 can be found in the Siemens Simatic 300 Manual.

**NOTE:** All the interlock bits are active high. If a path to the interlock output bit is closed, it is active.

### 15.2.1 CUT FREE E-STOP - DB200.DBX8.5

The PLC Cut-Free E-Stop logic is used for machines with spindles. The purpose of this fault is to relieve pressure from the spindle cutter before activating an E-Stop.

A *CUT-FREE E-STOP* will stop all axes motion (feedhold) allowing for a time delay.

- Activate a feedhold for 5 seconds.
- Activate a spindle stop after 2 seconds.
- Activate an emergency stop after 5 seconds.

### 15.2.2 IMMEDIATE E-STOP - DB200.DBX8.6

This interlock (when high) will stop all axes, stop the spindle, exit the part program, cancel all miscellaneous (M) and preparatory (G) codes except for the default codes, and remove power to all non-essential CNC outputs. Recovery from an E-Stop is accomplished by correcting the fault and pressing the E-Stop Reset push-button.

**NOTE:** Referencing (homing) an axis is not necessary after an e-stop unless the fault occurred due to a loss of feedback or other faults associated with the CNC axis positioning loop.

### 15.2.3 CUT FREE CYCLE STOP - DB201.DBX40.0

This signal (when high) will stop feeding all control axes in automatic or semi-automatic mode. This signal sets the axis feedrate to zero (0). The move is stopped once the axes have gone through deceleration. When the signal goes low, restarting automatic operation is accomplished by pressing the Cycle Start push-button.

### 15.2.4 IMMEDIATE CYCLE STOP - DB201.DBX40.1

This interlock (when high) will stop executing and lock the start of automatic or semi-automatic operation. This bit would act the same as pressing the Cycle Stop push-button. All axes are zeroed (0) but the spindle (if any) will continue to rotate. When the signal goes low, restarting automatic operation is accomplished by pressing the Cycle Start push-button.

### 15.2.5 END OF BLOCK STOP - DB201.DBX40.2

This interlock bit (when high) will finish the active block but will not start the next programmed block. The operator must press Cycle Start to execute the next block.

### 15.2.6 CYCLE START INHIBIT - DB201.DBX40.3

This interlock bit (when high) will finish the active blocks, but prevents the Cycle Start pushbutton from starting any additional blocks. Once the interlock goes low, the Cycle Start pushbutton can be operated as normal.

### 15.2.7 FEEDHOLD - DB201.DBX40.4

This signal (when high) will stop feeding all axes. This signal sets the axes feedrate to zero (0). The move is stopped once the axes have gone through their deceleration. Once the signal has gone low, the move will continue.

#### 15.2.8 AUTO INTERLOCK - DB201.DBX40.5

This signal (when high) will stop feeding all control axes in automatic mode. This signal sets the axes feedrate to zero (0). The move is stopped once the axes have gone through their deceleration. Once the signal has gone low, the automatic cycle will continue.

#### 15.2.9 BLOCK START INHIBIT - DB201.DBX40.6

This interlock bit (when high) will finish the active block but will not start the next programmed block. With the interlock active, the next block is prepared for execution. Once the interlock goes low, the next block is executed.

#### 15.2.10 CUTTING BLOCK START INHIBIT - DB201.DBX40.7

This interlock bit (when high) will finish the active block but will not start the next programmed block that has a feedrate other than rapid. Rapid traverse (G0) moves are allowed with this inhibit active. With the interlock active, the next block is prepared for execution. Once the interlock goes low, the next block is executed.

#### 15.2.11 SPINDLE STOP - DB201.DBX41.0

This signal (when high) will stop the spindle(s). This signal sets the spindle speed to zero (0). The spindle is stopped once it has gone through deceleration. Once the signal has gone low, the spindle must be restarted manually or through program codes.

#### 15.2.12 PLC DIAGNOSTIC SCREEN

The inhibit bits set by the PLC can be viewed on the PLC Diagnostic screen on the CNC. To display this screen:

1. On the Siemens CNC monitor, press the “*Menu Select*” key
2. Select the horizontal softkey “*Diagnosis*”.
3. Select the menu headed “*PLC Status*”.



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### 15.3 ALARMS

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Any e-stop or interlock condition will generate an alarm. The CNC and PLC can also generate other alarm conditions that may or may not stop operations.

The CNC monitors the machine axes and generates alarms associated with axis control, part programs, and other CNC functions. The PLC logic monitors the input and outputs on the machine, controls most of the devices on the machine, and issues appropriate alarms when required.

All alarms generated by the CNC and PLC are reported to the CNC. The operator can view all alarms on the CNC alarm screen and respond to them if required. For more

information on the CNC alarm display, see the Siemens 840D Operator Manual.

Depending on the severity of an alarm, the logic may do one or more of the following actions:

- ....display a message
- ....flash a light
- ....sound the beeper
- ....cause a feedhold (or other inhibit) at the end of the current block
- ....cause an immediate feedhold
- ....cause an e-stop

### **15.3.1 CNC ALARM SCREEN**

The CNC alarm screen displays all active CNC and PLC generated alarms with alarm numbers, date, clearance criteria and descriptions.

To display the CNC alarm screen:

4. On the Siemens CNC monitor, press the “*Menu Select*” key 
5. Select the horizontal softkey “*Diagnosis*”.
6. Select the menu headed “*Alarms*”.
7. For some CNC generated alarms, additional help can be obtained by pressing the “*Help*” key.

### **15.3.2 FIRST FAULT INDICATION**

When the control goes into an e-stop condition, most systems on the machine are shutdown rapidly and asynchronously, so several alarm messages may be generated. The PLC logic attempts to trap and identify the first fault that occurred while going into e-stop, in order to make diagnosing the problem easier. In addition to displaying the fault messages, the PLC logic uses the following data words to store the first fault.

DB200.DB12 = First Cut Free E-stop Request

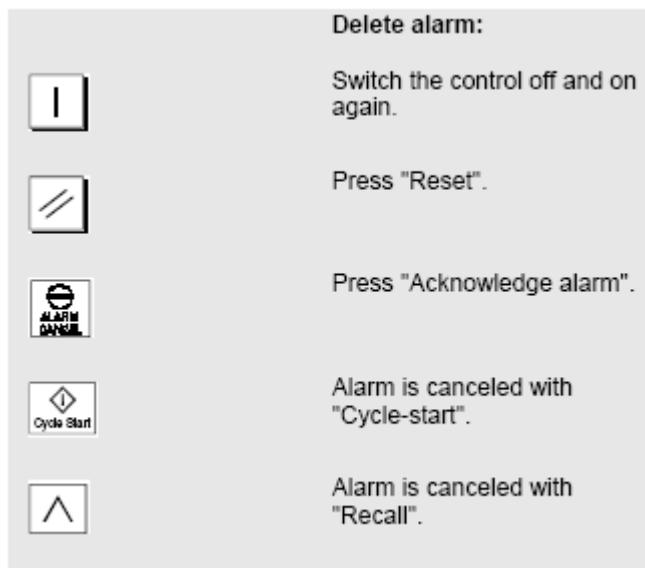
DB200.DB16 = First Immediate E-stop Request

### **15.3.3 PLC DIAGNOSTIC MESSAGES**

Additional PLC diagnostic messages can be displayed on the CNC alarm screen by pressing and holding the Emergency Stop Reset pushbutton for more than five (5) seconds. The E-stop Reset button is located at the control console, just above the Emergency Stop pushbutton. The PLC will generate alarm messages for any e-stop or inhibit that is currently active.

#### 15.3.4 CLEAR ACTIVE ALARM

To clear an alarm may require the operator to take various actions, including powering down the control. The symbol displayed next to the alarm text on the CNC shows the cancel criterion that may be required. The various cancel criterion symbols are shown below.



Those alarms whose conditions remain active, will not clear. These alarms will remain in affect until the actual fault conditions are resolved (then the operator may clear the fault).

# **CHAPTER 16 - PREVENTIVE MAINTENANCE**



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## 16.1 INTRODUCTION

---

**WARNING**

**OBSERVE ALL GENERAL SAFETY PRECAUTIONS  
GIVEN AT THE BEGINNING OF THIS MANUAL.**

**CAUTION**

**STUDY, BECOME FAMILIAR WITH, AND MAINTAIN  
YOUR SYSTEM DRAWINGS.**

This chapter assumes familiarity with all machine components on the MasterMill Gantry. For more information on any machine component, please refer to the specific chapter on that device.

Service reliability and machine accuracy are possible when all the notes and instructions are carefully followed.

The time intervals for suggested maintenance work are shown for standard conditions. However, the actual working conditions in a customer's plant may force some alterations in the schedule:

Preventive maintenance must be done at shorter intervals if the machine is operated in dirty or dusty surroundings.

The frequency of inspections depends on the nature of the foundation soil, the degree of machine loading, and machining accuracy required.

Irregularities and malfunctions must be taken care of immediately.

Any questions or comments regarding the operation or maintenance of your machine are welcome and will be handled promptly by our service department at any time.

---

**NOTE: Maintenance is the key for effective operation of this machine. Inform the Maintenance Department if there are any problems, or if systems are not functioning properly.**

---

### 16.1.1 VENDOR DOCUMENTATION

Refer to the vendor manuals supplied with this machine. These manuals provide specific technical data on periodic maintenance and repair of these components. Read and become familiar with the maintenance required for each piece of vendor-supplied equipment. Note recommendations on fuses, filters, bulbs, cleaning kits, and spare materials.

Maintenance information for the following systems is provided in the respective manuals supplied with those systems:

- Trabon (Lubriquip) lubrication system manual
- Dimplex (Koolant Koolers) chiller manual
- Mayfran coolant system
- Donaldson mist collection manual
- Oman Tool Changer manual
- Siemens 840D control system DocOnCD

### 16.1.2 HOUSEKEEPING

This category applies to areas around the machine, regardless of their condition, that will not directly affect machine performance. This includes areas between workstations, top of head, slides, and control cabinets.

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**NOTE:** Cleaning should be done on a monthly basis. Safety and access to machine work areas may be affected.

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## 16.2 MACHINE GEOMETRY

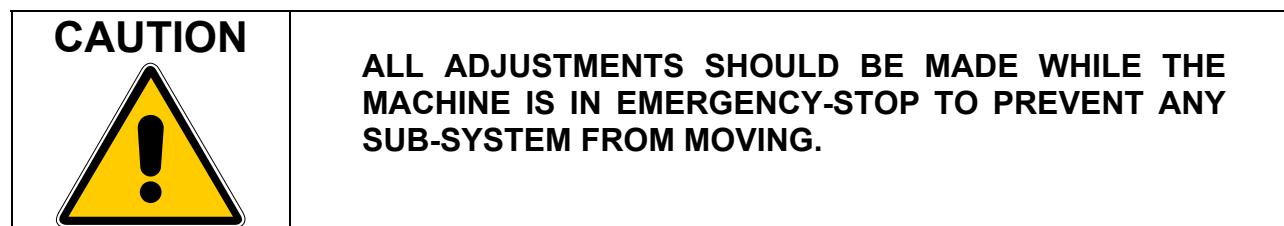
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Because the primary guiding assemblies of the machine are mounted on adjustable spacers, the machine geometry, in general, does not require readjustment during normal operation. The following events may require adjustment:

- An external shock to the machine
- A defective roller bearing
- An impact on the mechanical stop(s)
- A collision with a part
- Foundation instability

If the machine does require adjustment, it is important to check the current alignment, geometry, and positioning accuracy prior to disassembly to be sure the actual machine condition is known prior to making any adjustments.

Refer to the Inspection Procedures chapter in this manual for more information on checking and realigning the machine components.



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## 16.3 HEIDENHAIN SCALES

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The Heidenhain scales must be kept clean and free of dirt and chips. Damaged scales will not provide the positioning accuracy required. No other maintenance is possible.

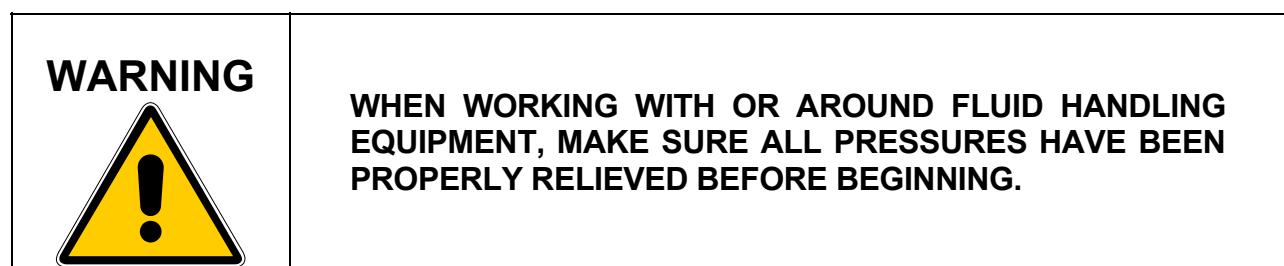
Use only the special tools and procedures recommended by Heidenhain when installing, replacing, aligning or cleaning these scales.

To prevent abrasion, shorting, and/or failure, be sure the interconnecting wiring is not contacting the tape.

---

## 16.4 FLUIDS MAINTENANCE

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### 16.4.1 FLUID SYSTEM GUIDELINES

#### 16.4.1.1 CLEANLINESS

Whenever servicing hydraulic systems and components, special care must be taken to insure cleanliness. The smallest foreign particle in the system can result in failure.

- Perfectly clean oil should be used for filling the tanks.

- Use clean containers and clean or new filter elements.
- All piping must be cleaned and free of dirt, chips, and scale.
- Start threaded fittings before applying sealing tape or pipe dope to threads to prevent sealants from entering the system.

#### 16.4.1.2 FILLING TANKS

The following guidelines will help to insure proper machine operation.

- Top off the oil tanks if the oil level drops in the sight gauges due to losses from maintenance or by the release of trapped air.
- Use only the recommended oil types specified in the lubrication charts.
- If the machine is equipped with hydraulic pressure reservoirs (accumulators) these reservoirs must be filled to the pressure prescribed on the assembly drawing with Nitrogen. Refer to FLUID FILL CAPACITIES in this chapter.

#### 16.4.1.3 START-UP

- Check that all valves in the suction line and the respective valves in the pressure lines are open.
- Switch motor momentarily on and off until you are certain the pump works satisfactorily.

#### 16.4.1.4 EVACUATION OF TRAPPED AIR

Air trapped in the system is evacuated by unscrewing the upper most pipe fitting, and at the same time, operating the corresponding valve until "bubble free" oil emerges. For this purpose the pressure switch is set to a lower pressure (approximately 45 to 75 PSI), and the pump is allowed to run.

After evacuation of the air, tighten the loosened fitting, top off the oil tanks, switch on the pumps, then check the operation of each complete system including valves, etc.

#### 16.4.1.5 FILTERS

The filters must be frequently cleaned during the initial start-up period as the hydraulic and hydrostatic systems will scrub themselves clean. Further replacement of filter elements should be done periodically at predetermined times gained from experience. Check for the proper operation of pressure and dirty filter warning switches.

#### 16.4.1.6 TROUBLESHOOTING

If at any time the hydraulic system seems to be operating inefficiently, refer to the TROUBLESHOOTING charts in this chapter.

#### 16.4.1.7 PRESSURE SETTINGS

Before the machine is released to the user, all pressures are properly adjusted. These settings should be changed only when necessary and only after the user has received approval from the manufacturer to make a change.

#### 16.4.1.8 PRESSURE CHECKS

The gauge isolators furnished are for checking pressures at different parts of the machine. Upon completion of the installation, all final pressures should be recorded for future reference.

### 16.4.2 TROUBLESHOOTING FLUID SYSTEMS FAILURES

<b>Table A - EXCESSIVE NOISE</b>	
<b>CAUSE</b>	<b>SOLUTION</b>
<b>AIR BUILD-UP IN PUMP</b>	
A. Suction filter block.	Clean or repair filter.
B. Local restriction in suction line, ie. partly closed valve damaged pipe or faulty hose.	Repair or modify valve so that it operates smoothly. Repair or replace pipe or hose.
C. Feed pump failure.	Repair or replace pump.
<b>OIL FOAMS</b>	
A. Oil level in tank is too low.	Top off the tank.
B. Shaft seal allows air to enter.	Replace seal.
C. Loose fittings allow air to enter.	Tighten or replace fitting.
D. Porous intake hose.	Replace hose.
E. Pressure line air evacuation not properly done.	Bleed air from system.
<b>MECHANICAL VIBRATION</b>	
A. Clutch loose or misaligned.	Align or tighten clutch.
B. Vibration in the lines.	Tighten clamps.
<b>PUMP</b>	
A. Worn out or damaged.	Repair or replace pump.
<b>DRIVE GEAR</b>	
A. Worn out or damaged.	Repair or replace gear.

<b>Table B – INSUFFICIENT OR NO PRESSURE</b>	
<b>CAUSE</b>	<b>SOLUTION</b>
<b>PUMP NOT PROPERLY PRIMED</b>	
A. Air in the suction line.	Clean or replace filter.
<b>HIGH PUMP TEMPERATURE</b>	
A. Worn out or damaged pump.	Repair or replace pump.
B. Incorrect cooling.	Proper flow of coolant or air must be assured.
<b>LOSS OF PRESSURE THROUGH LEAKAGE FROM PRESSURE SIDE TO RETURN SIDE</b>	
A. Incorrect pressure setting.	Set pressure correctly.
B. Safety valve open because of dirt, defective part, or failure of electronics.	Identify damaged unit and adjust, clean, repair, or replace.
C. Damaged cylinder bore, piston rod, or seal.	Repair or replace part.
<b>FEED PUMP FAILURE</b>	
A. Damaged pump or faulty drive system.	Repair or replace pump.

<b>Table C - ABNORMAL PRESSURE/FLOW-FLUCTUATION/VIBRATION</b>	
<b>CAUSE</b>	<b>SOLUTION</b>
<b>CAVITATION IN THE PUMP, OIL FOAMS, MECHANICAL VIBRATION</b>	
See Table A	See Table A
<b>WOBBLING OF THE LIMIT OR SAFETY VALVE</b>	
See Table A	See Table A
B. Damaged valve seat.	Repair or replace.
<b>STUCK VALVES</b>	
A. Dirty oil and parts.	Drain oil, clean system, fill with clean oil.
<b>IRREGULAR ACTION CAUSED BY TRAPPED AIR</b>	
A. System incompletely evacuated.	Bleed air from system.

<b>Table D - TOO LOW / NO DELIVERY AND HIGH TEMPERATURE</b>	
<b>CAUSE</b>	<b>SOLUTION</b>
<b>CAVITATION IN THE PUMP</b>	
A. See Table A	See Table A
<b>LOSS THROUGH LEAKAGE FROM PRESSURE SIDE TO RETURN SIDE</b>	
A. See Table A	See Table A
<b>HIGH TEMPERATURE</b>	
<b>SAFETY VALVE OR PRESSURE LIMIT SWITCH OVERLOADED</b>	
A. Valve operating poorly and faulty seals.	See Table A
B. Oil viscosity too low.	Drain oil and fill with clean oil of the recommended viscosity.
C. Safety pressure set too low.	Adjust to correct pressure setting.
D. Insufficient relief.	Consult with Ingersoll.

#### **16.4.3 OILS**

These fluid fill quantities are for totally dry systems, and are based on reservoir capacity. Filling of pipes, filters, valves, cylinders and other components, as well as bleeding and/or minor leaks before repairs, may require approximately 10% more fluid.

When topping-off during normal system operation, oil levels should be checked after all fluid systems are running properly and while axes are not moving. Reservoirs must have room to allow fluids to drain back without overflowing.

#### **16.4.4 GREASES**

When the component is grease packed, no lubrication is required. Re-lubricate only when a mechanical failure has occurred and rebuilding of the component is required.

## 16.5 COUNTERBALANCE STRUCTURES

---

When conducting any machine maintenance, extreme care must be followed to block, inhibit or otherwise de-mobilize any structure that can move due to gravity.

Company-approved lockout/tag-out procedures must also be followed during maintenance to lock and tag electrical circuits prior to working on a circuit or the mechanical equipment supplied by the circuit.

Maintenance personnel are required to BLOCK AND LOCK all machine components such as counterbalanced rams and crossrails so their movement downward cannot occur. Blocking should only be conducted with approved devices.

<b>WARNING</b> 	<p>The Z-axis (ram) on this machine carries a large amount of weight and is a counterbalanced axis. It is essential that the counterbalance system is functioning at all times to prevent the axis from inadvertently falling, which could result in severe machine damage or injury to personnel.</p> <p>Prior to any maintenance work on the ram, the axis must be driven to its lower limit and screw jacks placed to support the ram from falling.</p>
--	--

### 16.5.1 COUNTERBALANCE MAINTENANCE

The counterbalance system requires thorough inspection and maintenance at regular intervals. The longer it has been in service or the more severe the service, the more thoroughly and frequently it should be inspected. Be sure to maintain records of each inspection. Refer to the Maintenance Checklist at the end of this chapter for recommended counterbalance maintenance checks and intervals.

Inspections should be carried out by a person who has learned through special training or practical experience what to look for, and who knows how to judge the importance of any abnormal conditions they may discover.

**WARNING**

Stored energy is present in the Z-axis counterbalance circuits. When power and air supply are removed from the machine, the air receivers and the cylinders will remain pressurized. Repairs and adjustments must be made by trained service personnel using proper tools and instructions. All counterbalanced systems should be blocked and locked out prior to servicing. Please refer to the Fluids Schematics for information on safely discharging and charging the counterbalance system.

The counterbalance circuit will experience some leakage with normal machine usage. Any leaked oil will drain into a collection pan on the column. If the monitored pressure in the counterbalance system falls below a predefined limit, a message is posted and the machine will be stopped. The counterbalance system must then be manually recharged with oil.

If the alarm indicating a counterbalance pressure fault occurs frequently, maintenance should be performed using the following procedure to ensure there is not a problem with leakage of nitrogen gas or oil in the system.

**WARNING**

Refer to the Fluid Schematics for full details on the counterbalance systems and safety precautions when charging and discharging the systems.

**16.5.1.1 CHECK GAS PRESSURE (OR FOR RUPTURED BLADDER)**

1. Drive the Z-axis ram to the lowest position and block it so it will not fall.
2. Close the ball valves at the bottom of the accumulators [F1298].
3. Open the needle valve [F256] in the oil side of the accumulator being checked and allow all the oil to flow back to the hydraulic reservoir.
4. After the oil has stopped flowing from the accumulator, open the fitting in the tubing after the needle valve and inspect to determine if any gas is escaping. Escaping gas is an indication of a ruptured accumulator bladder. Refer to the accumulator changing procedure for instructions for repair sequence. If no gas leak appears, close needle valve, reconnect the tubing, and replace plug.
5. Repeat steps 3 and 4 for the remaining accumulators.

6. Check the nitrogen gas pressure by attaching a nitrogen-charging regulator to the top of the accumulator. The pressure should be 1100 PSI. If the nitrogen gas pressure is low or high, add or release nitrogen accordingly.
7. Repeat step 6 for the remaining accumulators.

#### 16.5.1.2 CHARGING ACCUMULATORS WITH NITROGEN

---

**NOTE:** This procedure is used for the **initial charging** when no oil is in accumulators.

---

1. Verify that the ram is at the lowest position and blocked. Refer to previous section on blocking counterbalanced structures.
2. Close the ball valve [F1298] in the oil line side of the accumulator to be charged.
3. Open the needle valve [F256] in the oil line side of the accumulator to be charged.
4. Attach a nitrogen-charging regulator with supply to the top of the accumulator to be charged.
5. Set nitrogen-charging pressure to lowest possible setting, 10 PSI, if possible.
6. Allow the system to stabilize at this pressure (no more nitrogen gas flowing into system).

**NOTE:** **This step in the procedure must be followed explicitly; damage to the bladders will occur if they are allowed to fill too rapidly.**

---

7. Continue charging the system with nitrogen gas until the pressure has reached 1100 PSI.
8. Repeat the procedure for all the accumulators.

#### 16.5.1.3 CHARGING COUNTERBALANCE SYSTEM WITH OIL

---

**Note:** **Prior to charging with oil, verify that the system has been charged with nitrogen gas to 1100 PSI (refer to procedure for nitrogen charging above).**

---

1. Verify that the Z-axis ram is at its lowest position and blocked.
2. Verify that Z-axis ballscrews and motors are connected and the brakes engaged.

**Note:** **If the ballscrews and motors are not connected, and the brakes not engaged, the Z-axis ram may move upward during charging.**

---

3. Needle valve [F210] at the transducer is open.
4. Needle valves [F256] in the oil line side of the accumulators are closed.

5. Ball valves [F1298] in the oil line side of the accumulators are open.
6. Needle valve [F256] in the counterbalance charge line is open slightly.
7. Energize the Z-axis counterbalance system-charging valve.
8. With the Z-axis ram at the lowest position, the system should charge to 1350 PSI.
9. Open the needle valve [F256] in the oil side of one of the accumulators and allow the oil to flow back to the hydraulic reservoir for approximately 30 seconds to allow trapped air to escape.
10. Close the needle valve [F256] in the oil side of the accumulators being bled.
11. Repeat steps 9 and 10 until the air has been bled from all of the accumulator circuits.
12. Verify that the system is charged with oil to 1350 PSI.

The hydraulic counterbalance system is now fully charged and ready for Z-axis motion. Periodic bleeding of air from the hydraulic system is done automatically via the counterbalance bleed circuit [1376].

The state of the valves during normal operation is as follows:

- Ball valves [F1298] are open.
- Needle valve [F210] at the transducer is open.
- Needle valves [F256] in the oil line side of the accumulators are closed.
- Needle valve [F256] in the counterbalance charge line is open slightly.
- Needle valve [F256] in the counterbalance bleed circuit line is open slightly.

If it has been determined in step 4 in the Checking Gas Pressure procedure that there is a gas leak, follow this procedure for removing, replacing, and charging the damaged accumulator. Trained technicians are required for bladder replacement in the accumulator.

#### 16.5.1.4 CHANGING DAMAGED ACCUMULATOR

1. Verify that Z-axis ram is at the lowest position and blocked.
2. Close the ball valves in the oil line side of all of the accumulators. [F1298]
3. Open the needle valve [F256] in the oil side of the damaged accumulator and allow all the oil to escape back to the hydraulic reservoir.
4. Remove and replace the damaged accumulator.
5. Refer to the procedures for charging the system with oil and nitrogen.

## 16.6 ELECTRICAL MAINTENANCE

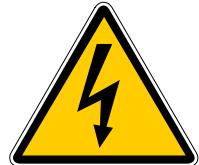
**WARNING**

THIS WARNING SIGN IS A REMINDER THAT THERE IS DANGER TO PERSONNEL. BE VERY CAREFUL!

- AVOID ELECTRICAL SHOCK!!
- BE SURE TO REMOVE ELECTRICAL POWER BEFORE WORKING ON ANY ELECTRICAL DEVICE.
- NOT ALL POWER WILL BE REMOVED WHEN USING THE ELECTRICAL CABINET CIRCUIT BREAKER.
- IT MAY BE NECESSARY TO OPEN AND LOCK-OPEN THE MAIN POWER DISCONNECTS.

### 16.6.1 STORED ENERGY

There may be several circuits that have voltage when the main disconnect is pulled downward to the off position. These circuits can be recognized from other circuits by having either yellow wires or black wire wrapped with yellow tape.

**CAUTION****DANGER  
“HOT”**

WHENEVER THE MAIN DISCONNECT (LOCATED IN THE ELECTRICAL CABINET) IS TURNED OFF, IT IS EXPECTED THAT THIS ACTION WILL REMOVE ALL POWER FROM THE MACHINE.

THE ELECTRICAL CIRCUITS THAT HAVE VOLTAGE (“HOT”) WHEN THE MAIN BREAKER IS DE-ENERGIZED ARE IDENTIFIED BY HAVING YELLOW WIRES OR BLACK WIRES WRAPPED WITH YELLOW TAPE.

IT IS ALWAYS GOOD PRACTICE TO MEASURE THE VOLTAGE ON THE CIRCUITRY YOU ARE WORKING ON, TO PREVENT ANY ELECTRICAL RELATED INJURY. BE PREPARED TO OPEN THE APPROPRIATE ELECTRICAL CABINET TO OPEN THE CIRCUIT BREAKER WIRED TO THE HOT CIRCUITRY.

### **16.6.2 GENERAL INSPECTION**

Always be alert for any erratic operation or unusual sounds from motors, sliders, or other components with moving parts.

Visually inspect the entire machine for damaged or defective parts.

Replace defective light bulbs, and repair or replace push buttons and control switches immediately.

Periodically check, clean, adjust, repair or replace the following components as specified.

### **16.6.3 WIRING**

#### **16.6.3.1 FOUNDATION**

Every six months, inspect and clean all machine electrical runs, and repair any damage. Check all bolts holding the electrical and electronic cabinets and auxiliary machines.

#### **16.6.3.2 CABINETS AND JUNCTION BOXES**

Every six months, examine all cabinets and junction boxes. Inspect all wiring, and clean the interior if necessary. Repair or replace the gaskets, and securely close the covers to prevent contamination.

#### **16.6.3.3 POWER CARRIERS**

Every four months, check all electrical wiring in the power carriers. Inspect for abrasion, kinks, and/or loose debris.

Replace any worn wiring or cable with the same type and grade. Also, be sure to replace the wire code labels.

#### **16.6.3.4 LOOSE CONNECTIONS**

Every six months, check all electrical connections for loose screws. Re-tighten all loose screws. Also, tighten all screws and bolts that secure electrical equipment, brackets and cabinets.

#### **16.6.3.5 CONTACTORS**

Every six months, examine all relays, starters, and contactor contact poles. Check for alignment, deposits, and burning. Clean or replace as necessary.

#### **16.6.3.6 SOLENOIDS**

Every six months, check all valve solenoids for proper operation (head and table). Use the valve isolators and pressure gauges to check that each valve is actually opening and closing. If a solenoid is not operating, take an amperage check to confirm that the solenoid coil is defective. Replace the defective solenoid.

#### 16.6.3.7 ENCODERS

Every month, check and clean all read-out racks and pinions on the resolvers. Resolvers must be kept clean and free of dirt and chips. No other maintenance is possible.

Make sure any problem is confined to the resolver before replacing it. Return a suspect resolver to the vendor for service or replacement.

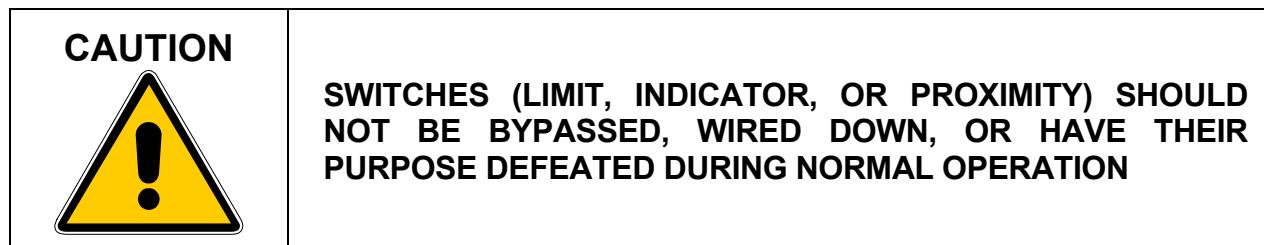
#### 16.6.4 LIMIT, INDICATOR, AND PROXIMITY SWITCHES

Every four months, check limit switch mountings, levers, and dogs. Tighten any loose parts, and check for proper operation of the switch. Make sure the switch is properly adjusted so the system operates correctly.

Every four months, check indicator switches on filters. Be sure that the switch operates smoothly, and that it is properly adjusted.

Check proximity switches for proper operation, and tight fasteners. Adjust the switch position, if necessary, to operate properly.

Defective proximity switches cannot be repaired. Replace them with exact or equivalent replacement switches. Make sure the new proximity switch is positioned in correct relation to the trip element. Test for proper system operation.



#### 16.6.5 CLEANING ELECTRICAL COMPONENTS

##### 16.6.5.1 AIR FILTERS

Every week, check all electrical cabinet and motor blower filters. Clean or replace all dirty filter media.

##### 16.6.5.2 CLEANING ELECTRONIC COMPONENTS

Use a Freon spray for cleaning these components. DO NOT use air or solvents for cleaning electronic boards or DC motors. Dry air can build-up a static charge that will destroy integrated circuitry. Solvents will carry dirt into unreachable areas and leave a build-up, as well as possibly degrading insulating materials.

##### 16.6.5.3 CLEANING A.C. MOTORS

Every six months, use dry air or a Freon spray to clean out the A.C. motor windings, stators, rotors, heat fins, and the housing. Small amounts of electric motor cleaner may be

used to spot clean dirty areas. Direct the air pressure to blow dirt and cleaner back out the way it came in, and not deeper into the motor or into the motor bearings.

### **16.6.6 ELECTRONIC EQUIPMENT**

#### **16.6.6.1 HANDLING CIRCUIT BOARDS**

Electronic circuit boards must be handled carefully. Keep new and defective boards in the anti-static bags and in the protective carton unless they are being installed or removed from their slots.

Before handling any board, discharge static from your hands or clothes by touching the metal cabinet. Use an anti-static spray inside the cabinet or on any work surface to help prevent static discharges. Handle the boards with clean hands on the plain edges and the retaining clips only. DO NOT touch the contacts on the edge connectors, or the components on the board.

Use care when removing boards from the equipment. With power removed from the circuit, disconnect any cable connectors from the board. Release the clips, then slowly pull the board straight out from its contacts. Continue to slowly pull the board straight-out in line with the edge guides, while making sure no connecting plugs or wires are interfering with the board components. Once the board is clear, put it directly into its anti-static bag.

Use care when inserting new boards. Make sure any wires or connecting plugs are out of the way. Remove it carefully from its anti-static bag. Orient the board and line up the edges with the edge guides, and slowly slide it straight into the contacts. Push the board slowly into place, seating the edge connectors firmly. Snap the retaining clips into place. Connect the cable connectors into place on the board. Turn on the power, and check for proper machine operation.

Return defective boards to the manufacturer for repairs.

#### **16.6.6.2 POWER SUPPLIES**

Every six months, check all power supplies for correct output.

### **16.6.7 ARC WELDING**

**Arc welding SHOULD NOT be performed on the machine at any time.** Arc welding can cause power line surges as well as heavy current flow, by induction, which can cause integrated circuit failure.

### **16.6.8 MOTORS**

#### **16.6.8.1 MOTOR CURRENT CHECKS**

Every six months, or when the machine fails to function properly, check the motor currents. Motor current checks are valuable for determining:

- Proper braking action
- Mechanical binding
- Any inefficient operation

#### 16.6.8.2 MOTOR MOUNTINGS

Every six months, check all motor mounting bolts and covers. Tighten any loose fasteners.

#### 16.6.8.3 FAN MOTORS

Every six months check all fans and blowers for proper operation. Repair or replace as necessary.

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### 16.7 PREVENTIVE MAINTENANCE SCHEDULE

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Intervals between inspections should be adjusted based on environmental and operating conditions, and adjusted when necessary according to history of findings.

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**NOTE:** All scheduled maintenance times that are recommended in this document are based on past experiences, and vendor information. This should be followed until different times can be scheduled based on the shop environment where the machine is located.

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## 16.7.1 MAINTENANCE CHECKLIST

ITEM	CHECK	FREQUENCY
1.	Check fluid levels and top-off to sight gauge level, if needed. a. Hydraulic power unit b. Axis lubrication tank c. Spindle lubrication tank d. Swivel Spindle Unit tank e. Chiller	Daily
2.	Inspect and close the console, cabinet, and panel doors.	Daily
3.	Check all indicator lights.	Daily
4.	Clean Z-axis bellows.	Daily
5.	Clean dust and chips from tools in tool magazine.	Daily
6.	Check that air conditioner fans on electrical cabinets are running.	Daily
7.	Visually check for oil or coolant leaks at spindle.	Daily
8.	Clean inside spindle.	Daily
9.	Whenever the OH150 spindle unit #14 is mounted on the ram, inspect the weep hole near the sight gage. If oil is dripping from this hole, the unit has excess oil. The unit should not be used until the cause of this oil has been found and corrected.	Daily
10.	Check all pushbuttons and switches for damage.	Weekly
11.	Inspect warning systems for proper operation.	Weekly
12.	Check the packing ring in the clamping unit of the Spindle Tool Gripper. (Visual check).	Weekly
13.	Check the spindle tool gripper. Is it damaged or dirty? Is it sufficiently greased? (Visual check)  The re-grease cycle depends on the loss of lubrication of the clamping unit. Causes for the loss of lubrication: <ul style="list-style-type: none"><li>• Seal in the clamping cone is defective.</li><li>• Type medium used can dissolve grease.</li><li>• Cleaning spray from outside directly on the clamping unit, etc.</li></ul> NOTE: Metaflux Moly-Spray No. 70-82 is recommended for a quick re-greasing of the clamping unit without gripper-disassembly.	Weekly
14.	Wipe dust and dirt from all painted surfaces. Clean windows in operator cab.	Weekly
15.	Keep work area clear of excess debris.	Weekly
16.	Check that all gates, latches, and safety systems work properly.	Weekly
17.	Check that all pressure gauges are operating within limits.	Weekly

ITEM	CHECK	FREQUENCY
18.	Check and record motor amperages required to position axes. Compare results to previous checks.	Monthly
19.	Check counterbalance gas pressure and check for ruptured accumulator bladder. Refer to procedure in this chapter.	Monthly
20.	Wipe off dust, debris, rust, and footprints on machine guide ways, and apply a light film of oil. Replace wipers as needed.	Monthly
21.	Remove dirt buildup from fan gratings on drive motors.	Monthly
22.	On the tool changer, make sure that there is no dirt that may cause a malfunction of the inductive sensors and photoelectric sensors.	Monthly
23.	Check and record axes following error, and compare results to previous checks.	3 Months
24.	Inspect for proper operation of all cooling fans, including all motors, PC's, servo drives, power supplies, etc.	3 Months
25.	Inspect all air conditioning units for proper operation.	3 Months
26.	Replace disposable filters in panels and cabinets or clean permanent type.	3 Months
27.	Replace all motor filters.	3 Months
28.	Replace disposable filters or clean permanent type.	3 Months
29.	Bleed air from the counterbalance hydraulic system.	3 Months
30.	Check and record positions and repeatability of axes movements.	6 Months
31.	Perform ballbar checks.	6 Months
32.	Check and record input and output voltages of all power supplies. Compare results to previous checks.	6 Months
33.	Check all limit switch arms, plungers, and dogs. Also, check the machine tags.	6 Months
34.	Check and record voltage and amperage outputs of all servomotors. Compare to previous checks.	6 Months
35.	Check and record all servo motor feedback signals for stability and overshoot. Compare to previous checks.	6 Months
36.	Check and record voltages and amperages of all other motors, including pump and spindle motors. Compare results to previous checks.	6 Months
37.	Check motor feedback for min/max RPM.	6 Months
38.	Vacuum the inside of all control panels, consoles, and cabinets.	6 Months
39.	Check relays for freedom of movement and clean pole faces. Check for cracked or broken parts of contacts.	6 Months
40.	Clean all motors.	6 Months
41.	Back-up the program logic on disk.	6 Months

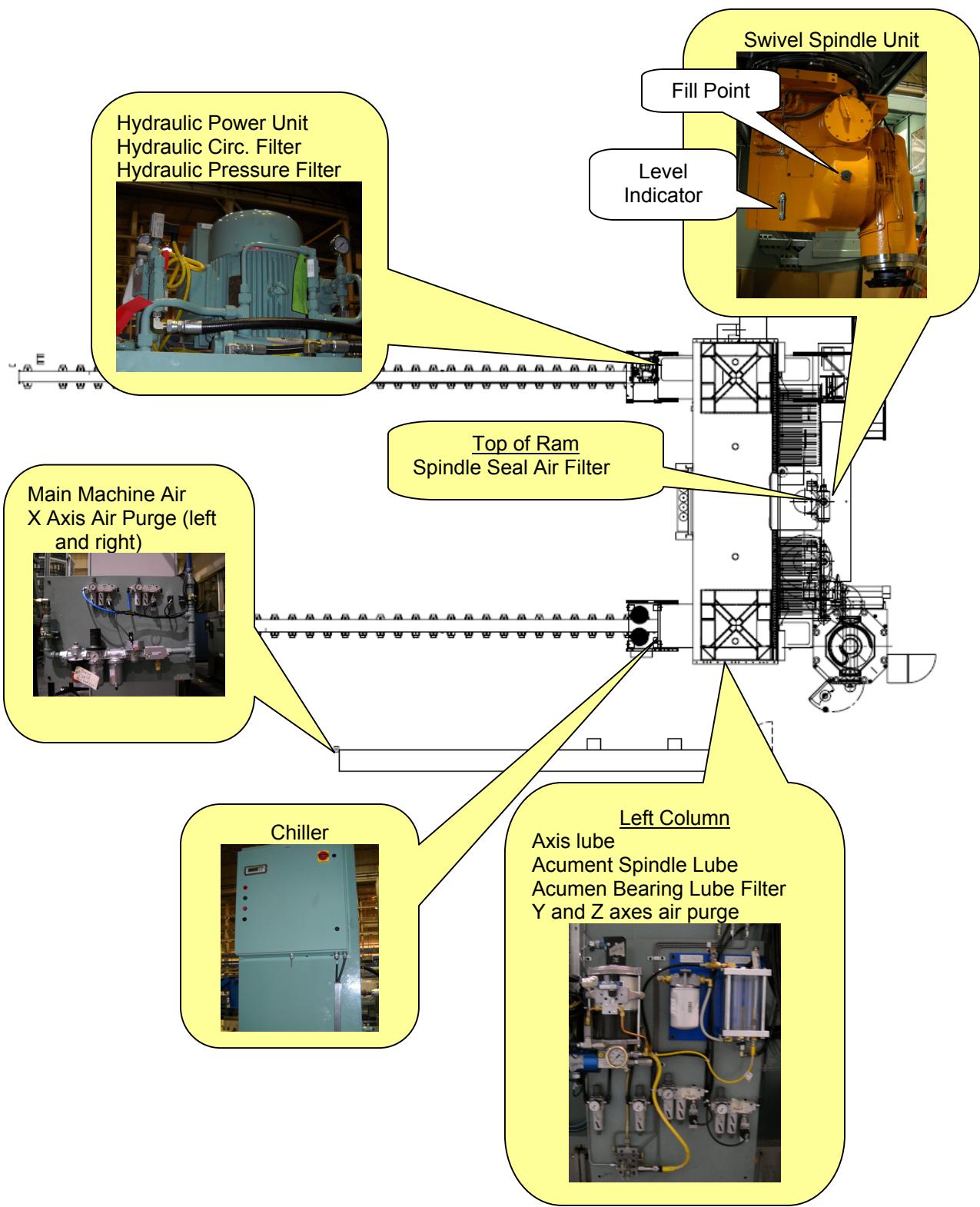
ITEM	CHECK	FREQUENCY
42.	Inspect power track for wear of cable shielding, freedom of movement at pivot points, and condition of pads and rollers.	12 Months
43.	Inspect all seals of panels, cabinets, junction boxes, consoles, etc.	12 Months
44.	Clean all junction boxes inside and out with air pressure and electric motor cleaner, if needed.	12 Months
45.	Check all threaded electrical connections. Include motors, solenoids, junction boxes, etc.	12 Months
46.	Visually check all wires for fraying or overheating.	12 Months
47.	Check all electrical connections for tightness. (Note: All electrical connections should be inspected annually. Divide the machine in half, then check half the connections in the first part of the year and the other half in the second part of the year.)	12 Months
48.	Check gelled cell batteries for the proper voltages.	12 Months
49.	Visually check tool changer grippers and replace in case of damage.	12 Months
50.	Lubricate the tool changer manipulator's horizontal and vertical axes by greasing the points specified in the Oman Tool Changer manual.	12 Months
51.	Check reference gauge dimension (E.M.) of the spindle tool gripper. (Check in unclamped position.)	Every 200,000 tool changes or 6 months
52.	Re-tighten the lock nut (through clamped tool) in spindle tool gripper.	Every 200,000 tool changes or 6 months
53.	Test Pull-in-force of the Spindle tool gripper (recommend Power-Check). If the pull-in-force is smaller than 70% of the nominal value, the following procedures have to be performed in the following sequence: 1. Re-grease and test pull-in force again 2. Exchange gripper and test again 3. Exchange draw bar completely	Every 200,000 tool changes or 6 months
54.	Exchange the packing ring of the spindle tool gripper.	Every 500,000 tool changes or 12 months

### 16.7.2 FILTRATION AND LUBE POINT LOCATIONS

The following table details filtration and lubrication points and fill frequency of all the lube points and filters on this machine. The location of these devices is shown in the pictures on the following page.

FILTRATION			
DESCRIPTION	NOTES	TAG	SCHEMATIC LOC.
Hydraulic Circulation Filter	Schroeder - TF11AZ5SMS14 filter Schroeder - AZ5 element	16	N00073-F2-653,001
Hydraulic Pressure Filter	Schroeder - NF301NZ10SMS14 filter Schroeder - NZ10 element	15	N00073-F2-653,001
Main Machine Air Coalescing Filter	Camouzzi - C401-FB0 filter Camouzzi - C401-F26 element	F1308	N00073-F4-656,001
Main Machine Air Particulate Filter	Camouzzi - C401-D00 filter Camouzzi - C401-F25/1 element	F1308	N00073-F4-656,001
X Left-Axis Heidenhain Air Purge Coalescing Filter	Camouzzi - MC104-FB0TF filter Camouzzi - C104-F26 element	F1492	N00073-F4-656,001
X Left-Axis Heidenhain Air Purge Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1492	N00073-F4-656,001
X Right-Axis Heidenhain Air Purge Coalescing Filter	Camouzzi - MC104-FB0TF filter Camouzzi - C104-F26 element	F1492	N00073-F4-656,001
X Right-Axis Heidenhain Air Purge Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1492	N00073-F4-656,001
Y-Axis Heidenhain Air Purge Coalescing Filter	Camouzzi - MC104-FB0TF filter Camouzzi - C104-F26 element	F1492	N00073-F4-656,001
Y-Axis Heidenhain Air Purge Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1492	N00073-F4-656,001
Z-Axis Heidenhain Air Purge Coalescing Filter	Camouzzi - MC104-FB0TF filter Camouzzi - C104-F26 element	F1492	N00073-F4-656,001
Z-Axis Heidenhain Air Purge Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1492	N00073-F4-656,001
Machine Chiller Filter	Big Blue - 150236 filter Pentair - 155053-43 element (2 required)		N00073-F7-655,001
Spindle Bearing Lubrication Reservoir Air Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1099	N00073-F4-656,001
Spindle Front Seal Pressurization Front Seal Air Particulate Filter	Camouzzi - MC104-D00TF filter Camouzzi - C104-F20/3 element	F1694	N00073-F4-656,001
Spindle Bearing Lubrication Air Particulate Filter	Parker - 14F17B filter Parker - P3A-KA00EEN element	F1694	N00073-F4-656,001
LUBRICATION			
DESCRIPTION	NOTES	TAG	SCHEMATIC LOC.
Hydraulic Power Unit	Mobil DTE 25 (ISO VG 46 anti-wear) hydraulic oil - 60 gallons - level switch will indicate when filling is required	1	N00073-F2-653,001
Axis Lubrication Reservoir	Mobilux EP0 23 (NLGI grade 000) - app 6(lbs) - level switch will indicate when filling is required	F1094	N00073-F3-654,001
Spindle Lubrication Reservoir	Mobil SHC 626 (ISO VG 68) lubricating oil - 1 gallon - level switch will indicate when filling is required	F1257	N00073-F4-656,001
Swivel Spindle Unit -90	Mobil SHC 634 (ISO VG 460 OIL) - 2 gallon - check level weekly with spindle not running		N00073-F3-654,004
Machine Chiller	Dowtherm SR1 - 60 gallon - 60% DI water with 40% rust inhibiting ethylene glycol - top-off using sight gauge	F1395	N00073-F7-655,001

## MACHINE DIAGRAM SHOWING LOCATION OF LUBE POINTS AND FILTERS



# **CHAPTER 17 - INSPECTION PROCEDURES**



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## 17.0 INTRODUCTION

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This chapter contains the procedures used for inspection of this machine. These tests will be performed during installation of your machine. A record of the inspection results should be kept. These tests should be repeated after major repair work is done or a significant loss of accuracy is detected. The test results can then be compared to the original test results.

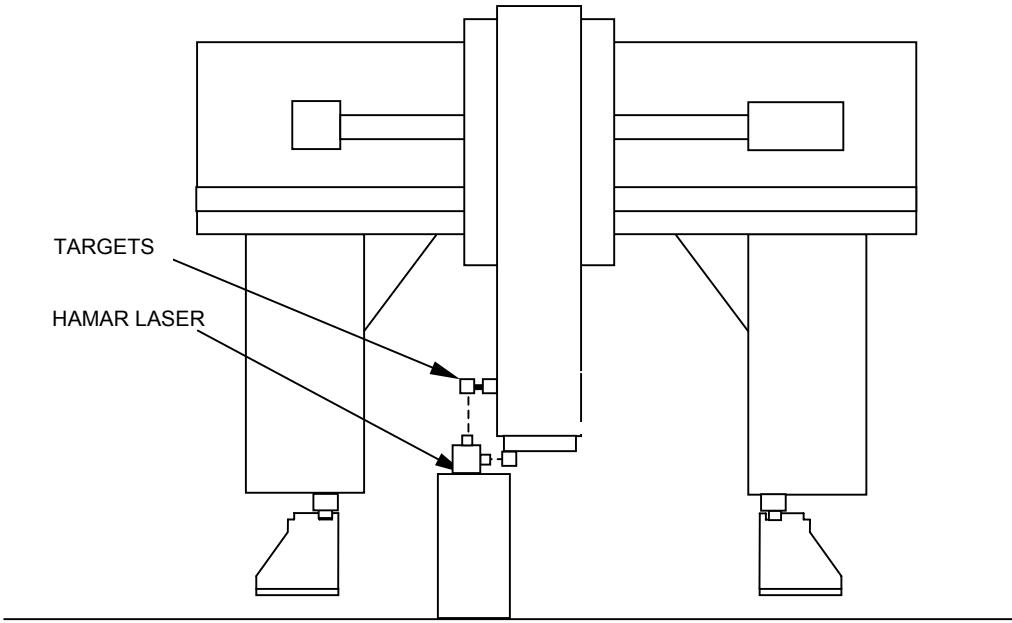
**17.1 X TO Y-AXIS SQUARENESS / X STRAIGHTNESS**

TEST <u>#1.</u>	SUBJECT: X TO Y AXIS SQUARENESS X STRAIGHTNESS			
INSPECTION DEVICE/S	TOLERANCE			METHOD
	ALLOWABLE	ACTUAL	DEVIATION	
HAMAR LASER TARGETS	<u>X AXIS STRAIGHTNESS</u> VERTICAL .01/1000 MM .1 MM TOTAL HORIZONTAL .01/1000 MM .1 MM TOTAL <u>X TO Y SQUARENESS</u> 3 SECONDS (.015/1000 MM)			ALIGN HAMAR LASER TO X AXIS TRAVEL WITH REFLECTOR MOUNTED TO END OF RAM AND CENTER OF Y AND Z TRAVEL. MEASURE VERTICAL AND HORIZONTAL STRAIGHTNESS. MEASURE IN 500MM INCREMENTS. USE ADJACENT BEAM TO MEASURE SQUARENESS OF Y AXIS. TAKE MEASUREMENTS IN 200MM INCREMENTS AND MAKE BEST FIT LINE THROUGH DATA TO CALCULATE ANGLE. USE AVAILABLE COMPENSATION SOFTWARE TO OBTAIN TOLERANCE SHOWN.
ISSUED	DATE	INSPECTOR	DATE	CUSTOMER DATE

## 17.2 X TO Z-AXIS SQUARENESS / Z STRAIGHTNESS

TEST <u># 2.</u>	SUBJECT: X TO Z AXIS SQUARENESS Z AXIS STRAIGHTNESS			
ILLUSTRATION				
INSPECTION DEVICE/S	TOLERANCE			METHOD
	ALLOWABLE	ACTUAL	DEVIATION	
HAMAR LASER TARGETS	<u>Z AXIS STRAIGHTNESS</u> VERTICAL .01/1000 MM .1 MM TOTAL <u>HORIZONTAL</u> .01/1000 MM .1 MM TOTAL <u>X TO Z SQUARENESS</u> 3 SECONDS (.015/1000 MM)			MOUNT HAMAR LASER TO MACHINE BASE OR BED. ALIGN LASER TO X AXIS TRAVEL. PROJECT BEAM PERPENDICULAR TO X AXIS AND MOUNT TARGET TO Z AXIS RAM. MEASURE SQUARENESS OF BEST-FIT LINE THROUGH Z AXIS TRAVEL IN 100 MM INCREMENTS.  ZERO THE ENDS OF DATA FOR EACH AXIS TO RECORD STRAIGHTNESS.
ISSUED	DATE	INSPECTOR	DATE	CUSTOMER DATE

### 17.3 Y TO Z-AXIS SQUARENESS / Y STRAIGHTNESS

TEST <u>#3.</u>	SUBJECT Y TO Z AXIS SQUARENESS Y AXIS STRAIGHTNESS	ILLUSTRATION																														
																																
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">INSPECTION DEVICE/S</th> <th colspan="3">TOLERANCE</th> <th rowspan="2">METHOD</th> </tr> <tr> <th>ALLOWABLE</th> <th>ACTUAL</th> <th>DEVIATION</th> </tr> </thead> <tbody> <tr> <td rowspan="6">HAMAR LASER TARGETS</td> <td><u>Y AXIS STRAIGHTNESS</u> VERTICAL .01/1000 MM .1 MM TOTAL</td> <td>_____</td> <td>_____</td> <td rowspan="6">MOUNT HAMAR LASER TO MACHINE BASE OR BED. ALIGN LASER TO Y AXIS TRAVEL. PROJECT BEAM PERPENDICULAR TO Y AXIS AND MOUNT TARGET TO Z AXIS RAM. MEASURE SQUARENESS OF BEST-FIT LINE THROUGH Z AXIS TRAVEL IN 200 MM INCREMENTS.  ZERO THE ENDS OF DATA FOR EACH AXIS TO RECORD STRAIGHTNESS.</td> </tr> <tr> <td>HORIZONTAL .01/1000 MM .1 MM TOTAL</td> <td>_____</td> <td>_____</td> </tr> <tr> <td><u>Y TO Z SQUARENESS</u> 3 SECONDS (.015/1000 MM)</td> <td>_____</td> <td>_____</td> </tr> <tr> <td></td> <td>_____</td> <td>_____</td> </tr> <tr> <td></td> <td>_____</td> <td>_____</td> </tr> <tr> <td></td> <td>_____</td> <td>_____</td> </tr> </tbody> </table>					INSPECTION DEVICE/S	TOLERANCE			METHOD	ALLOWABLE	ACTUAL	DEVIATION	HAMAR LASER TARGETS	<u>Y AXIS STRAIGHTNESS</u> VERTICAL .01/1000 MM .1 MM TOTAL	_____	_____	MOUNT HAMAR LASER TO MACHINE BASE OR BED. ALIGN LASER TO Y AXIS TRAVEL. PROJECT BEAM PERPENDICULAR TO Y AXIS AND MOUNT TARGET TO Z AXIS RAM. MEASURE SQUARENESS OF BEST-FIT LINE THROUGH Z AXIS TRAVEL IN 200 MM INCREMENTS.  ZERO THE ENDS OF DATA FOR EACH AXIS TO RECORD STRAIGHTNESS.	HORIZONTAL .01/1000 MM .1 MM TOTAL	_____	_____	<u>Y TO Z SQUARENESS</u> 3 SECONDS (.015/1000 MM)	_____	_____		_____	_____		_____	_____		_____	_____
INSPECTION DEVICE/S	TOLERANCE			METHOD																												
	ALLOWABLE	ACTUAL	DEVIATION																													
HAMAR LASER TARGETS	<u>Y AXIS STRAIGHTNESS</u> VERTICAL .01/1000 MM .1 MM TOTAL	_____	_____	MOUNT HAMAR LASER TO MACHINE BASE OR BED. ALIGN LASER TO Y AXIS TRAVEL. PROJECT BEAM PERPENDICULAR TO Y AXIS AND MOUNT TARGET TO Z AXIS RAM. MEASURE SQUARENESS OF BEST-FIT LINE THROUGH Z AXIS TRAVEL IN 200 MM INCREMENTS.  ZERO THE ENDS OF DATA FOR EACH AXIS TO RECORD STRAIGHTNESS.																												
	HORIZONTAL .01/1000 MM .1 MM TOTAL	_____	_____																													
	<u>Y TO Z SQUARENESS</u> 3 SECONDS (.015/1000 MM)	_____	_____																													
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		_____	_____																													
		_____	_____																													
ISSUED	DATE	INSPECTOR	DATE	CUSTOMER																												
					DATE																											

## 17.4 X-AXIS POSITIONING ACCURACY

TEST <u>#4.</u>	SUBJECT	X AXIS POSITIONING ACCURACY					
ILLUSTRATION							
INSPECTION DEVICE/S	TOLERANCE			METHOD			
	ALLOWABLE	ACTUAL	DEVIATION				
LASER INTERFEROMETER RETRO REFLECTOR	<u>ACCURACY</u> .076MM TOTAL  <u>REPEATABILITY</u> .015 MM	_____	_____	MOUNT REMOTE INTERFEROMETER TO STEADY REST. ATTACH RETRO-REFLECTOR TO FRONT OF RAM WITH MAGNETIC BASE. ALIGN LASER BEAM AND TAKE READINGS AT 500 MM INCREMENTS. COMPENSATE FEEDBACK TO REQUIREMENTS. 1 ISO 230 2 3 BI-DIRECTIONAL RUNS 3 QUASI-PILGRIM STEP METHOD.			
ISSUED	DATE	INSPECTOR	DATE	CUSTOMER			

**17.5 Y-AXIS POSITIONING ACCURACY**

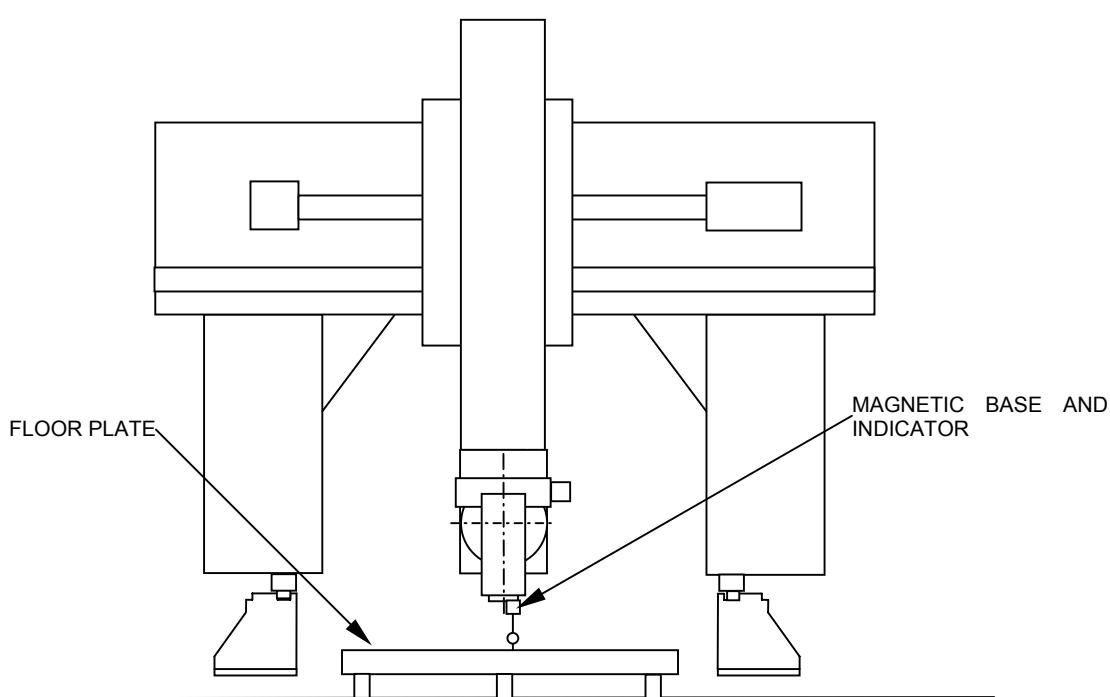
TEST <u>#5.</u>	SUBJECT: Y AXIS POSITIONING ACCURACY				
INSPECTION DEVICE/S	ILLUSTRATION				
	ALLOWABLE	ACTUAL	DEVIATION		
LASER INTERFEROMETER RETRO REFLECTOR	<u>ACCURACY</u> .03 MM TOTAL <u>REPEATABILITY</u> .015 MM	_____	_____	MOUNT REMOTE INTERFEROMETER TO STEADY REST MOUNT RETRO-REFLECTOR TO SPINDLE, USING MAGNETIC BASE. ALIGN LASER BEAM AND TAKE READINGS AT 500 MM INCREMENTS. COMPENSATE FEEDBACK TO REQUIREMENTS. 1. ISO 230 2. BI-DIRECTIONAL RUNS 3. QUASI-PILGRIM STEP METHOD.	
ISSUED _____	DATE _____	INSPECTOR _____	DATE _____	CUSTOMER _____	DATE _____

## 17.6 Z-AXIS POSITIONING ACCURACY

TEST <u>#6.</u>	SUBJECT: Z AXIS POSITIONING ACCURACY		
INSPECTION DEVICE/S	ILLUSTRATION		
	ALLOWABLE	ACTUAL	DEVIATION
LASER	<u>ACCURACY</u> .03 MM TOTAL	_____	_____
INTERFEROMETER	<u>REPEATABILITY</u> .015 MM	_____	_____
RETRO REFLECTOR			MOUNT REMOTE INTERFEROMETER TO STEADY REST IN THE MIDDLE OF THE WORK ZONE IF PRACTICAL. MOUNT RETRO-REFLECTOR TO THE SPINDLE FACE OR NEAR THE TOOL POINT USING MAGNETIC BASE. ALIGN LASER BEAM AND TAKE READINGS AT 300 MM INCREMENTS. COMPENSATE FEEDBACK TO REQUIREMENTS.  1 ISO 230 2 BI-DIRECTIONAL RUNS 3 QUASI-PILGRIM STEP METHOD.
ISSUED	DATE	INSPECTOR	DATE
			CUSTOMER
			DATE

## INSPECTION PROCEDURES

### 17.7 FLOORPLATE TRACKING

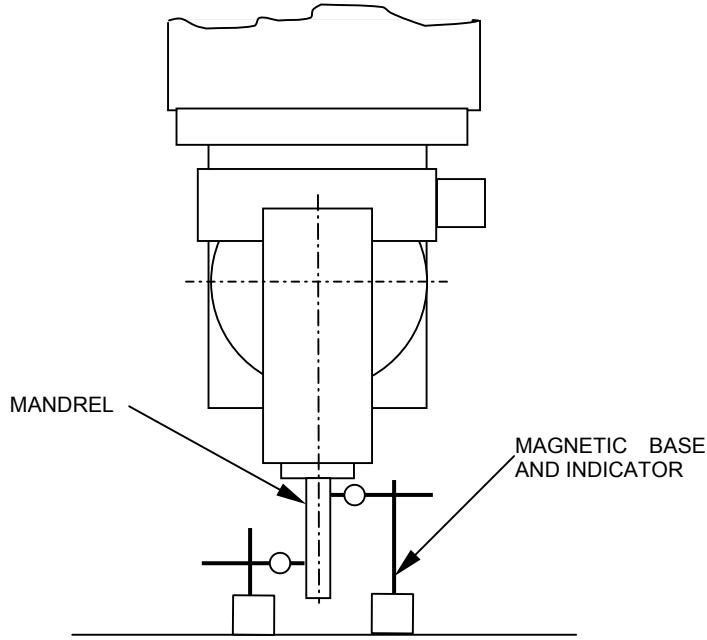
TEST <u>#7.</u>	SUBJECT: FLOORPLATE TRACKING			
ILLUSTRATION				
				
INSPECTION DEVICE/S	TOLERANCE			METHOD
	ALLOWABLE	ACTUAL	DEVIATION	
MAGNETIC BASE AND INDICATOR	<u>X DIRECTION</u> .015 MM / M .03 MM TOTAL  <u>Y DIRECTION</u> .015 MM / M .03 MM TOTAL	_____	_____	USING AN INDICATOR MOUNTED TO THE SPINDLE, 1. ISO 230 2. 3 BI-DIRECTIONAL RUNS 3. QUASI-PILGRIM STEP METHOD.
ISSUED	DATE	INSPECTOR	DATE	CUSTOMER DATE

## 17.8 KEYWAY TRACKING

TEST <u>#8.</u>	SUBJECT: KEYWAY TRACKING			
INSPECTION DEVICE/S	TOLERANCE			METHOD
	ALLOWABLE	ACTUAL	DEVIATION	
MAGNETIC BASE AND INDICATOR	1) .015/1000 MM .03 MM TOTAL 2) .015/1000 MM .03 MM TOTAL 3) .015/1000 MM .03 MM TOTAL 4) .015/1000 MM .03 MM TOTAL 5) .015/1000 MM .03 MM TOTAL 6) .015/1000 MM .03 MM TOTAL	<hr/>	<hr/>	USING AN INDICATOR MOUNTED TO THE SPINDLE, TRACK THE 6 KEYWAYS AND RECORD THE TOTAL INDICATOR READING.
ISSUED                    DATE	INSPECTOR                    DATE	CUSTOMER                    DATE		

## INSPECTION PROCEDURES

### 17.9 SPINDLE RUNOUT

TEST <u># 9.</u>	SUBJECT: SPINDLE RUNOUT					
ILLUSTRATION						
						
INSPECTION DEVICE/S	TOLERANCE					
	ALLOWABLE	ACTUAL	DEVIATION			
MANDREL MAGNETIC BASE AND INDICATOR	<u>25 MM FROM SPDL NOSE</u> .008 MM  <u>300 MM FROM SPDL NOSE</u> .015 MM	_____	_____	PLACE MANDREL IN SPINDLE. POSITION TWO MAGNETIC BASE AND INDICATORS SUCH THAT ONE STYLUS IS 25 MM AWAY FROM THE SPINDLE NOSE, AND THE OTHER 300 MM. SET INDICATORS TO ZERO AND ROTATE THE SPINDLE TWO REVOLUTIONS. RECORD THE TOTAL INDICATOR MOVEMENT.		
ISSUED	DATE	INSPECTOR				

# **CHAPTER 18 - MACHINE DRAWINGS**



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## CHAPTER 18 - MACHINE DRAWINGS

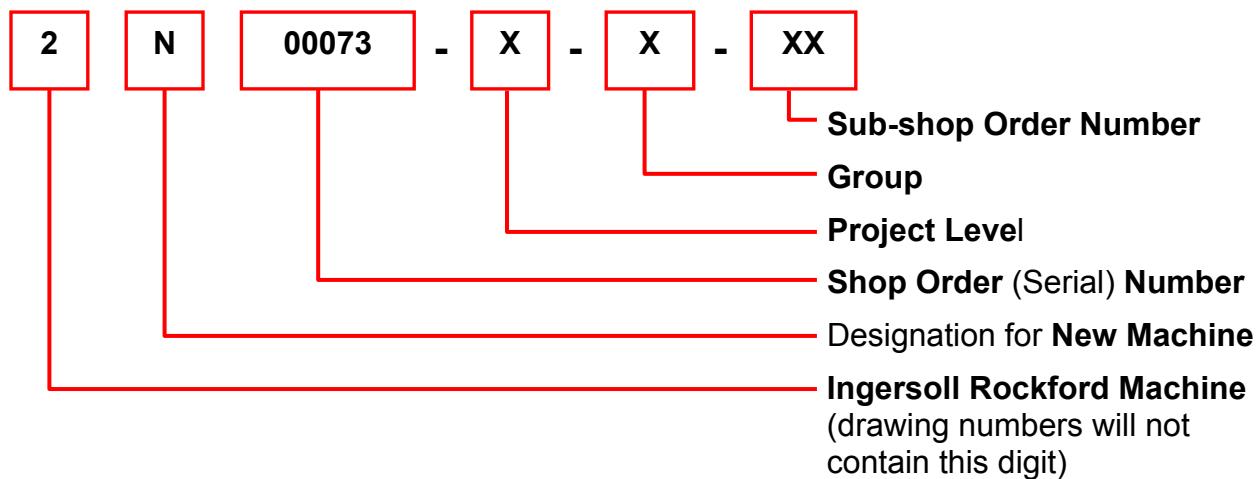
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## 18.1 PROJECT NUMBERING STRUCTURE

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Ingersoll uses a numbering method to identify the machines and related parts for this project. Understanding how this system works will enable maintenance and engineering personnel to access necessary information. Each component in the project is identified with a number as shown below.



The level numbers assigned for this project are:

- 1 = Machine
- 2 = Spindle Units

The group and sub-shop order numbers under each project level are detailed in the next section.

For example, to identify the bill of material or part drawings for the saddle on the machine, the number used will be 2N00073-1-3-30.

### 18.1.1 MACHINE PROJECT GROUP AND SUB-SHOP ORDERS

The following is the list of group and sub-shop order numbers for the machine.

GROUP IDENTIFIER	GROUP	SUB-SHOP ORDER	DESCRIPTION
<b>X-Axis</b>	-1	-10	X-Axis Runways
		-14	X-Axis Power Carriers
		-15	X-Axis Way Covers
		-16	Chip Conveyors
		-18	Floor Plate
		-E2	X-Axis Electrical Hardware
		-E9	X-Axis Electrical Boxes
		-F2	X-Axis Fluids
		-P9	X-Axis Utility Panels
<b>Y-Axis</b>	-2	-20	Y-Axis Column
		-21	Y-Axis Bridge
		-24	Y-Axis Power Carriers
		-25	Y-Axis Way Covers
		-E2	Y-Axis Electrical Hardware
		-E9	Y-Axis Electrical Boxes
		-F2	Y-Axis Fluids
		-P9	Y-Axis Utility Panels
<b>Z-Axis</b>	-3	-30	Y/Z-Axis Saddle
		-34	Z-Axis Power Carriers
		-35	Z-Axis Way Covers
		-38	Ram
		-E2	Z-Axis Electrical Hardware
		-E9	Z-Axis Electrical Boxes
		-F2	Z-Axis Fluids
<b>Head</b>	-4	-39	C-Axis
		-E2	C-Axis Electrical Hardware
		-F2	C-Axis Fluids
<b>Tool Changer</b>	-6	-61	Tool Carousel
		-E2	Electrical Hardware
		-E9	Electrical Boxes

GROUP IDENTIFIER	GROUP	SUB-SHOP ORDER	DESCRIPTION
<b>Controls</b>	-C	-C1	Main Cabinets
		-C2	Operator Console
		-C4	CNC Controller & Equipment
		-C7	Part Probe
		-C8	Tool Probe
		-C9	Chip Reader and Camera System
<b>Electrics</b>	-E	-E2	Electrical Hardware
		-E9	Electrical Boxes
<b>Fluids</b>	-F	-F2	Fluids
		-F3	Lubrication Equipment
		-F4	Pneumatic Equipment
		-F5	Coolant Equipment
		-F6	Hydraulic Tank Unit
		-F7	Chiller
		-F8	Mist Collection, Part Wash
<b>Pipe, Wire &amp; Shielding</b>	-P	-P1	Enclosure and Safety Equipment
		-P2	Platforms, Ladders, and Stairs
		-P3	Operator Platform
		-P4	Shielding
		-P5	Safety Placards

### 18.1.2 SPINDLE UNIT PROJECT GROUP AND SUB-SHOP ORDERS

The following is the list of group and sub-shop order numbers for the spindle units, which are level number 2.

GROUP	GROUP IDENTIFIER
-90	Offset Spindle Unit

## 18.2 INGERSOLL PART NUMBERS

---

This explanation helps you use the Ingersoll mechanical drawings. Understanding this system will eliminate confusion when searching for a particular assembly.

The Ingersoll part number is formatted differently for standard and purchased parts versus machine-specific parts. The standard/purchased part numbers are written XXX-XXXX-XX-XX and the machine-specific part numbers are written XXXXXX -XX-XXX.

### 18.2.1 NUMBERING SYSTEM FOR STANDARD OR PURCHASED PARTS

An eleven-digit number represents standard Ingersoll components or items purchased by Ingersoll for use on this machine. Ingersoll assigns all purchased parts an eleven-digit part number compatible with its bill of material system. All purchased components listed on our layout drawings are given the Ingersoll part number, and the vendor's name and part number. The bill of material also lists the Ingersoll part number, as well as the vendor's name and number. This system helps when defining and ordering spare parts for purchased components.

Example purchased part number: 975-1896-30-02

### 18.2.2 NUMBERING SYSTEM FOR MACHINE SPECIFIC PARTS

A twelve character number represents parts that Ingersoll has produced specifically for your machine or parts previously produced that are not standard Ingersoll components. An explanation of the number is as follows:

Example machine-specific part number: N00073-13-007

The first six characters in the part number (**N00073-13-007**) are the machine number or shop order number that Ingersoll has assigned to the machine. (The shop order may also be shown with the digit 2 in front of these six characters).

The two-digit number (**N00073-13-007**) is referred to as the "sub-shop order number". This number relates to the different sub-systems of the machine. Each sub-system, (electrical system, hydraulic system, heads, slides, fixtures, etc.), has its own sub-shop number.

The three-digit number following the sub-shop order number (**N00073-13-007**) indicates either a layout or a detail number. The layout number relates to an assembly of manufactured and/or purchased parts. The detail number relates to individual parts in the assembly. As the engineer designs the assembly, the details are drawn starting with the first detail or 001.

Each manufactured part will have a unique and specific number. Layout drawings show the assembly and gives specific assembly instructions where they are needed. Purchased assemblies are 400 series numbers and layouts are 600 series numbers.

Example layout part number: N00073-13-**620**

## 18.3 MECHANICAL DRAWINGS

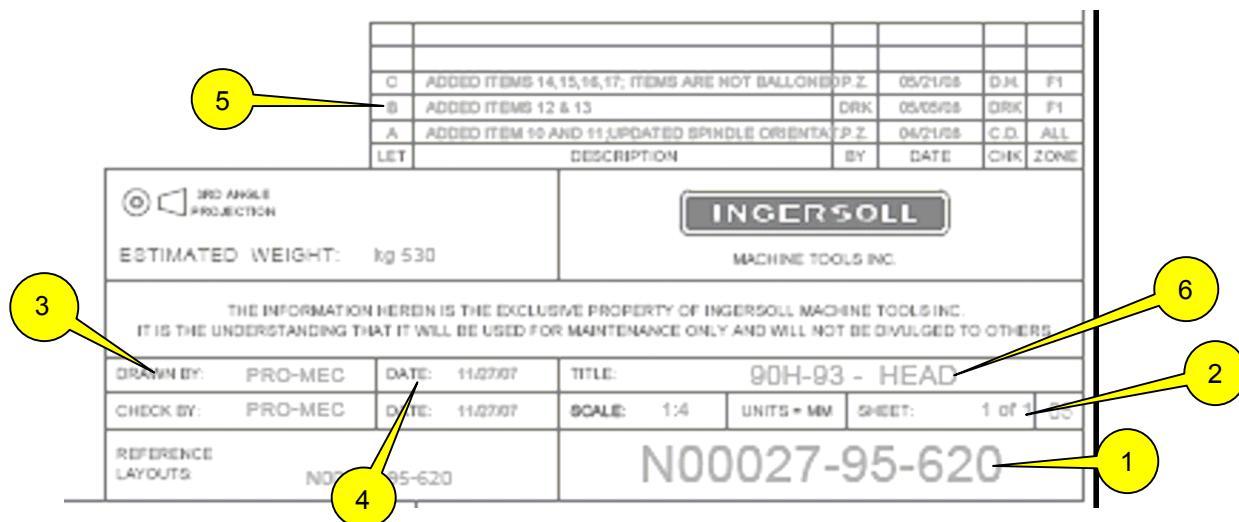
Ingersoll provides a set of mechanical layout drawings with each machine. The layouts show each mechanical component's assembly.

Information contained within the mechanical drawings shall not be copied or disclosed to others except as authorized in writing by Ingersoll Machine Tools, Inc.

### 18.3.1 TITLE BLOCK

In the lower right hand corner of each sheet in the drawing sets is a title block that is used to identify the particular page. The title block includes:

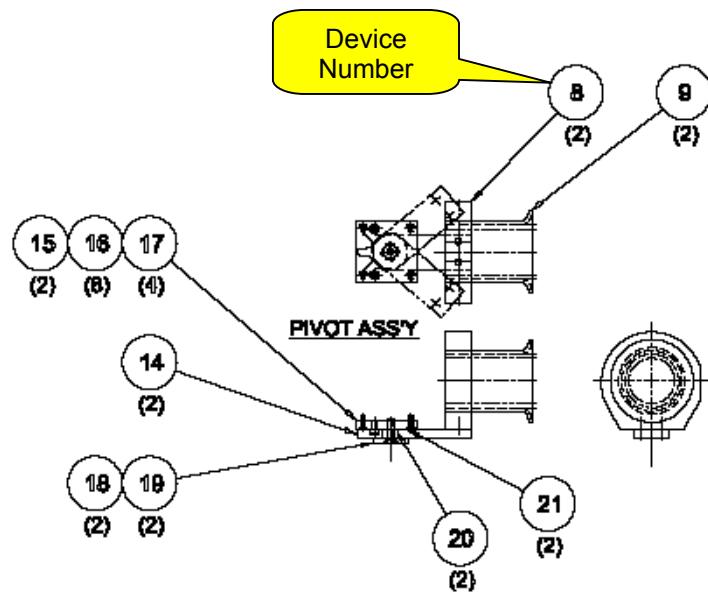
- (1) the mechanical drawing set number
- (2) the sheet number
- (3) the design engineer or company
- (4) the date the drawing was produced
- (5) a record of any changes made on this page
- (6) a title that designates what device is shown on the page



When communicating with Ingersoll regarding mechanical questions (or other related questions), please refer to the drawing number in the title block.

### 18.3.2 ADDITIONAL DEVICE INFORMATION

Each device in the mechanical drawings is identified with a device number. This device number is used to create a parts list on each page. This parts list includes quantity, Ingersoll part number and a description. An example is shown below.



ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	N00011-35-005	BRACKET,HEAD MOUNTING
2	20	910-0886-30-00	SCREW,SOCKETHEADCAP*M8x1.25x25 MM LG DIN 912-12
3	1	N800-1843-30-00	PIN,DOWEL *McMASTER-CARR#81585A180*M8x18 LG.88
4	1	N00011-36-006	Y-AXIS FESTOON EXTENSION
5	28	910-4118-30-00	SCREW,BUTTONHEADSOCKETCAP*M8x1.0x12 MM LG
6	2	N800-0775-30-00	FITTING,ELEC.*PMA*BGG-70 (FLNG,STRAT.8 HLMOUNT)
7	1	N800-0774-30-00	CONDUIT,NONMETALLICFLEX*PMA*PPCO-70B.10
8	2	N800-0778-30-00	FITTING,ELEC.*PMA*BSH-R70 (TUBE CLAMP)
9	2	N800-0777-30-00	FITTING,ELEC.*PMA*BKE-R70G (BALL JOINT TERMINATION)
10	1	N00011-35-007	WRIST UTILITIES BOX
11	4	910-1215-30-00	SCREW,SOCKETHEADCAP*M8x1.25x25 MM LG DIN 912-12
12	2	N00011-36-008	SPACER
13	2	N00011-35-010	RING, UTILITIES
14	2	N00011-35-008	ARM,CONDUIT
15	2	N00001-1-30-044	PLATE,CONDUIT
16	8	910-1578-30-00	SCREW,FLATHEADSOCKETCAP*M8x1.0x20 MM LG DIN 7891
17	4	910-1627-30-00	SCREW,SOCKETHEADCAP*M8x1.25x12 MM LG DIN 912-12
18	2	N00001-1-30-045	WASHER,FLATHEAD
19	2	910-5024-30-00	SCREW,FLATHEADSOCKETCAP*M10x1.5x35 MM LG DIN 7891
20	2	N00001-1-30-046	SPACER

## 18.4 FLUIDS DRAWINGS

Ingersoll provides a set of fluids drawings with each machine. The fluids drawings show the lubrication and filtration points on the machine and all the pneumatic circuits.

Information contained within the fluids drawings shall not be copied or disclosed to others except as authorized in writing by Ingersoll Machine Tools, Inc.

The schematics are arranged using the following numbering convention for the main categories of fluids being represented:

Drawing Number	Type
N00073-F1-665	Information
N00073-F2-653	Hydraulics
N00073-F3-654	Lubrication
N00073-F4-656	Pneumatics
N00073-F5-655	Cutting Coolant
N00073-F7-655	Motor Cooling

### 18.4.1 TABLE OF CONTENTS

Page 2 of the fluids drawing set contains a table of contents, which identifies the information on each sheet of the drawing set.

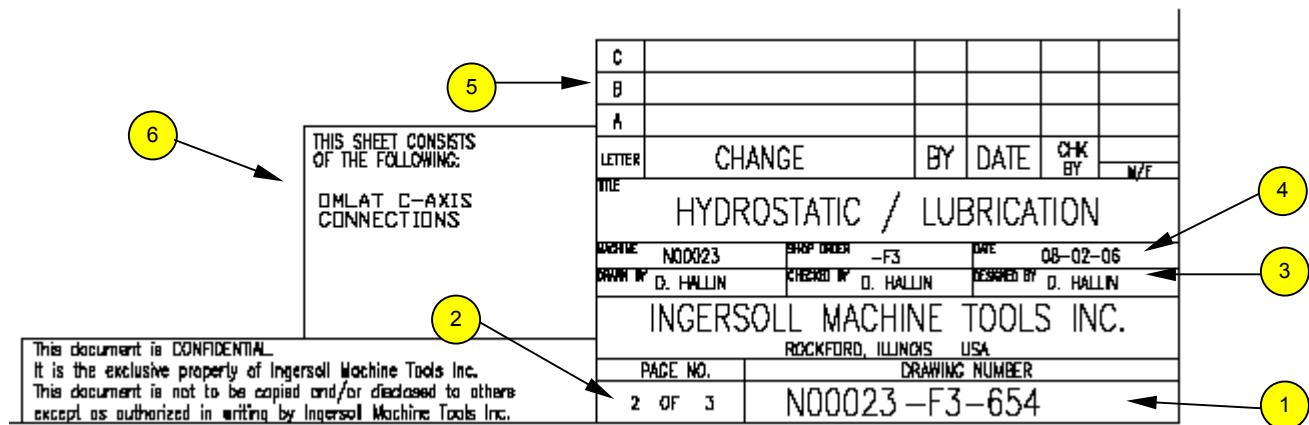
DRAWING NUMBER	PAGE NUMBER	TYPE	CONTENTS
N00073-F1-665	1	INFORMATION	COVER SHEET
N00073-F1-665	2	INFORMATION	TABLE OF CONTENTS
N00073-F2-653	1	HYDRAULIC	POWER UNIT, Z-AXIS COUNTERBALANCE
N00073-F2-653	2	HYDRAULIC	C,A-AXIS CLAMP, TOOL GRIPPER, ATTACHMENT LUBE, CORNER GRIPPER
N00073-F3-654	1	LUBRICATION	AXIS
N00073-F3-654	2	INFORMATION	C-AXIS, SPINDLE MOTOR CONNECTIONS
N00073-F3-654	3	INFORMATION	RAM FACE CONNECTIONS
N00073-F3-654	4	INFORMATION	SPINDLE UNIT
N00073-F4-656	1	PNEUMATIC	PNEUMATIC DISTRIBUTION, TOOL PROBE PURGE, TOOL CHANGE
		PNEUMATIC	XY-AXIS HEIDENHAIN PURGE, SPINDLE LUBRICANT SUPPLY
N00073-F5-655	1	COOLANT	CUTTING COOLANT
N00073-F7-655	1	COOLING	MOTOR COOLING

The title block of each schematic sheet will match the Contents column of the Table of Contents.

### 18.4.2 TITLE BLOCK

In the lower right hand corner of each sheet in the drawing sets is a title block that is used to identify the particular page. The title block includes:

- (1) the fluids drawing set number
- (2) the current page
- (3) the design engineer
- (4) the date the drawing was produced
- (5) a record of any changes made on this page
- (6) a label that designates what fluids circuit is shown on the page

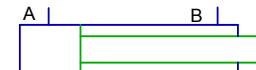
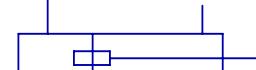
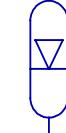
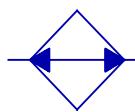
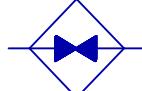


When communicating with Ingersoll regarding fluids questions (or other related questions), please refer to the drawing number in the title block.

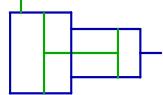
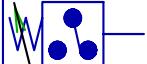
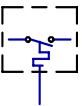
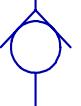
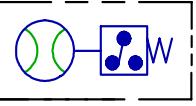
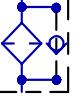
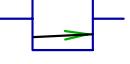
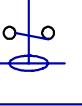
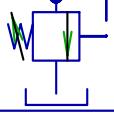
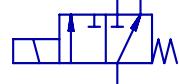
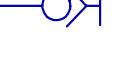
### 18.4.3 FLUID SYMBOLS

Shown in the following tables are the common symbols used in the fluids drawings and their identification.

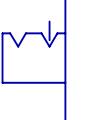
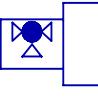
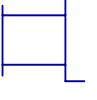
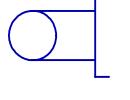
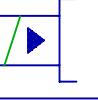
WORKING LINE		PLUGGED LINE	
PILOT or DRAIN LINE		LINE to VENTED MANIFOLD	
CONNECTOR		FLOW CONTROL FIXED	
FLEXIBLE HOSE		FLOW CONTROL VARIABLE	
LINES JOINING		PUMP FIXED DISPLACEMENT	
LINES PASSING		PUMP VARIABLE DISPLACEMENT	
DIRECTION of FLOW HYDRAULIC		PUMP VARIABLE DISPLACEMENT PRESSURE COMPENSATED	
DIRECTION of FLOW PNEUMATIC		HYDRAULIC MOTOR FIXED DISPLACEMENT SINGLE DIRECTION	
LINE to TANK above FLUID LEVEL		HYDRAULIC MOTOR VARIABLE DISPLACEMENT	
LINE to TANK below FLUID LEVEL		OSCILLATING MOTOR	

	HYDRAULIC CYLINDER SINGLE ACTING		TEMPERATURE GAGE
	HYDRAULIC CYLINDER DOUBLE ACTING		FLOW METER
	HYDRAULIC CYLINDER DIFFERENTIAL ROD		MOTOR
	HYDRAULIC CYLINDER DOUBLE END ROD		ACCUMULATOR SPRING LOADED
	HYDRAULIC CYLINDER with CUSHIONS		ACCUMULATOR GAS CHARGED
	DIRECTION of ROTATION		AIR LINE LUBRICATION
	COMPONENT ENCLOSURE		AIR LINE COALESCING FILTER
	TANK VENTED		AIR LINE FILTER
	TANK PRESSURIZED		CHILLER
	PRESSURE GAGE		HEATER

## COMMON FLUID SYMBOLS

	HEAT EXCHANGER		3 WAY MANUAL OVERRIDE VALVE
	INTENSIFIER		4 WAY with MANUAL OVERRIDE VALVE
	PRESSURE SWITCH		TEMPERATURE SWITCH
	CHECK VALVE		FLOW SWITCH
	MANUAL SHUT OFF VALVE		FILTER with BYPASS
	VALVE: SINGLE FLOW NORMALLY CLOSED		FLUID LEVEL SWITCH. DOUBLE
	VALVE: SINGLE FLOW NORMALLY OPENED		FLUID LEVEL SWITCH. SINGLE
	RELIEF VALVE		IMMERSION HEATER in BULB WELL
	2 WAY SOLENOID VALVE		NOZZLE
	3 WAY SOLENOID VALVE		QUICK DISCONNECT

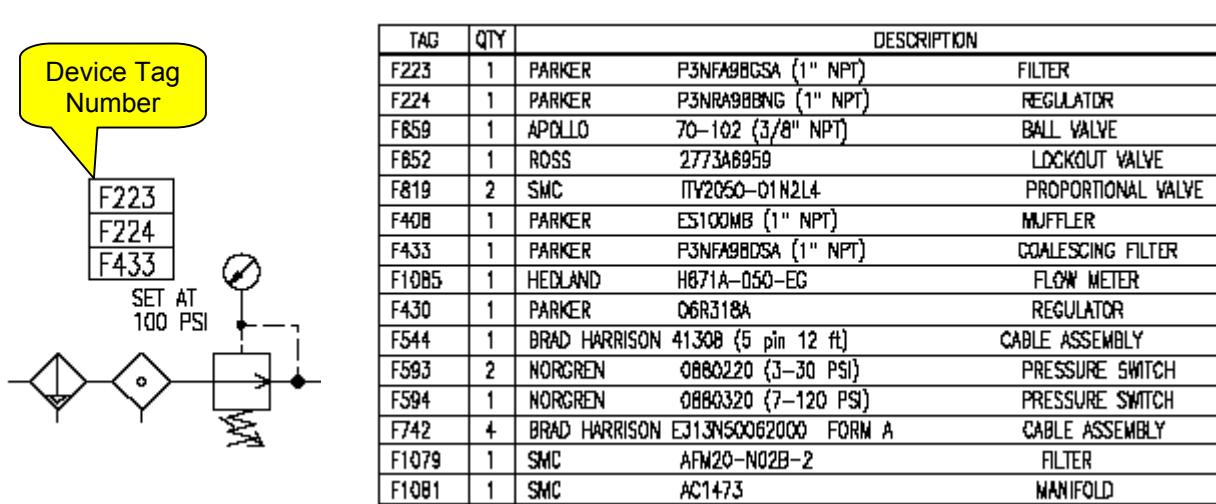
COMMON FLUID SYMBOLS

PRESSURE COMPENSATOR		SPRING	
DETENT		SERVO	
MANUAL			
MECHANICAL			
PEDAL			
PUSH BUTTON			
LEVER			
PILOT PRESSURE			
SOLENOID			
SOLENOID CONTROLLED PILOT PRESSURE OPERATED			

COMMON FLUID SYMBOLS

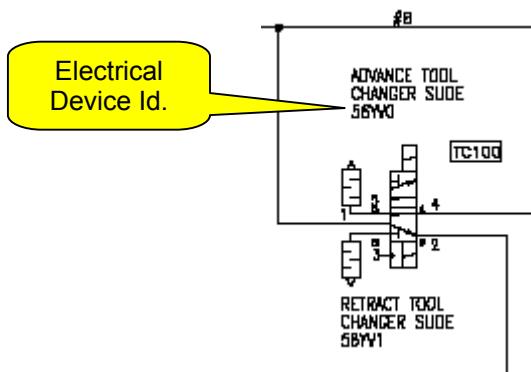
#### 18.4.4 ADDITIONAL DEVICE INFORMATION

Each device in the fluids schematics is identified with a component tag number. This tag number is used to create a parts list on each page. This parts list includes part description, quantity, vendor, and vendor part number. An example is shown below.



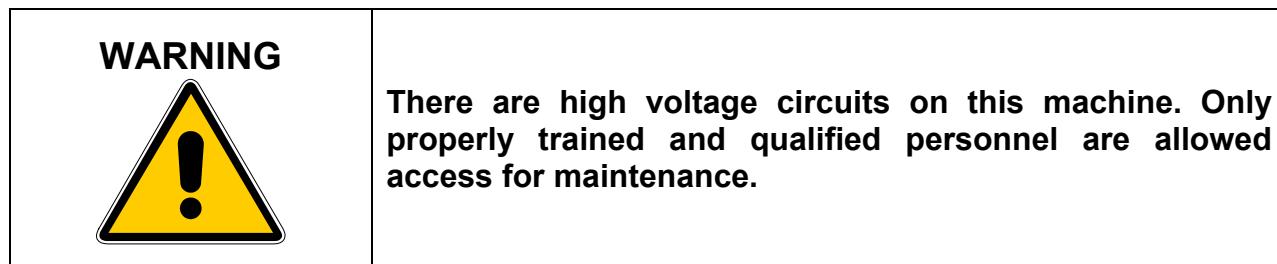
#### 18.4.5 FLUIDS-ELECTRICAL CROSS-REFERENCE

Each fluids device that is associated with an electrical input or output on the machine is labeled with the input/output name and device identification used in the electrical drawings and the PLC logic.



## 18.5 ELECTRICAL DRAWINGS

An electrical drawing set is provided with each machine containing detailed line drawings showing all of the machine and control cabinet wiring. These drawings also show each electrical console and junction box, the device wiring associated with every box, the routing of wires between the boxes, and an electrical part list.



**BEFORE BEGINNING ANY REPAIRS, MAINTENANCE, OR INSTALLATION WORK, ENSURE THAT THE POWER IS OFF, PROPER LOCKOUT TAG-OUT PROCEDURES HAVE BEEN FOLLOWED, AND ALL STORED ENERGY HAS BEEN RELEASED.**

Information contained within the electrical drawings shall not be copied or disclosed to others except as authorized in writing by Ingersoll Machine Tools, Inc.

### 18.5.1 TITLE BLOCK

In the lower right hand corner of each sheet in the electrical drawing set is a title block that is used to identify the particular page. A sample title block is shown below.

I/O RACK LAYOUT				
ELECTRICAL SCHEMATICS				
LETTER	CHANGE	BY	DATE	CHK BY M/F
MACHINE 2N00034      SHOP ORDER E2      DATE 1/15/07				
DRAWN BY SCOTT KUHAR      CHECKED BY SCOTT KUHAR      DESIGNED BY SCOTT KUHAR				
INGERSOLL MACHINE TOOLS, INC. ROCKFORD, ILLINOIS USA				
SHEET NUMBER	DRAWING NUMBER			
76	N00034-E2-651			

Record of any changes made to this page

Label that designates what electrical circuit is shown on this page

Design engineer

Date the drawing was produced

Page Number

Drawing Number

When communicating with Ingersoll regarding electrical questions (or other related questions), please refer to the drawing number (machine shop order number) in the title block.

### **18.5.2 INDEX**

The first page of the drawing set is a title page that identifies the machine. Page 2 contains an index, which summarizes the contents of each page in the drawing set. There are gaps intentionally left in the drawing set to accommodate inserted sheets for future designs and enhancements. This page also includes general information on wire colors, wire sizes, and definitions of various identifiers and nomenclature used in the schematics.

In general, the electrical drawing set is organized as follows:

<b><u>Sheet #</u></b>	<b><u>Contents</u></b>	<b><u>Description</u></b>
1-199	Electrical schematics	Detailed line drawing of electrical circuits
300's	Box Layouts	Wiring within junction boxes and wire routing
900's	Part List	List of all electrical parts shown on the electrical drawings

### **18.5.3 SCHEMATICS**

The Electrical Schematics are the detailed line drawings showing all of the machine and control cabinet wiring. The general order of the schematics from beginning to end, is as follows:

- Informational pages – title page, table of contents, etc.
- Control Commons – shows routing and connection of common or ground circuits.
- Line Side Power – these are circuits “ahead” of the main circuit breaker. These circuits remain “hot” when the main circuit breaker is turned off.
- High Voltage Equipment - including motors and transformers.
- Servo Drives – All machine servomotors and their associated amplifiers.
- AC Control – 115Vac circuits
- DC Control – 24Vdc circuits
- CNC
- Digital and Analog I/O – One sheet for each I/O card. The sheets are arranged in the order that the I/O cards are laid out in the racks. Spare sheets are inserted for spare slots.
- Grounding diagrams
- Panel Layout drawings

#### **18.5.3.1 DEVICE & WIRE IDENTIFICATION NUMBERS**

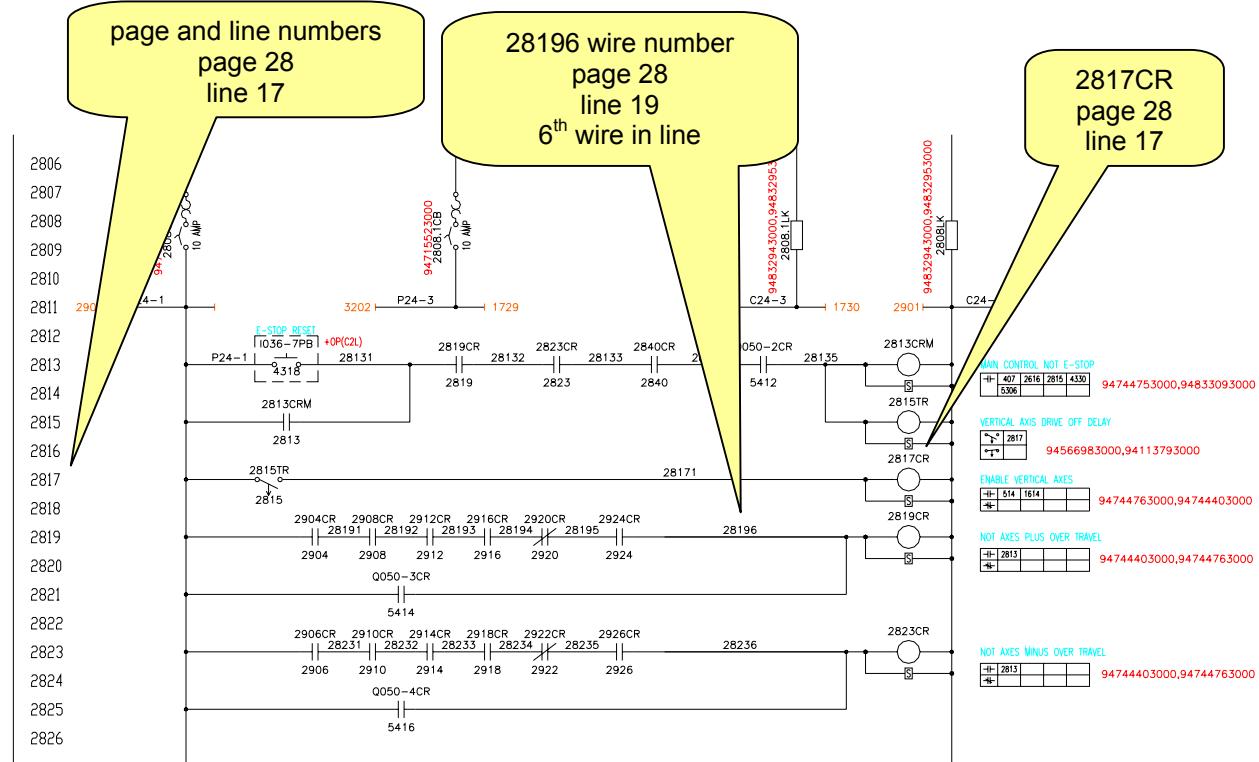
Cross-referencing for Component Identification is performed via a “page and line” method. The first (one or two) digits represent the page number, and the last two digits represent the line number on the page.

The **page and line numbers** are located along the left side of each sheet.

**Electrical device ID's** use this “page and line” numbering for component identifications. For example: 2817CR is the device id for a control relay located on page 28, line 17.

Located next to every component, is a device tag with its device ID engraved on it. This device tag exists for all components located in the control cabinets and for all devices located on the machine.

**Wire number ID's** are based on this “page and line” numbering. For example: wire number 28196 is located on page 28, line 19, and is the 6<sup>th</sup> wire in the chain of the circuit shown.



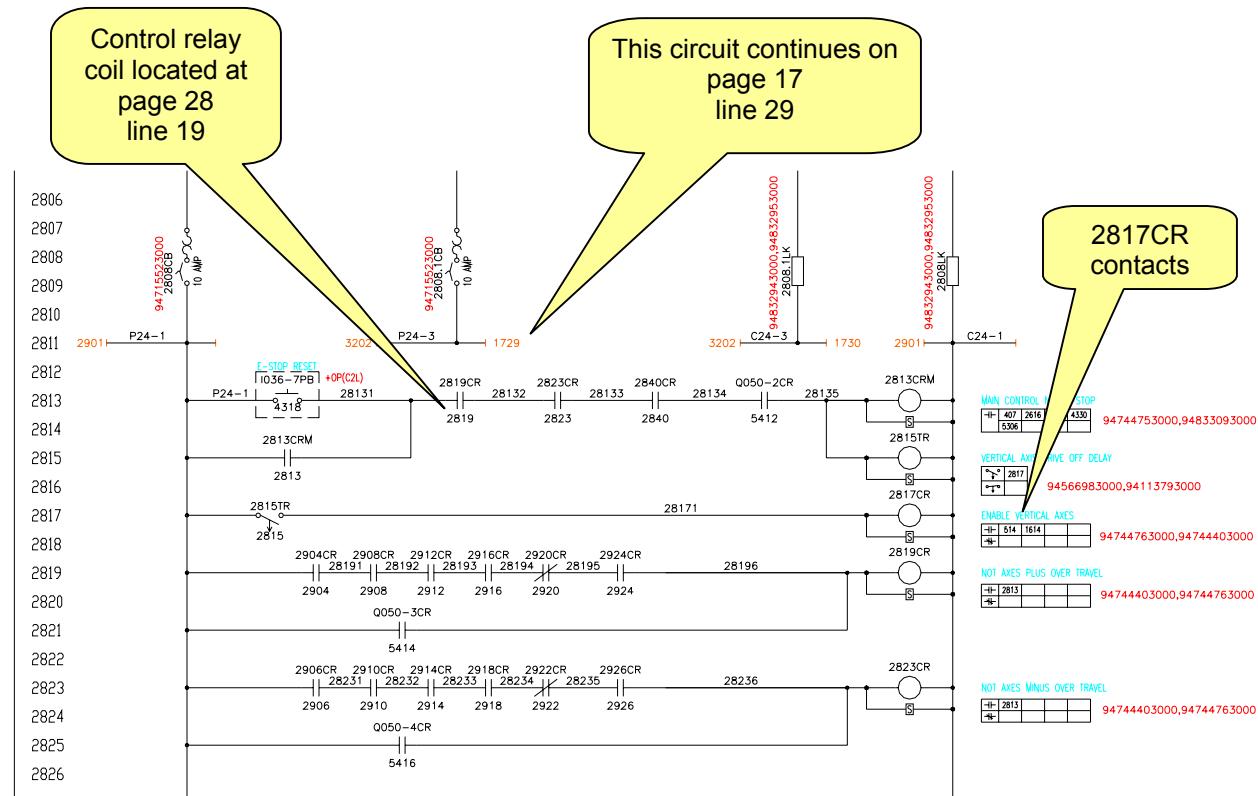
### 18.5.3.2 CROSS-REFERENCES

When wiring for a circuit continues from one page on to another page, this “page and line” numbering scheme is used for wire targets. For example: a target of 1729 indicates the wiring in that circuit continues on page 17, line 29.

Next to the coil of a control relay, there is a box that shows where the contacts of that relay are used in the schematics. Again, the “page and line” numbering method is used. The type of contact (normally open, normally closed, time delayed) is included in this box.

This practice is also used throughout the schematic for overload relay, and any other device that has an auxiliary contact associated with the device.

Below each control relay contact, there is a cross-reference number to indicate the location of the control relay coil associated with that contact.



### 18.5.3.3 ADDITIONAL DEVICE INFORMATION

The electrical schematics contain additional important information about many of electrical components.

- Device tag number

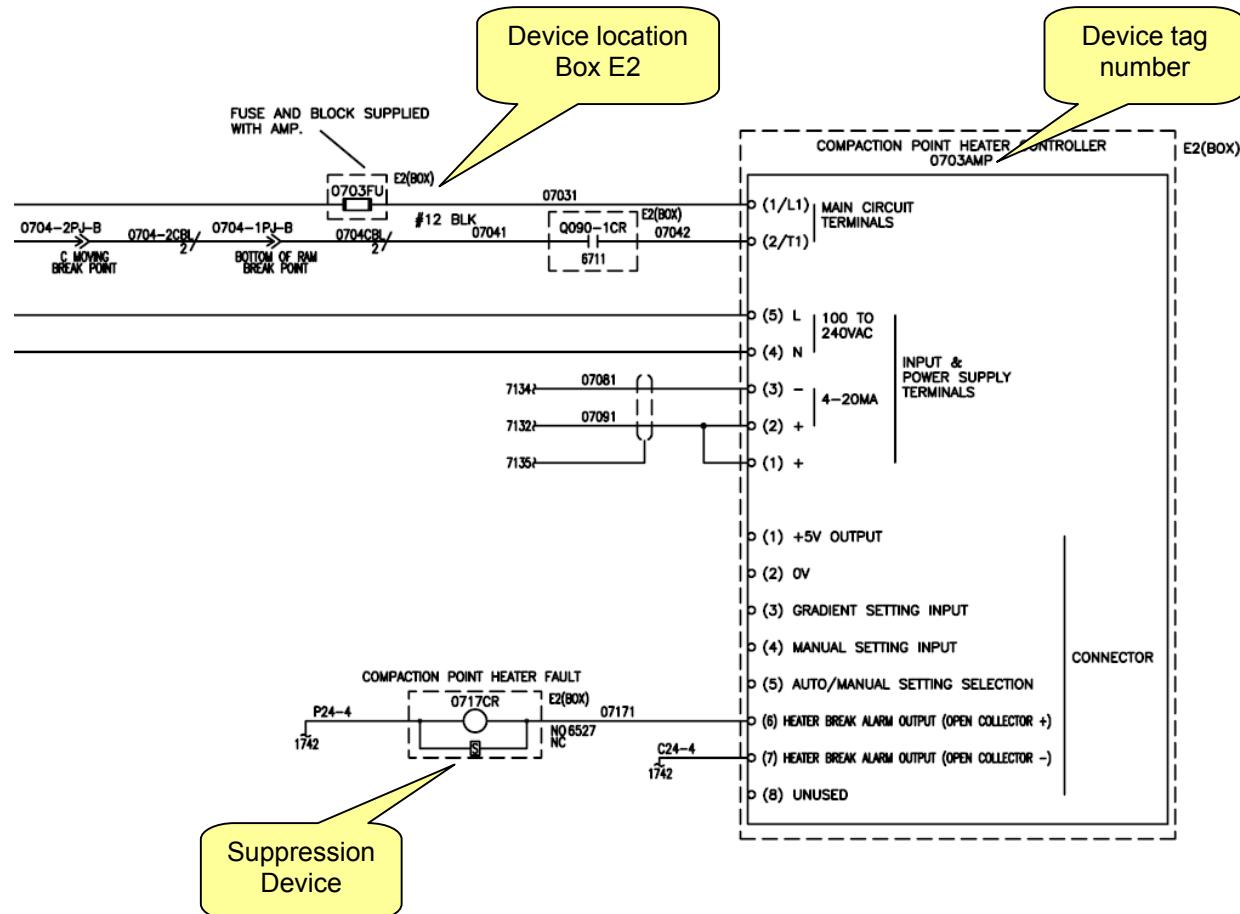
Each device is identified with a unique tag number. This tag number can be referenced to an Ingersoll part number and description, using the part list described in a later section.

- Suppression devices

All suppression devices for motor, contactors, control relays, and solenoids are shown and identified in the electrical schematics.

- Device location

When a device is located on the machine itself, instead of in the main control cabinets, the physical location of the device is noted in the schematics with a device location symbol. For example, a device located in or wired to box F will have a “+F” symbol next to the component in the schematics.



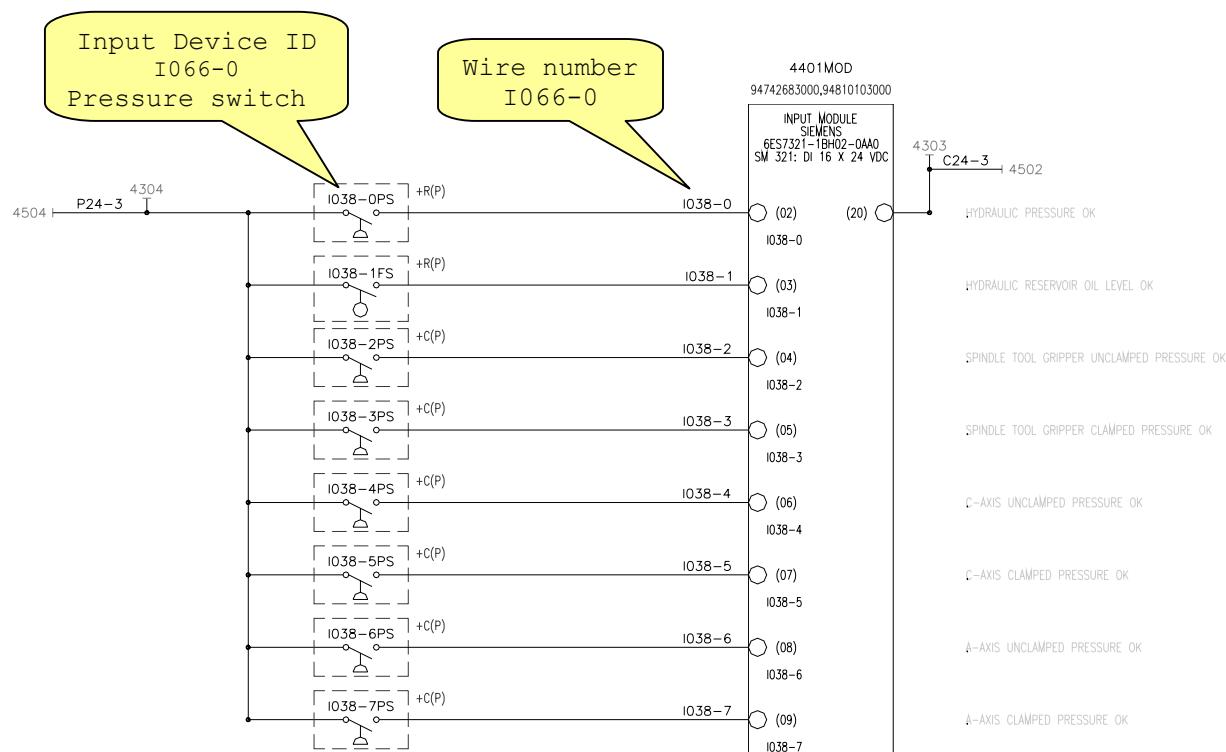
### 18.5.3.4 INPUTS & OUTPUTS

Each input and output is assigned a unique address for use in the PLC ladder logic.

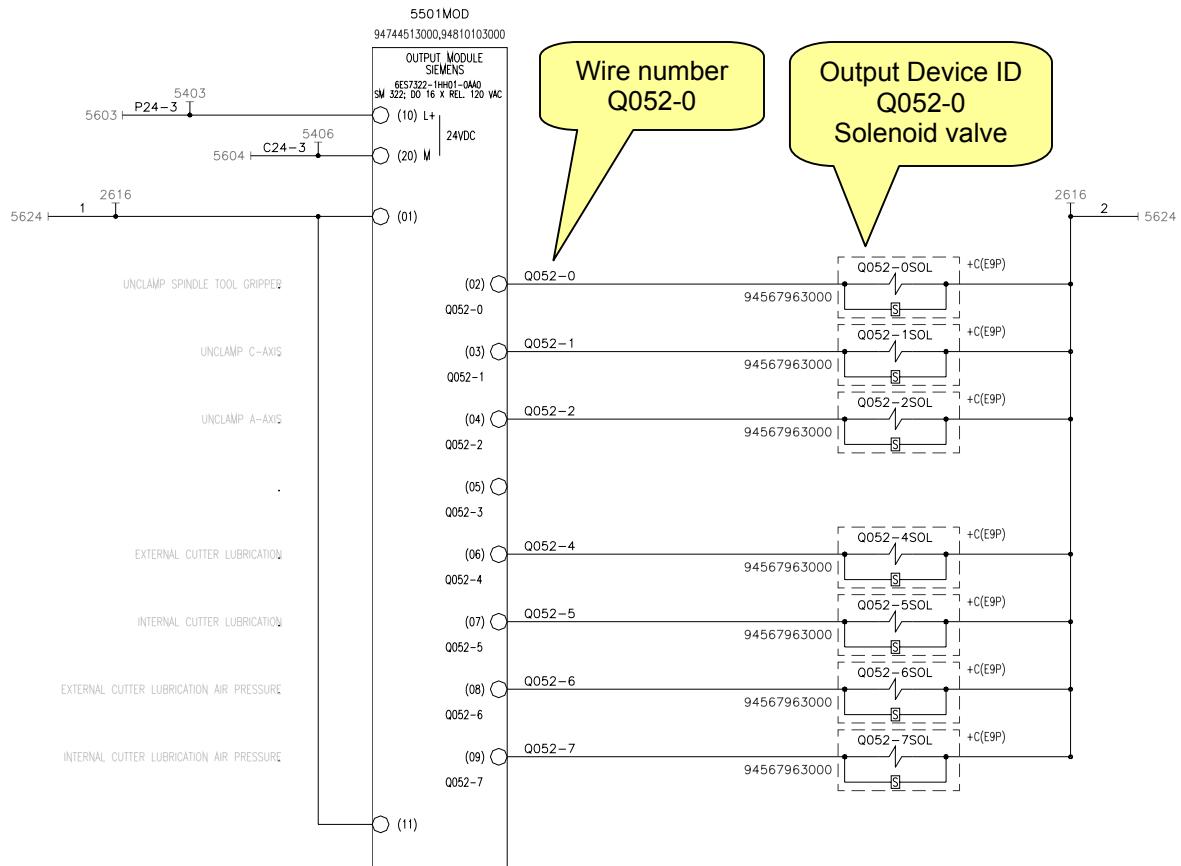
- Inputs are assigned addresses starting with the letter “I”.
- Outputs are assigned addresses starting with the letter “Q”.

To simplify logic debug, the device ID's and the wire numbers for inputs and outputs are labeled to match the PLC address.

Input Module:



## Output Module:



This device ID scheme greatly simplifies machine maintenance, and problem debugging. For example, if a maintenance person suspects a problem with a limit switch, and the device ID tag shows it is 2904LS, the maintenance person knows the switch is located on page 29 line 04 in the schematics. On this page, the schematics show the wiring circuit, subsequent places the circuit is used, and information on the parts in the circuit.

**18.5.3.5 GROUNDING**

For operator safety and proper machine performance, the machine requires a properly sized, reliable earth ground. Ingersoll recommends that a machine ground wire be attached between the machine and a metal building column that is tied to a building ground grid. A properly anchored and tested ground rod driven into the earth could also be used.

A grounding diagram is included in the schematics.

**18.5.3.6 PANEL LAYOUTS**

The locations of devices that are housed in the main control cabinets are shown in the Panel Layout section of the schematics.

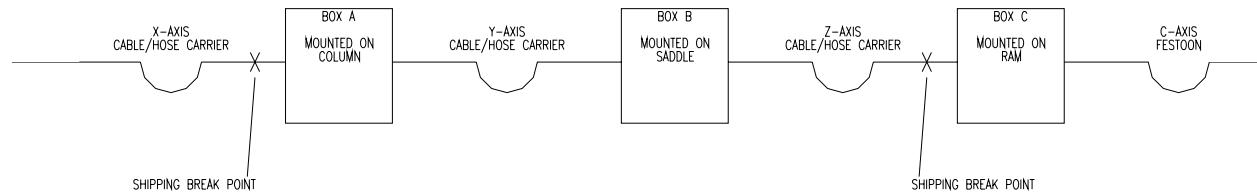
#### 18.5.4 BOX LAYOUTS

The Box Layouts begin with sheet number 300 and are used to locate the electrical boxes around the machine and identify the circuits inside, wiring terminals or wires pulled through the box, wiring to the electrical panels, and cable routings between electrical boxes and electrical cabinets.

##### 18.5.4.1 ELECTRICAL BOX LOCATIONS

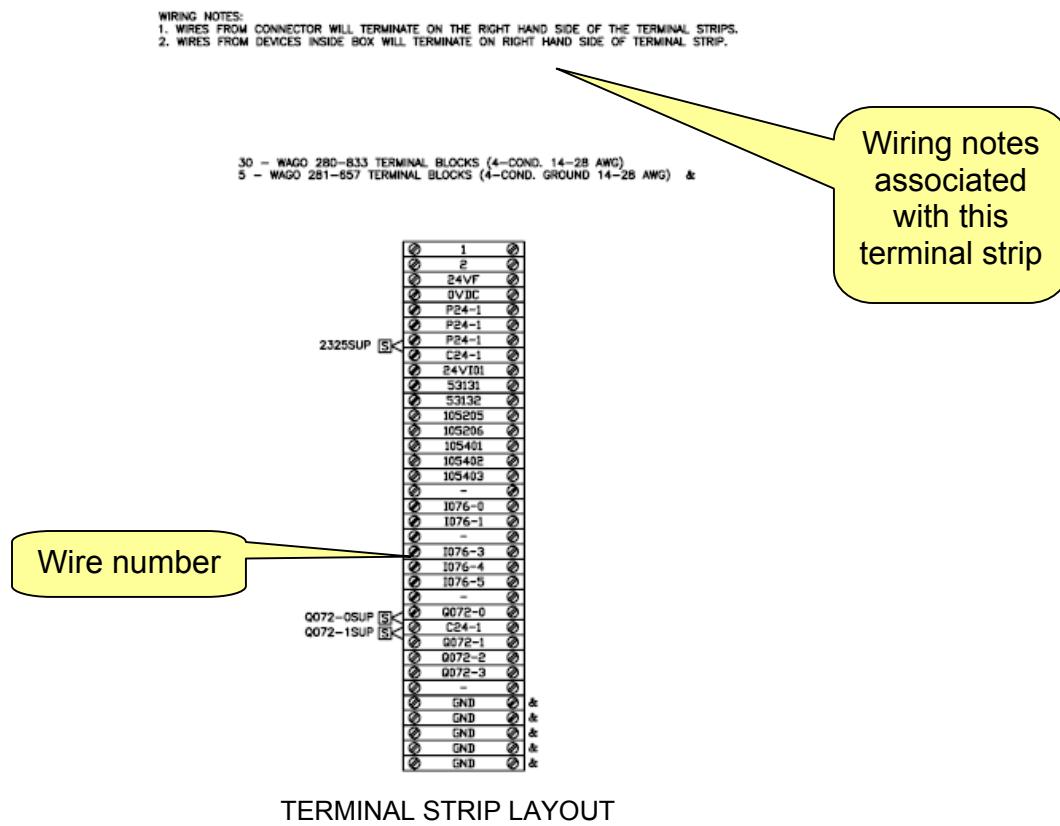
The first sheet of the Interconnections has a graphical “overview” of all electrical boxes, and identifies the box designation (usually a letter), the location of the box, and wire routings between the boxes.

Each electrical box on and around the machine is represented with a sheet in the Interconnections.

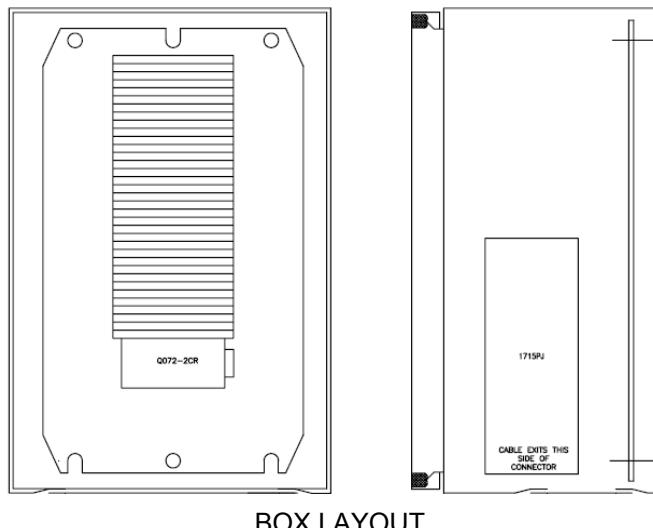


#### 18.5.4.2 ELECTRICAL BOX DETAILS

Each electrical box will be represented on at least two sheets, with the first sheet showing the terminal strip and the second sheet showing the box layout and any connectors for this box.



The terminal blocks are numbered. The number on the terminal block is the wire number.



#### 18.5.4.3 DEVICE & WIRE IDENTIFICATION NUMBERS

The “page and line” device ID’s and wire numbers ID’s used throughout the drawings provide a quick cross-reference between components shown in the Interconnects and their corresponding circuits in the electrical Schematics.

#### 18.5.5 PART LIST

A list of all electrical parts used on this machine begins on page 900 of the electrical drawings. This list gives information on each device shown in the electrical drawings. A sample, partial list is shown below.

The columns in the part list include:

TAG	- The electrical tag number given to this device
QTY	- The device quantity used on the machine
INGERSOLL #	- The Ingersoll part number associated with this device
KEYWORD	- The device type

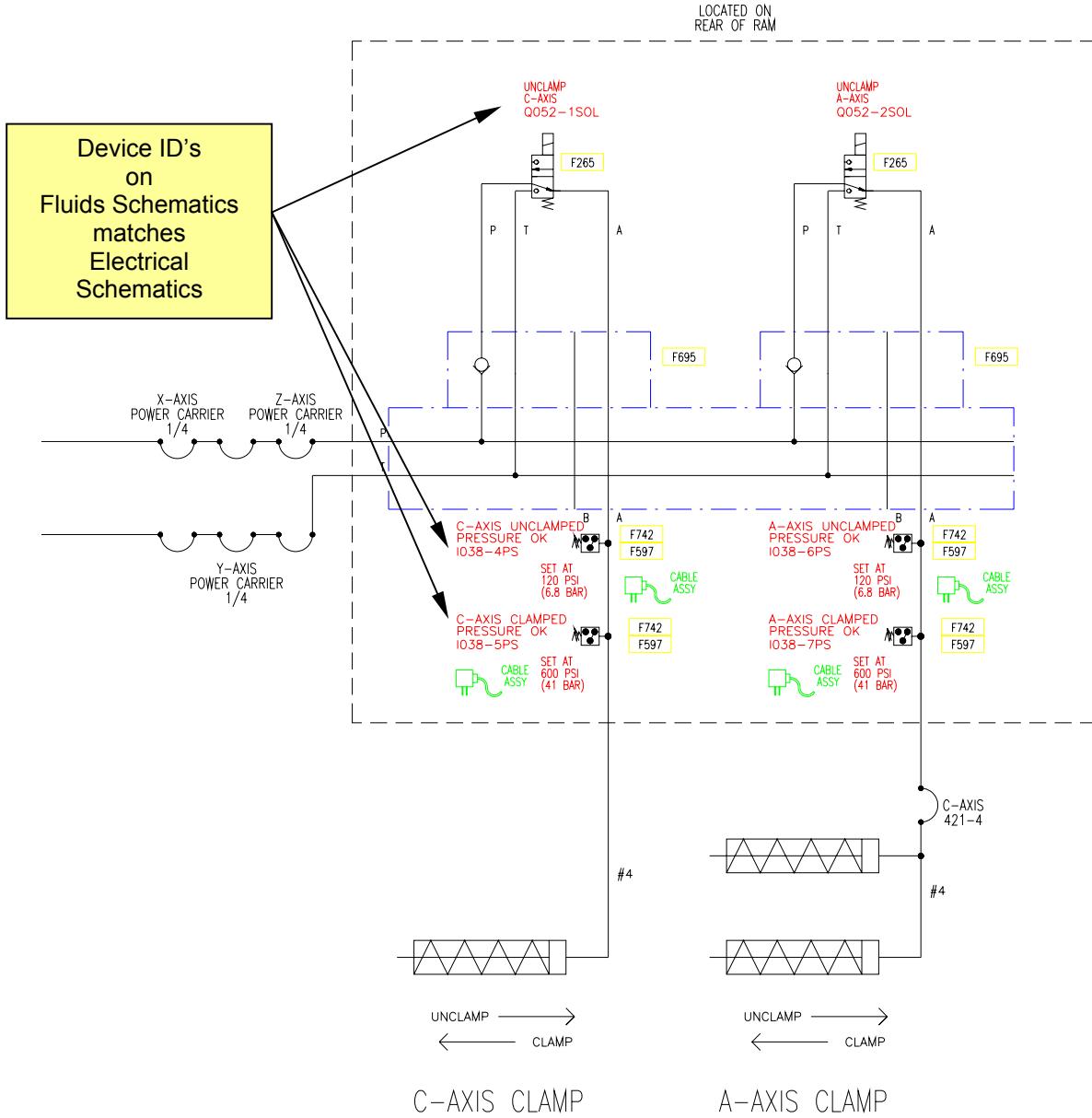
TAG	QTY	INGERSOLL #	KEYWORD
D303-1CB	1	945-6696-30-00	CIRCUIT BREAKER
D303-1CBL	1	N210-0134-97-02	CABLE ASSEMBLY
D303-2CBL	1	N210-0135-97-01	CABLE ASSEMBLY
D303-3CBL	1	N900-2052-30-03	CABLE
D303CB	1	945-6696-30-00	CIRCUIT BREAKER
D303CBL	1	N210-0134-97-01	CABLE ASSEMBLY
D303PJ	1	N944-0017-30-01	CONNECTDR
D303T	1	N900-1066-30-00	TRANSFORMER

SAMPLE PART LIST

#### 18.5.6 FLUIDS – ELECTRICAL CROSS REFERENCES

Many fluids components are electrically monitored as PLC inputs (pressure switches, temperatures, level switches, filter switches, etc.) or electrically controlled as PLC outputs (solenoid valves, pump motors, etc.).

In the fluids schematics, these components have the same device ID’s as shown in the electrical schematics.



The “page and line” device ID’s used in the Electrical Schematics provides a quick cross-referencing between components shown in the Fluids Schematics and their corresponding circuits in the Electrical Schematics.

**INGERSOLL**

**Machine Tools**

## **CHAPTER 19 - SPARE PARTS**



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## **CHAPTER 19 - SPARE PARTS**

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## 19.1 MACHINE SPARE PARTS

To maximize productivity from your custom built Ingersoll machine, maximum machine availability and up time is very important. For this reason, Ingersoll provides a list of recommended spare parts in the following table.

For equipment supplied by third-party vendors on this machine, refer to the vendor manuals for component lists. This includes the Oman Tool Changer manual.

Ingersoll suggests the customer contact their local Siemens CNC representative to verify which CNC components are readily available from Siemens, so the customer may be able to reduce on-hand spare parts.

Items marked with an asterisk(\*) in the Spare column are critical spares that the customer should definitely stock.

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
	1	2N00073-1-1-10		<b>RUNWAYS</b>		
1*	1	N945-0435-30-00	ENCODER	ENCODER, LINEAR, TAPE/PARTS SET, 16840 LG.	HEIDENHAIN	315422-69
1*	1	N945-0436-30-00	ENCODER	ENCODER, LINEAR, TAPE/PARTS SET, 16840 LG.	HEIDENHAIN	315422-N6
1	16	210-3069-97-05	ENCODER	SPECIFICATION, HOUSING ENCODER, 1800MM*	HEIDENHAIN	315423-05
1*	2	945-6565-30-00	ENCODER	ENCODER, READHEAD, FOR LB382C	HEIDENHAIN	315420-04
	1	2N00073-1-1-F2		<b>FLUIDS</b>		
1*	2	948-2714-30-00	SWITCH	SWITCH, PRESSURE, 3-30 PSI ADJ. RANGE	NORGREN	880220
1*	1	948-2715-30-00	SWITCH	SWITCH, PRESSURE, 120 PSI ADJUST.RANGE	NORGREN	880320
1*	1	N900-1185-30-00	COIL	COIL	CAMOZZI	P/N U77
	1	2N00073-1-2-20		<b>COLUMN</b>		
1*	4	N940-0143-30-00	MOTOR	MOTOR, NEW BEARINGS, INCLUDES PINION	PHASE MOTION CONTROL	TK450-300.33B
1*	1	948-0371-30-00	SWITCH	SWITCH, LIMIT, ELECTRO-MECHANICAL	BALLUFF	BNS-819-D-03-D12-62-10
	1	2N00073-1-2-21		<b>BRIDGE</b>		
1*	1	N945-0301-30-00	ENCODER	ENCODER, LINEAR, LB382C, LENGTH 4240MM	HEIDENHAIN	315422-06
1	2	210-3069-97-05	ENCODER	SPECIFICATION, HOUSING ENCODER, 1800MM*	HEIDENHAIN	315423-05
DUP	1	945-6565-30-00	ENCODER	ENCODER, READHEAD, FOR LB382C	HEIDENHAIN	315420-04
	1	2N00073-1-2-E2		<b>ELECTRICS</b>		
1*	2	945-6885-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY, L=1M	HEIDENHAIN	310128-01

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	2	N947-0052-30-06	MODULE	MODULE, DIGITAL INPUT, 8DI	SIEMENS	6ES7141-4BF00-0AA0
1*	5	N947-0052-30-07	MODULE	MODULE, DIGITAL OUTPUT, 4DO, 2A	SIEMENS	6ES7142-4BD00-0AA0
1*	2	N947-0052-30-09	MODULE	MODULE, ANALOG INPUT 4CH	SIEMENS	6ES7144-4GF00-0AB0
1*	1	N947-0052-30-01	MODULE	MODULE, POWER, 24VDC	SIEMENS	6ES7148-4CA00-0AA0
1*	1	N947-0052-30-00	MODULE	MODULE, INTERFACE 1M154-1 DP	SIEMENS	6ES7154-1AA00-0AB0
1*	1	N947-0052-30-02	MODULE	MODULE, CONNECTION, CM IM M12 7/8	SIEMENS	6ES7194-4AD00-0AA0
1*	7	N947-0052-30-04	MODULE	MODULE, CONNECTION, CM 4XM12	SIEMENS	6ES7194-4CA00-0AA0
1*	2	N947-0052-30-05	MODULE	MODULE, CONNECTION, CM 8XM12	SIEMENS	6ES7194-4CB00-0AA0
1*	2	N947-0049-30-00	FUSE	FUSE, 12.5AMP FAST BLOW REPLACEMENT	SIEMENS	6ES7194-4HB00-0AA0
1*	2	N900-2773-30-01	SWITCH	SWITCH, SAFETY	TELEMECANIQUE	XCSL768B3
1*	2	942-8763-30-00	KEY	KEY, SAFETY INTERLOCK ADJUSTABLE LOCKABLE	TELEMECANIQUE	ZCK-Y091
1*	1	N947-0052-30-03	MODULE	MODULE, CONNECTION, CM PM 7/8	SIEMENS	6ES7194-4BD00-0AA0
1	2N00073-1-2-E9		JUNCTION BOXES			
1*	4	N947-0316-30-00	DIODE	DIODE, SUPPRESSION, 1N4004	NEWARK	18C8917
1*	1	941-3085-30-00	SUPPRESSOR	SUPPRESSOR, IMMCO STOCK #21939	R-K ELECTRIC	RCY-6-A-30
1*	6	947-4492-30-00	BLOCK	BLOCK, CONTACT, 1 N.O., 1 N.C.	SIEMENS	3SB3400-0A
2*	4	N947-0322-30-00	RELAY	RELAY	SIEMENS	3TX7114-5LC03
1*	1	947-4446-30-00	POWER SUPPLY	POWER SUPPLY, AC*	SIEMENS	6EP1436-3BA00
1	2N00073-1-2-F2		FLUIDS			
1*	10	N900-3088-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY, 5 PIN MICRO	BRAD HARRISON	805S01D04M050
1*	13	N944-0347-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY*	CANFIELD	5F64201EU0A
1*	11	N944-0348-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY*	LUMBERG	VB1A-1-2-212-5M
1*	4	N923-0012-30-00	SENSOR	SENSOR, FLOW	SMC PNEUMATICS	PF2W540-N04N-2
1*	1	N923-0072-30-00	SWITCH	SWITCH, LEVEL, 1/8NPT, 3/4 IN BUNA FLOAT	GEMS	177818
1*	1	N923-0032-30-00	SWITCH	SWITCH, PRESSURE	NORGREN	0863624 250 BAR
DUP	3	948-2714-30-00	SWITCH	SWITCH, PRESSURE, 3-30 PSI ADJ. RANGE	NORGREN	880220
1*	1	948-2718-30-00	SWITCH	SWITCH, PRESSURE, 70-1015 PSI ADJ.RANGE	NORGREN	882119
1*	2	948-2719-30-00	SWITCH	SWITCH, PRESSURE, 150-2320 PSI ADJ. RANGE	NORGREN	882219
1*	4	N922-0084-30-00	VALVE	VALVE, 4-WAY	ATOS	DHI-0631/2-X-24DC
1*	1	N922-0281-30-00	VALVE	VALVE, 4-WAY	ATOS	DHI-0711/X-24DC

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	2	N922-0178-30-00	VALVE	VALVE, PROPORTIONAL	ATOS	HZGO-A-031-210
1*	2	N941-0197-30-00	PLUG	PLUG, ELECTRICAL	LYNCH	LEPG221
1*	1	948-0727-30-00	SWITCH	SWITCH, PROXIMITY, 24VDC 5-PIN CONNECTION	TRABON	527-005-670
1*	1	N922-0114-30-00	VALVE	VALVE, 2-WAY	DELTA	MAS2E-00-HC24-AS
1*	1	N922-0157-30-00	VALVE	VALVE, 2-WAY	DELTA	DE-S2H-00-HC-24-S
1*	1	920-1142-30-00	VALVE	VALVE, NEEDLE	PARKER	N400-S-10
1*	4	N922-0028-30-00	VALVE	VALVE, 5-WAY	CAMOZZI	951-000-P15-23-U77
1*	2	N922-0144-30-00	VALVE	VALVE, 5-WAY	CAMOZZI	961-000-P11-23-U77
1*	1	N923-0010-30-00	TRANSDUCER	TRANSDUCER, PRESSURE	NORGREN	863544
1*	4	N923-0039-30-00	TRANSDUCER	TRANSDUCER, PRESSURE	NORGREN	863644
1	<b>2N00073-1-3-30</b>			<b>SADDLE</b>		
DUP	2	N940-0143-30-00	MOTOR	MOTOR, NEW BEARINGS, INCLUDES PINION	PHASE MOTION CONTROL	TK450-300.33B
DUP	1	948-0371-30-00	SWITCH	SWITCH, LIMIT, ELECTRO-MECHANICAL	BALLUFF	BNS-819-D-03-D12-62-10
1*	1	N942-0162-30-00	SWITCH	SWITCH, ELECTROMECHANICAL, MULTIPLE POS.*	BALLUFF	BNS-819-B03-D12-72-10
1*	2	N00027-40-401	CYLINDER	SPECIFICATION, CYLINDER		
1*	1	N900-1077-30-00	SCALE	SCALE, LB382C, 2240 MM LENGTH	HEIDENHAIN	315418-10
1*	13	N00003-1-20-005	SHIM	SHIM		
1*	1	N00073-30-620		LAYOUT, SADDLE		
1*	2	N00073-30-621ASY	DRIVE	ASSEMBLY, Z-AXIS DRIVE		
1	6	962-5019-30-00	BEARING	BEARING, ANGULAR CONTACT THRUST, Ø50, Ø140*	SKF	BEAM 050140-2RS
1	4	605-0228-49-00	RING	RING	WACO	78400.02.514.03
1	4	605-0227-49-00	RING	RING, LOCATING	WACO	78400.02.513.04
1*	2	N00027-40-400	BALLSCREW	SPECIFICATION, BALLSCREW		
1	2	40175-21-003-9	RETAINER	RETAINER, BEARING	BRADLEY THOMPSON	
1	2	40175-21-005-9	RETAINER	RETAINER		
1	2	40175-21-006-9	RETAINER	RETAINER		
1	2	N932-0008-30-00	BELT	BELT, POLYCHAIN TIMING	GATES RUBBER	1760-8MGT-50
1*	2	930-0590-30-00	BRAKE	BRAKE, ELECTRO-MAGNETIC, SIZE 15*	ORTLINGHAUS	0-207-102-15-170-000
1	30	913-5882-30-00	SPRING	SPRING, COMPRESSION, COLOR CODED YELLOW*	DANLY	9-0804-36
1	<b>2N00073-1-3-E2</b>			<b>ELECTRICS</b>		
1*	2	945-6885-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY, L=1M	HEIDENHAIN	310128-01
1	<b>2N00073-1-3-E9</b>			<b>JUNCTION BOXES</b>		
1*	2	945-6844-30-00	MONITOR	MONITOR, VIBRATION, CARD HOLDER	CEMB	T1-EA10110000

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	2	941-9608-30-00	CONNECTOR	CONNECTOR, HOUSING BULKHEAD MOUNTING, LOW*	HARTING	9300240301
DUP	3	N947-0316-30-00	DIODE	DIODE, SUPPRESSION, 1N4004	NEWARK	18C8917
1	2	2N00073-1-3-F2		FLUIDS		
DUP	5	N900-3088-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY, 5 PIN MICRO	BRAD HARRISON	805S01D04M050
1*	1	N923-0025-30-00	SENSOR	SENSOR, FLOW	SMC PNEUMATICS	PF2W511-N06N-2
DUP	4	N923-0012-30-00	SENSOR	SENSOR, FLOW	SMC PNEUMATICS	PF2W540-N04N-2
1*	2	N923-0027-30-00	SENSOR	SENSOR, TEMPERATURE	NOSHOK	8000/14011280253
DUP	1	N922-0114-30-00	VALVE	VALVE, 2-WAY	DELTA	MAS2E-00-HC24-AS
1	2	2N00073-1-4-39		MASTERMILL		
1*	1	924-8806-30-00	COUPLER	COUPLER, AUTO	CEJN	10 925 1552
1*	1	N940-0264-30-02	MOTOR	MOTOR, ROTOR*	PHASE MOTION CONTROL	TKRT.340.540.A
1	24	N913-0179-30-00	SPRING	SPRING, DIE*	SPEC	ST50310
1*	1	N961-0262-30-00	BEARING	BEARING	SNFA	SEB130/NS 7CE3
1	1	N910-0510-30-00	NUT	NUT, LOCK	SKF	KMTA26
1*	1	N961-0263-30-00	BEARING	BEARING	SNFA	SEB150/NS 7CE3 DD80DAN
1	5	N918-0017-30-00	O-RING	O-RING	PARKER	2-171
1*	1	N923-0035-30-00	TRANSDUCER	TRANSDUCER, ACCELERATION	CEMB	M16
1*	1	N947-0232-30-00	RTD	RTD	OMEGA	RTD-2-F3105-100-T-OTP
1*	1	N945-0221-30-00	ENCODER	ENCODER, ASSEMBLY CONSISTING OF*	LENORD BAUER	GEL-2442-KN1G3A150
1*	1	N941-0395-30-00	WHEEL	WHEEL, READING, 512 TEETH, I.D. 100MM	LENORD & BAUER	ZAN30512100.0
1	2	918-7233-30-00	O-RING	O-RING	PARKER	2-029 V747-75
1	2	918-7686-30-00	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-012 V884-75
1	3	918-8216-30-00	O-RING	O-RING, CORDSTOCK, .275 BROWN VITON, QTY=FT	PARKER	V747-75
1*	1	N940-0264-30-03	MOTOR	MOTOR, STATOR*	PHASE MOTION CONTROL	TKST.340.540.010.A
1*	1	N924-0540-30-00	UNION	UNION, ROTARY, ROTOR MOUNTED ROTATING	DEUBLIN	1114-021-188
1*	1	N947-0272-30-00	ENCODER	ENCODER, ANGULAR, RESM RING, 550MM DIA.	RENISHAW	RESM 20 USA 550
1*	1	N947-0273-30-00	ENCODER	ENCODER, READER, FOR ENCODER RESM A 550*	RENISHAW	A-9570-2001
1*	1	N947-0282-30-00	INTERFACE	INTERFACE, LOW NOISE, LIMITED BAND*	RENISHAW	SIGNUM A-9572-1083
1*	1	N947-0283-30-00	SOFTWARE	SOFTWARE, SIGNUM, CD ROM	RENISHAW	A-9572-0020

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	1	N922-0182-30-00	SEAL	SEAL, V-RING, TYPE VR3 SIZE 500X8 LIP CODE	CHICAGO RAWHIDE	405002
1	2	N900-1673-30-00	SWITCH	SWITCH, LIMIT	BALLUFF	BNS-819-100-K-12
1*	1	N940-0218-30-01	ROTOR/STATOR	ROTOR/STATOR, ASSEMBLED W/SHIMS*	PHASE MOTION CONTROL	TK.570.300.55.D
1	1	N942-0241-30-00	SWITCH	SWITCH, PROXIMITY	BALLUFF	BES-M08MI-PSC20B-BV03
4	4	N924-0348-30-00	CONNECTOR	CONNECTOR, #11FOR PLATE MTG.W/#8 SAE PORT	CEJN	10-965-1556 & 10-945-4365
1	4	924-8155-30-06	FITTING	FITTING, HYDRAULIC	PARKER	8F5OX-S
12	12	N924-0351-30-00	CONNECTOR	CONNECTOR, #6 FOR PLATE MOUNTING*	CEJN	10 925 1552 & 10-925-4362
1	12	924-8155-30-00	FITTING	FITTING, HYDRAULIC, CONNECTOR*	PARKER	4F5OX
1	1	D00036-39-046	PLATE	PLATE, COUPLING		
1	1	D00036-39-047	PLATE	PLATE, COUPLING		
1	2	D00036-39-036	BAR	BAR, UNION		
1	2	D00036-39-037	BAR	BAR, UNION		
1	1	D00036-39-038	BAR	BAR, UNION		
1	2	D00036-39-050	FLANGE	FLANGE		
1	1	D00036-39-026	SUPPORT	SUPPORT, INTERMEDIATE PLATE		
1*	3	D00036-39-404	CONNECTOR	SPECIFICATION, FEMALE CONNECTOR, 37 PIN		
1	2	N942-0210-30-00	SWITCH	SWITCH, PROXIMITY, M12 ANALOG	CONTRINEX	DW-AD-509-M12-320
1	<b>2N00073-1-4-F2</b>			<b>FLUIDS</b>		
DUP	2	N944-0347-30-00	CABLE ASSEMBLY	CABLE ASSEMBLY*	CANFIELD	5F64201EU0A
1*	1	N921-0021-30-00	PUMP/MOTOR	PUMP/MOTOR COMBINATION, 3.3GPM, 1.5HP	DELTA	C8+C3154
DUP	1	948-2714-30-00	SWITCH	SWITCH, PRESSURE, 3-30 PSI ADJ. RANGE	NORGREN	880220
1*	1	N922-0274-30-00	VALVE	VALVE, 2-WAY	DELTA	MA-S2A-00-HC24-S
1	<b>2N00073-1-6-E2</b>			<b>ELECTRICS</b>		
1*	1	942-9811-30-00	HEAD	HEAD, READER, HEAD FOR TOOL ID*	BALLUFF	BIS-C-306-03
1*	1	N900-1912-30-00	PROCESSOR	PROCESSOR, PROFIBUS INTERFACE	BALLUFF	BIS-C-6022-019-050-03-ST10
1*	1	N900-2636-30-00	SENSOR	SENSOR, 5 PIN FEMALE, ROUND W/CABLE GRIP	BALLUFF	BKS-S79-00
1*	2	N900-2635-30-00	SENSOR	SENSOR, 12 PIN MALE, ROUND, W/PG GRIP*	BALLUFF	BKS-S86-00
1	<b>2N00073-1-C-C1</b>			<b>MAIN CONTROLLER</b>		
1*	25	947-4083-30-00	BLOCK	BLOCK, CLASS J FUSE	BUSSMANN	JTN60030
2*	6	944-6309-30-00	FUSE	FUSE, 1 AMP, 600V, CLASS J	BUSSMANN	LPJ-1SP
2*	10	944-6501-30-00	FUSE	FUSE, 4 AMP, 600V, CLASS J	BUSSMANN	LPJ-4SP
2*	9	944-6307-30-00	FUSE	FUSE, 5AMP 600V CLASS J	BUSSMANN	LPJ-5SP

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	1	N900-0575-30-00	AMPLIFIER	AMPLIFIER, IBV 606	HEIDENHAIN	331918-13
1*	2	N947-0249-30-02	CONTACTOR	CONTACTOR, 120VAC COIL*	JOSLYN CLARK	5DP4-01100
1*	2	N947-0249-30-03	CONTACTOR	CONTACTOR, 120VAC COIL*	JOSLYN CLARK	5DP4-02100
DUP	9	N947-0316-30-00	DIODE	DIODE, SUPPRESSION, 1N4004	NEWARK	18C8917
1*	2	947-4498-30-00	CAPACITOR	CAPACITOR	ORTLINGHAUS	0-085-500-02-000
1*	2	948-3335-30-00	SUPPRESSOR	SUPPRESSOR	ORTLINGHAUS	0-085-800-00-000
2*	15	945-6708-30-00	FUSE	FUSE, 250A, SIZE 1 500V	SIEMENS	3NA3144
1*	3	N900-0101-30-00	RELAY	RELAY, OVERLOAD, 3-12A SCREW TERMINALS	SIEMENS	3RB2016-1SB0
1*	1	N941-0118-30-00	RELAY	RELAY, OVERLOAD	SIEMENS	3RB2026-1QB0
1*	9	947-4475-30-00	RELAY	RELAY, 4N.O.-0 N.C., 24VDC*	SIEMENS	3RH1140-2BB40
2*	10	945-6709-30-00	PROCESSOR	PROCESSOR, THERMISTOR MOTOR PROTECTION*	SIEMENS	3RN1013-1BW10
1*	2	N941-0323-30-00	TIMER	TIMER	SIEMENS	3RP1540-2BB31
1*	12	948-3309-30-00	SUPPRESSOR	SUPPRESSOR, 12-250 VDC, DIODE	SIEMENS	3RT1916-1DG00
2*	15	N900-0025-30-00	STARTER	STARTER, MOTOR	SIEMENS	3RV1021-0DA10
1*	2	N900-0025-30-01	STARTER	STARTER, MANUAL MOTOR	SIEMENS	3RV1021-0FA10
1*	4	N941-0061-30-00	STARTER	STARTER, MANUAL MOTOR	SIEMENS	3RV1021-1EA10
1*	21	N945-0036-30-00	CONTACT	CONTACT, AUXILIARY	SIEMENS	3RV1901-1E
DUP	38	N947-0322-30-00	RELAY	RELAY	SIEMENS	3TX7114-5LC03
2*	38	N947-0340-30-00	SUPPRESSOR	SUPPRESSOR, 24VAC/DC	SIEMENS	3TX7144-H9
DUP	2	947-4446-30-00	POWER SUPPLY	POWER SUPPLY, AC*	SIEMENS	6EP1436-3BA00
1*	6	N941-0165-30-00	CONTACTOR	CONTACTOR	SPRECHER & SCHUH	CA7-90-M22-120
1*	6	N941-0165-30-01	SUPPRESSOR	SUPPRESSOR, RC MODULE, 110-280VAC 50/60HZ	SPRECHER & SCHUH	CRC7-280
1	2N00073-1-C-C4		CNCMOTORSDRIVES			
1*	1	945-6617-30-00	INTERFACE	INTERFACE, DISTRIBUTION BOX FOR HANDHELD*	SIEMENS	6FX2006-1BF00
1*	1	945-6626-30-00	MODULE	MODULE, MONITORING SERVO	SIEMENS	6SN1112-1AC01-0AA1
1*	15	945-6634-30-00	BLOWER	BLOWER, FOR 300MM MODULE	SIEMENS	6SN1162-0BA02-0AA2
1*	10	945-6653-30-00	MODULE	MODULE, 611-D POWER SECTION IMAX=400A*	SIEMENS	6SN1123-1AA00-0KA1
1*	5	945-6654-30-00	MODULE	MODULE, 120/156KW INFEED/REGEN SERVO*	SIEMENS	6SN1145-1BB00-0FA1
1*	2	945-6701-30-00	MODULE	MODULE, POWER, 611D, IMAX=200A*	SIEMENS	6SN1123-1AA01-0FA1
1*	5	945-6899-30-00	MODULE	MODULE, ANALOG INPUT, 8 INPUTS	SIEMENS	6ES7331-7KF02-0AB0
1*	8	945-6903-30-00	MODULE	MODULE, 32 INPUT, 24VDC	SIEMENS	6ES7321-1BL00-0AA0
1*	8	945-6904-30-00	CONNECTOR	CONNECTOR, 40-PIN SCREW FRONT	SIEMENS	6ES7392-1AM00-0AA0
1*	7	947-4451-30-00	MODULE	MODULE, 16 OUTPUT, RELAY, DIGITAL	SIEMENS	6ES7322-1HH01-0AA0

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1*	5	947-4456-30-00	CARD	CARD, OVERVOLTAGE LIMITING MODULE	SIEMENS	6SN1111-0AB00-0AA0
1*	5	947-4499-30-00	MODULE	MODULE, COMMUNICATION	SIEMENS	6ES7153-1AA03-0XB0
1*	13	948-1010-30-00	CONNECTOR	CONNECTOR, SCREW, TYPE EDGE 20 PIN	SIEMENS	6ES7392-1AJ00-0AA0
1*	1	948-3298-30-00	DISPLAY	DISPLAY, DIGITAL, OPERATOR PANEL*	SIEMENS	6FC5203-0AF03-0AA0
1*	1	N900-1046-30-00	PANEL	PANEL, CONTROL, CNC, 19" MACHINE*	SIEMENS	6FC5203-0AF22-0AA2
1*	1	N900-1440-30-00	PENDANT	PENDANT, HAND-HELD UNIT B-MPI 3-WIRE, *	SIEMENS	6FX2007-1AC14
1*	1	N900-1442-30-00	CNC CONTROL	CNC CONTROL, 3MB USER MEMORY*	SIEMENS	6FC5357-0BB35-0AA0
1*	2	N940-0113-30-02	MOTOR	MOTOR, W/FAN, 140NM, 1239LBIN*	SIEMENS	1FT6134-6SF71-1AB0
1*	6	N947-0019-30-00	MODULE	MODULE, BRAKING, SINAMICS, 600V DC, 100K W	SIEMENS	6SL3100-1AE31-0AB0
1*	8	N947-0020-30-00	MODULE	MODULE, VOLTAGE, VPM 200 DYNAMIC*	SIEMENS	6SN1113-1AA00-1KC1
1*	1	N947-0120-30-00	CNC CONTROL	CNC CONTROL, SINUMERIK PCU	SIEMENS	6FC5210-0DF31-2AA0
1*	1	N947-0274-30-00	KEYBOARD	KEYBOARD, COMPUTER, SINUMERIK 840D	SIEMENS	6FC5203-0AF20-0AA1
1*	12	N947-0437-30-00	MODULE	MODULE, CARD*	SIEMENS	6SN1118-0DJ23-0AA2
1*	5	N947-0440-30-00	HFD BUNDLE	HFD BUNDLE WIDEBAND 120 KW CONTAINS*	SIEMENS	6SN1111-0AA00-1FV0
1*	1	945-6902-30-00	MODULE	MODULE, SM332 ANALOG OUTPUT, 4CH, 12BITS, IS	SIEMENS	6ES7332-5HD01-0AB0
1	<b>2N00073-1-E-E2</b>		<b>ELECTRICS</b>			
2*	6	N900-2773-30-01	SWITCH	SWITCH, SAFETY	TELEMECANIQUE	XCSL768B3
1*	1	<b>2N00073-2-90</b>		<b>OH 150 SPINDLE UNIT</b>		
1*	1	N918-0267-30-00	SEAL	SEAL, PISTON	BUSAK & SHAMBAN	PG4400825-T46 N
2*	2	962-3419-30-20	BEARING	BEARING, ANGULAR CONTACT	SKF	71924CD/P4ADBA
1	1	N900-2599-30-00	SEAL	SEAL, TYPE VR1 SIZE 500X20 LIP CODE V	CHICAGO RAWHIDE	405004
1*	1	N961-0234-30-00	BEARING	BEARING, AXIAL-RADIAL ROLLER*	MONDIAL	UNITEC RTB 395 GP
1*	1	962-2337-30-00	BEARING	BEARING, CYLINDRICAL ROLLER	SKF	NN 3032 K/SPW33
1*	1	961-6057-30-00	BEARING	BEARING, CYLINDRICAL ROLLER	SKF	NN3028K/SPW33
1	1	N918-0292-30-00	SEAL	SEAL, LABYRINTH, M160X190X20	GMN	
1*	1	N921-0051-30-00	PUMP	PUMP	VIKING	SG-0525-G0O/FM-0535 T DRIVE
1	1	922-4395-30-00	VALVE	VALVE, NEEDLE, #6 SAE PORTS	PARKER	N-620-S

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1	2	922-7440-30-00	VALVE	VALVE, FLOW CONTROL, C1/2NPT FEMALE*	DOLE	GB-2
1	1	923-5306-30-00	GUAGE	GAUGE, PRESSURE, 213.40-2.5-1/4NPT-LM*	WIKA	9734134
1	1	N923-0094-30-00	GAUGE	GAUGE, PRESSURE, 60 PSI, 1-1/2 FACE, 1/8NPT*	WIKA	9738258
1*	1	942-5074-30-00	SWITCH	SWITCH, 7011-4, N.O. CONTACTS, 1/8"NPT	SUCO	0166-40104-1-004
1*	1	N945-0386-30-00	MOTOR	MOTOR, DRAWING NUMBER 06721-0-A-1	PHASE MOTION CONTROL	TK240-160-050
1*	1	N947-0273-30-00	ENCODER	ENCODER, READER, FOR ENCODER RESM A 550*	RENISHAW	A-9570-2001
1*	1	N923-0035-30-00	TRANSDUCER	TRANSDUCER, ACCELERATION	CEMB	M16
1*	2	N947-0232-30-00	RTD	RTD	OMEGA	RTD-2-F3105-100-T-OTP
1*	1	N947-0463-30-00	ENCODER	ENCODER, ANGULAR, ROTARY RING 417MM DIA.	RENISHAW	RESM 20 USA 417
1*	1	N947-0282-30-00	INTERFACE	INTERFACE, LOW NOISE, LIMITED BAND*	RENISHAW	SIGNUM A-9572-1083
1*	1	N945-0496-30-00	ENCODER	ENCODER, ANGULAR, ABSOLUTE, RCN 226	HEIDENHAIN	533110-03
1*	1	N00073-90-401	GRIPPER	SPECIFICATION, TOOL GRIPPER		
1*	1	N00073-90-402	GEAR SET	SPECIFICATION, GEAR SET*GRIND AS SET*		
1*	1	N00073-90-403	GEAR SET	SPECIFICATION, GEAR SET*GRIND AS SET*		
1	1	N00073-90-404	CONNECTOR	SPECIFICATION, MALE PIN CONNECTOR		
1	2	N913-0164-30-00	SPRING	SPRING, DISC	SCHNORR	017300 A
1*	1	918-8141-30-00	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-278V884-75
1*	3	918-4952-30-03	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-173V884-75
1*	1	N918-0266-30-00	O-RING	O-RING	PARKER	2-132-V884-75
1	1	N975-0196-30-00	LOCKING ASSEMBLY	LOCKING ASSEMBLY, INTERNAL	B-LOC	B400 90X130
1*	1	918-7721-30-00	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-153 V884-75
1*	1	918-4463-30-00	O-RING	O-RING	PARKER	2-169V747-75
2*	5	N975-0024-30-00	COUPLER	COUPLER, AUTO, NIPPLE M24X1.5 MALE	CEJN	10-925-6552
2*	6	N975-0025-30-00	COUPLER	COUPLER, AUTO, NIPPLE M36X3 MALE	CEJN	10-965-6556
4	4	990-4155-49-00	KNOB	KNOB, RETENTION, #60, FOR SPINDLE UNITS		
1*	1	N941-0079-30-00	CONNECTOR	CONNECTOR, ELECTRIC PLUG*	ADVANCED MACHINE	ODU-01000

2N00073 GANTRY MILLING MACHINE						
Spare	Mch. Qty.	Component no.	Keyword	Object description	Manufactured by	Manufactured part number
1	2	948-2591-30-00	SWITCH	SWITCH, PROXIMITY, 8MM TUBULAR 1.5MM*	BALLUFF	BES-516-324-E0-C-05
1	1	913-3208-30-00	SPRING	SPRING, COMPRESSION, MUSIC WIRE 1.75 LENGTH	LEE SPRING	LC-045D-16
1*	1	918-8280-30-03	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-266V884-75
1*	1	N918-0261-30-00	O-RING	O-RING	PARKER	2-392-V884-75
1*	1	918-7544-30-00	O-RING	O-RING	PARKER	2-381V747-75
1*	1	N918-0262-30-00	SEAL	SEAL, QUAD RING	BUSAK & SHAMBAK	QRAR04460-N7004
1*	1	918-6261-30-01	O-RING	O-RING	PARKER	2-277V747-75
1*	1	N918-0264-30-00	SEAL	SEAL, QUAD RING	BUSAK & SHAMBAK	QRAR04379-N7004
1*	1	N918-0295-30-00	SEAL	SEAL, LABYRINTH, 285X311X36MM	INPRO	TN15363
1	1	923-3937-30-04	GAUGE	GAUGE, SIGHT	LUBE DEVICES	G605-04-A-1
1*	2	918-0706-30-00	O-RING	O-RING	PARKER	2-274V747-75
1*	1	N00073-90-003	SHAFT	SHAFT, SPINDLE		
8*	8	N918-0268-30-00	SEAL	SEAL, ROD	PARKER	M204OR05.5060-4-2A
1*	1	918-6730-30-00	O-RING	O-RING	PARKER	2-354-N674-70
7*	7	918-8410-30-00	O-RING	O-RING, MATERIAL-BROWN VITON	PARKER	2-109V884-75
1	3	948-2591-30-00	SWITCH	SWITCH, PROXIMITY, 8MM TUBULAR 1.5MM*	BALLUFF	BES-516-324-E0-C-05
2*	2	918-6296-30-00	O-RING	O-RING	PARKER	2-113V747-75
2*	2	918-7671-30-00	O-RING	O-RING	PARKER	2-111V747-75
1*	1	N961-0260-30-00	BEARING	BEARING, NEEDLE ROLLER, 115 IDX140 OD X40W	SKF	RNA 4920
2*	4	918-7427-30-00	O-RING	O-RING	PARKER	2-109V747-75
1	3	948-1397-30-00	SWITCH	SWITCH, PROXIMITY, 8MM DIA., PNP, SOURCING	BALLUFF	BES-516-324-G-E4-C-03
1*	1	918-7871-30-00	O-RING	O-RING, MATERIAL, VITON	PARKER	2-036 V747-75
1*	1	962-2385-30-00	BEARING	BEARING, ANGULAR CONTACT, TRIPLEX SET*	SKF	7020 ACD/P4ATBTA
1*	1	N961-0284-30-00	BEARING	BEARING, ANGULAR CONTACT, TRIPLEX	SKF	7032ACD/P4ATBTA
1	1	N00073-90-053	SPACER	SPACER		
1*	1	N961-0285-30-00	BEARING	BEARING, AXIAL-RADIAL ROLLER	MONDIAL	RTB-100
1*	1	N00063-90-405	GEARWORM	SPECIFICATION, GEARWORM		
				FILTERS		
2*		N900-2775-30-00		FILTERS	CAMOZZI	
2*		N900-2776-30-00		FILTERS	CAMOZZI	
1*		N900-2777-30-00		FILTERS	CAMOZZI	
1*		N900-2778-30-00		FILTERS	CAMOZZI	

## 19.2 MIST ENCLOSURE

ITEM NO.	HENNIG PART NUMBER	MANUFACTURER PART NUMBER	DESCRIPTION	QUANTITY
1	BE-7331	BE-7331	HENNIG HEAT SEALED BELLOW	2
2	872278	EBB30	TRACK ROLLER,30M	28
3	885262	OSPP320000000900000000100	CYLN,PNEUM,RODLESS,32MM BORE	2
4	872279	6738K221	TRACK ROLLER GUIDE BLOCK, MCMASTER	4
5	872280	6738K999	TRACK ROLLER GUIDE RAIL, MCMASTER	2
6	885263	PTF4PB10-1/4	G1/4 FLOW CONTRL 1/4 BSPP, 10 MM TUBE PARKER	4
7	885264	NN10x1	10MM, NYLON TUBE	145 FT
8	885265	WPB10	BULKHEAD, FITTING, 10MM, PARKER	4
9	885266	KL3047	MGNETC,REED SW . ,M8X1 QUICK CONN.	4
10	885267	NAN-T-3FP-10M	10M CABLE WITH M8X1 FEMALE CONN.	4
11	853003	SFD105BL	BRUSH, 3/4" OAT SEALEZE SFD108BL, CUT TO SUIT	1 METER
12	853007	XTG680CLA	HOLDER, XTG680CLA STRAIGHT, CUT TO SUIT	1.17 METERS
13	849019	8447A35	CYLN,PNEUM,RODLESS,32MM BORE	34
14	849020	8447A37	12"W VINYL REPLACEMENT STRIP, 12' LG.	30

## 19.3 OPERATOR CABIN

ITEM NO.	HENNIG PART NUMBER	MANUFACTURER PART NUMBER	DESCRIPTION	QUANTITY
1		SCE-6044CH	Electrical Box Assembly	2
2	880861	#190-015-995	Light Mounting Bracket, Waldmann	2
3	880938	RL70CE-136	Light, RL70CE-136, 24V	1
4	885260	DA230	10" Dia., VisiPort Discair DA230	1
5	880087		Laminate Safety Glass	4
6		XCSL768B3	Switch,Telemecanique supplied by IMTI	1
7		ZCK-YO91	Key, Telemecanique, supplied by IMTI	2
8	854077	HH-25	Handle, Rohde	4
9	861088		Handle Bumper, Outside	2
10	861089		Handle Bumper, Inside	2
11	872278	EBB30	Track Roller, 30mm Dia., M8	12
12	872258	K-20-50	Wheel, Iron, Takigen	4
13	851339		SHCS M6 X 1.0 X 10mm	225

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## 19.4 TOOL CHANGER DOOR

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ITEM NO.	HENNIG PART NUMBER	MANUFACTURER PART NUMBER	DESCRIPTION	QUANTITY
1	885272	P1XN032DAN0935WDGFN-B	CYLINDER, PARKER P1X 32BORE 935MM	1
2	885271	P8S-GRSHX	REED SWITCH,M8 QUICK CONN. 3M LG. PARKER	2
3	885267	NAN-T-3FP-10M	10M CABLE WITH M8X1 FEMALE CONN.	2
4	885265	WPB10	BULKHEAD. FITTING, 10MM, PARKER	
5	885264	NN10x1	10MM, NYLON TUBE	50 FT
6	885263	PTF4PB10-1/4	G1/4 FLOW CONTRL 1/4 BSPP, 10 MM TUBE PARKER	2
7	872280	6738K999	TRACK ROLLER GUIDE RAIL	2
8	872279	6738K221	TRACK ROLLER GUIDE BLOCK, MCMASTER	4
9	848032	M1650M	BUNA RUBBER BOTTOM SEAL	1

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## 19.5 TOOL CHANGER PLATFORM

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ITEM NO.	HENNIG PART NUMBER	MANUFACTURER PART NUMBER	DESCRIPTION	QUANTITY
1	854808	1102A78	DRAWER SLIDE, EXTRA HEAVY DUTY, 48"	2
2	854067	EMKA 1095-15	HANDLE, BLACK POLYMER, 122MM CTRS	1
3	850256	3391A15	BALL NOSE, SPRING PLUNGER, M8	1
4	850306	2531K207	LEVELER, STUDED, SWIVEL MOUNT	9
5	880951	BES M08MI-PSC20B-BV03	SWITCH, PROXIMITY, INDUCTIVE, 110V BALLUF	1

## **APPENDIX A - MISCELLANEOUS PROCEDURES**



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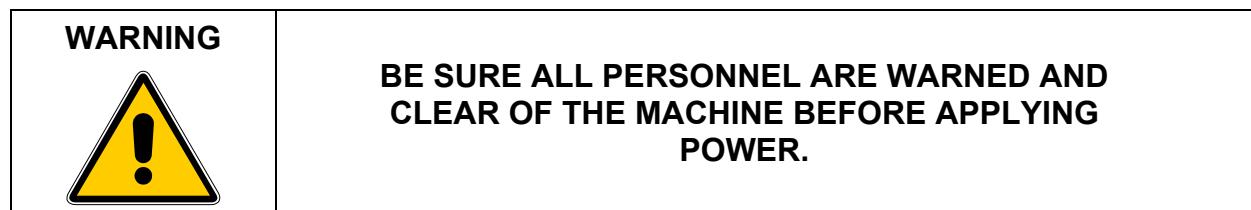
## APPENDIX A - MISCELLANEOUS PROCEDURES

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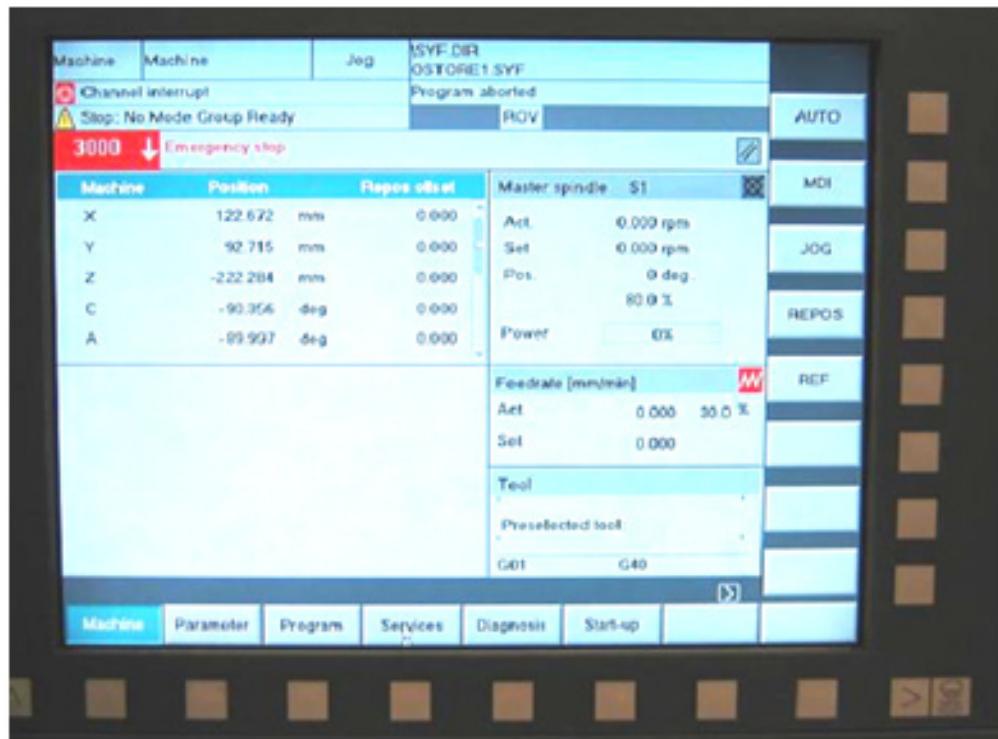


## A.1 MACHINE POWER-UP SEQUENCE

Perform this sequence if the machine has been shutdown for an extended period of time, (e.g., weekends, holidays, etc.).



- STEP 1:** Switch on the **main power disconnect** on the right side of control cabinet #1 (Maintenance Department Task) that supplies power to the entire machine.
- STEP 2:** The **CNC controller will power up** and go through its self-diagnostic routine. If the CNC does not power up, Maintenance should check appropriate subsequent circuit breakers and fuses.
- STEP 3:** Allow the **CNC to boot** until you are at the main screen (shown below) and the lights on the Machine Control Panel have stopped flashing.



SIEMENS CNC MAIN SCREEN

**STEP 4:** Bring Machine out of Emergency Stop.

Before attempting to start the machine, make sure none of the emergency stop pushbuttons are pushed in, as this will prevent the machine from starting.

Once that is done, press the Emergency Stop Reset pushbutton, located on the upper left hand corner of the operator console.

The lighted pushbutton should flash while the machine is being powering up and will go solid once the machine is out of e-stop. If not all e-stop conditions are satisfied, the light will go back off. If this occurs, see alarm information on the CNC to troubleshoot cause of problem.

**STEP 5:** After the machine is out of E-stop, the **Hydraulic System will start** and Fluids Systems will start.

**STEP 6:** Once up, you will need to **home all axes**, including the tool changer. Please refer to the Axis Operations in this document.

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## A.2 MACHINE POWER DOWN

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**STEP 1:** Move all axes to a convenient location before shutting down the machine.

**NOTE:** The A-axis on the Offset Indexing unit spindle unit **MUST** be in the vertical position (A at 0 degrees), before powering down. If not, oil can contaminate the grease-packed bearings in this unit.

**STEP 2:** Once the machine axes are in a stopped condition, place the control in E-stop, using the “E-stop” pushbutton on the main Operator Console machine control panel.

**STEP 3:** Press the “Menu Select” softkey.

**STEP 4:** Press the “Exit” softkey.

**STEP 5:** A message will be displayed saying when it is ok to remove power from the CNC.

If maintenance to the machine is required, turn off the main disconnect (Maintenance Task). The operator should **NOT** normally turn **OFF** the Main Disconnect. Ingersoll recommends leaving the power to the CNC controller “ON”, unless it is absolutely necessary to power down for a maintenance reason.

## A.3 AXES OPERATIONS

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### A.3.1 AXIS HOMING

- Verify the control is out of E-stop and there are no active alarms or messages that might inhibit motion.
- The control must be in feed start mode before any axis movement will be allowed. Confirm the light corresponding to the “Feed Start” pushbutton is on, if it is not press the “Feed Start” pushbutton.
- Select the axis to be jogged by pressing the corresponding pushbutton on the axis selection section of the Machine control panel. The corresponding light on the pushbutton should illuminate to show which axis is currently selected.
- Press the “Jog” pushbutton, the corresponding light on the pushbutton should illuminate.
- Jog the axis to a spot a suitable distance from the hard over-travels, i.e. middle of travel or at least a foot or two from the end of travel.
- Press the “Ref” button on the machine control panel to select reference mode. Hit the “+” jog key to initiate a reference cycle. The axis should jog for a distance and then stop. The indicator next to the drive letter on the CNC screen should now be on to indicate that the axis is homed.

### A.3.2 OVERTRAVEL RECOVERY

- Insert the key into the Over Travel Bypass switch and hold it in the ON position while completing the following steps.
- Push the e-stop reset button and wait for the machine to come out of e-stop.
- Select the over traveled axis by pressing the corresponding pushbutton on the axis selection section of the Machine Control Panel. The corresponding light on the pushbutton should illuminate to show which axis is currently selected.
- Press the “Jog” pushbutton, the corresponding light on the pushbutton should illuminate.
- Push the “+” or “-“ pushbutton that is in the **opposite** direction of the over-travel fault message. For example if you had an “X axis hardware over-travel plus” alarm you would select X, JOG, and then press the “-“ key while still holding the Over Travel Bypass key on.
- As soon as the axis has moved off the over-travel switch (usually a couple of inches is enough) and back within its normal travel limits, you can let off the “+” or “-“ pushbutton.
- Release the Over Travel Bypass key.
- Now if you hit the message reset button on the CNC, the over travel alarm should be cleared and you can resume normal operations.

**A.3.3 JOGGING AN AXIS**

- Verify that the control is out of E-stop and there are no active alarms or messages that might inhibit motion.
- The control must be in feed start mode before any axis movement will be allowed. Verify that the light corresponding to the “Feed Start” pushbutton is on, if it is not press the “Feed Start” pushbutton.
- Select the axis to be jogged by pressing the corresponding pushbutton in the axis selection of the Machine Control Panel. The corresponding light on the pushbutton should illuminate to show which axis is currently selected.
- Press the “Jog ” pushbutton to put the control into jog mode, the corresponding light on the pushbutton should illuminate.
- Set your feedrate override to the desired level.
- Press the “+” and “-“ keys to jog the axis.

**A.3.4 MOVING AN AXIS MANUALLY**

- Verify that the control is out of E-stop and there are no active alarms or messages that might inhibit motion.
- The control must be in feed start mode before any axis movement will be allowed. Verify that the light corresponding to the “Feed Start” pushbutton is on, if it is not press the “Feed Start” pushbutton.
- Press the “MDA” pushbutton to put the control into MDA mode, the corresponding light on the pushbutton should illuminate.
- Enter the program blocks you wish to run using the Siemens keyboard
- Press the “Cycle Start” pushbutton to start execution of the blocks.

**A.3.5 STARTING THE SPINDLE**

- Verify that the control is out of E-stop and there are no active alarms or messages that might inhibit motion.
- The control must be in spindle start mode before any spindle movement will be allowed. Verify that the light corresponding to the “Spindle Start” pushbutton is on, and if not press the “Spindle” pushbutton.
- Press the “MDA” pushbutton to put the control into MDA mode, the corresponding light on the pushbutton should illuminate.
- Program M3 (spindle run clockwise) or M4 (spindle run counter-clockwise) and a feedrate. For example to program the spindle to 10000 rpm rotating clockwise would look like: M3 S10000
- Press “Cycle start” pushbutton to start the spindle.
- Press “Reset” pushbutton or program an M5 to stop the spindle.

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## A.4 SELECTING AND RUNNING A PROGRAM IN AUTO MODE

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### A.4.1 SELECTING A PROGRAM IN AUTO MODE

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**NOTE:** A program must be selected before it can be run.

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- Press the “Menu Select” softkey on the Siemens CNC
- Press the “Program” softkey on the CNC
- Press the “Part programs” or “Sub-programs” softkey depending on where your programs are stored.
- Use the arrow softkeys to highlight the name of the program that you want to run.
- While the file is highlighted, press the “Select” softkey.
- If Auto mode is on, the name of the program you just selected will be displayed in the upper right hand portion of the screen.

### A.4.2 RUNNING A PROGRAM IN AUTO MODE

- Select a program to run as described in the steps above.
- Verify that the control is out of E-stop and there are no active alarms or messages that might inhibit motion.
- The control must be in feed start mode before any axis movement will be allowed. Verify that the light corresponding to the “Feed Start” pushbutton is on, if it is not press the “Feed Start” pushbutton.
- Press the “Auto” pushbutton to put the control into Auto mode. The corresponding light on the pushbutton should illuminate.
- Press the “Cycle Start” pushbutton to start the program.

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## A.5 BACK-UP PROCEDURES

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### A.5.1 SIEMENS CNC BACKUP

Backups of the Siemens CNC should be done in the following situations:

- after changing machine-specific settings
- during servicing (e.g. after replacing hardware, upgrading software), so that you can put the system back into operation as soon as possible

There are three types of data to be saved with the Siemens 840D:

- Data for NCK, drive and operator panel front settings
- Data for PLC
- Data for HMI/MMC.

Refer to the Siemens 840D Installation and Start-up Guide for additional information on backups.

#### A.5.1.1 ARCHIVING CHANGED DATA

Before starting any backups, check the settings on CNC machine data parameter MD 11210 UPLOAD\_MD\_CHANGES\_ONLY. This parameter can be set to define what gets included in an NC archive. This parameter can be viewed and changed by the following procedure.

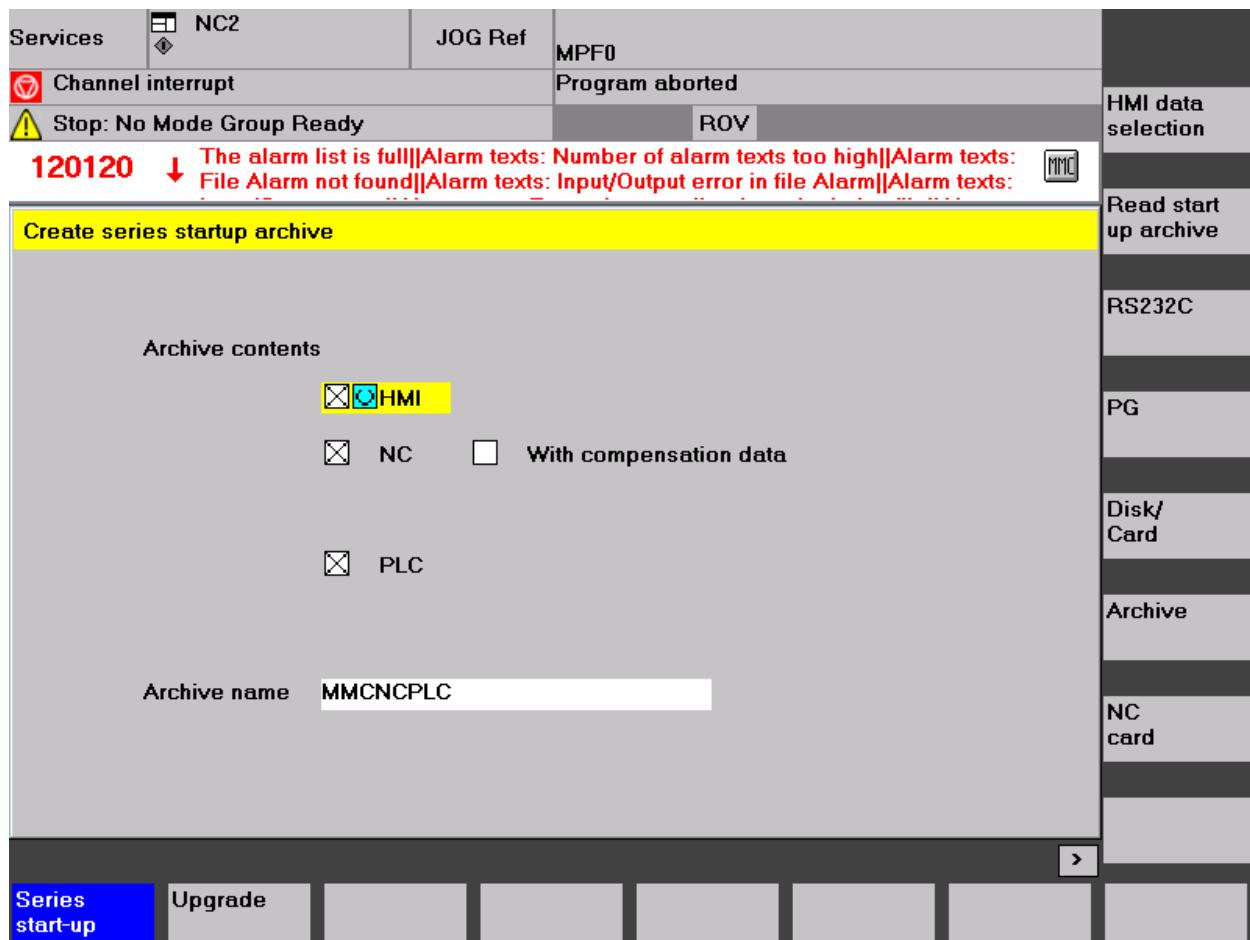
1. Press the Menu Select key  to get the Siemens predefined horizontal softkeys to be displayed.
2. Press the Start-up horizontal softkey.
3. Press the up arrow key  located to the left of the horizontal softkeys.
4. Press the Machine Data horizontal softkey.
5. Press the General MD horizontal softkey.
6. Use the up/down arrow keys or page down/up keys to get to parameter 11210.
7. MD 11210 UPLOAD\_MD\_CHANGES\_ONLY settings:

FFH = Changes only  
0H = Outputs all MD even things not changed (recommended setting)

### A.5.1.2 SERIES START-UP ARCHIVES

The Siemens “Series Start-up” function is used to backup the software. To start this backup software on the Siemens CNC, follow the steps below.

1. Press the Menu Select key  to get the Siemens predefined horizontal softkeys to be displayed.
2. Press the Services horizontal softkey.
3. Press the up arrow key  located to the left of the horizontal softkeys.
4. Press the softkey expansion key  located to the left of the horizontal softkeys.
5. Press the Series start-up horizontal softkey. The following screen should be displayed.



The Series Start-up software can be used to back up the following data:

- **HMI** - Saves individual files that are not active NC data and are stored on the PCU 50, such as mgud.def, param.com, unloaded NC programs, alarm files etc. (described below)

- **NC** - Backs up all the active data on the NCK board (machine data, loaded NC programs, user data values, etc)
- With compensation- adds the compensation data values to the NC archives.
- **PLC** - Backs up the project currently loaded on the PLC.

Use the steps outlined in the following sections to backup the NC, PLC, and HMI/MMC data.

#### A.5.1.3 SAVING NC DATA

The NC data should be saved in an archive file on the HMI/MMC's hard disk following the steps below. The NC archive file can then be ghosted with the rest of the HMI/MMC, or copied to a CD or another network computer.

1. With the Series start-up screen displayed (see instructions above).
2. Use the up/down arrow keys and the Select key to select only **NC** and **With Compensation** (the HMI and PLC boxes should not be checked). Use the default archive name (NC).
3. Press the **Archive** soft key.
4. The display changes and the task log appears. The file **NC.ARC** is created on the HMI/MMC, under the folder ARCHIVE.
5. When the “**task finished**” message appears, the NC backup is done.

#### A.5.1.4 SAVING PLC DATA

The PLC data should be saved in an archive file on the HMI/MMC's hard disk following the steps below. The PLC archive file can then be ghosted with the rest of the HMI/MMC, or copied to CD or another network computer.

1. With the Series start-up screen displayed (see instructions above).
2. Use the up/down arrow keys and the Select key to select only **PLC** (the HMI and NC boxes should not be checked). Use the default archive name (PLC).
3. Press the **Archive** soft key.
4. The display changes and the task log appears. The file **PLC.ARC** is created on the HMI/MMC's hard disk, under the folder ARCHIVE.
5. When the “**task finished**” message appears, the PLC backup is done.

#### A.5.1.5 SAVING HMI/MMC DATA

The HMI data should be saved in an archive file on the HMI/MMC's hard disk following the steps below. The HMI archive file can then be ghosted with the rest of the HMI/MMC, or copied to CD or another network computer.

1. Since the HMI backups are very large, it is a good idea to first delete the previous HMI backup file before doing another one. This can be done by:
  - a) Press the Menu Select key  to get the Siemens predefined horizontal softkeys to be displayed.
  - b) Press the Services horizontal softkey.
  - c) Use the cursor up and down keys to highlight the ARCHIVE folder.
  - d) Press the vertical softkey Delete... This displays the files in the Archive folder.
  - e) Use the cursor up and down keys to highlight the file MMC.ARC.
  - f) Press the Yes vertical softkey, which will delete the file.
2. Get the Series start-up screen displayed (see instructions above).
3. Press the vertical softkey HMI data selection. The Siemens backup software will save the HMI/MMC folders that are selected from this screen.
4. Use the up/down arrow keys and the Select key to highlight the following folders to include in the backup.

<b>Archive</b>	(Just to keep any backups you might have had)
<b>Definitions</b>	(Gud 5-7 for measuring cycles, Mgud.def, Smac.def, and Umac.def)
<b>Diagnosis</b>	(Saves any individual tea's or waveforms you may have created)
<b>MBDDE-Alarm-Text</b>	(ialp_uk.com, ialz_uk.com, iact_uk.com)
<b>User-cycles</b>	(Param.com)
5. After selecting the above folders, press the Ok vertical softkey.
6. From the Series Start-up screen, use the up/down arrow keys and the Select key to select only MMC (the NC and PLC boxes should not be checked). Use the default archive name (MMC).
7. Press the Archive soft key.
8. The display changes and the task log appears. The file MMC.ARC is created on the HMI/MMC's hard disk, under the folder ARCHIVE.
9. When the "task finished" message appears, the HMI/MMC backup is done.

#### A.5.1.6 HMI/MMC GHOSTING

After backing up the NC, PLC, and HMI/MMC data to the HMI/MMC's hard disk following the steps above, the Norton Ghost utility can be used to make an image backup of the HMI/MMC's hard disk. This saves the complete contents of the hard disk to an image file. The image file can be stored on an external disk for a later restoration, if required. Siemens provides the Ghost utility pre-loaded on the HMI. Follow the steps below to do an image backup.

1. Reboot to the **SERVICE** menu. To do this, reboot the control (power down and up). When prompted as to what operating system to start (Sinumerik will be highlighted), hit the down arrow key (a blank line will be highlighted) and then hit the input key.
2. Select choice 7. Backup/Restore
3. Enter the password: SUNRISE
4. Select 4. Partitions Backup/Restore with GHOST (locally)
5. Next select 2. Partition Backup Mode Local
6. This will back up everything on the HMI/MMC hard drive (except the stuff on the D:\ partition) to the folder D:\images\.
7. Specify an image name and image description and hit input.
8. When prompted to Make This My Emergency Boot Image, choose YES so that the most current image is the one it will use for an emergency backup.
9. If asked during the ghosting process do you want to enable spanning, enter YES.
10. Hit YES when asked if you want to verify the backup.
11. After the Ghost task finishes, the image files in folder D:\images\ can be copied to a networked computer for safe keeping.

## **APPENDIX B - INPUTS/OUTPUTS**



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## B.1 INPUT/OUTPUT VALUES BY FUNCTION

This chapter describes the inputs and outputs used to control the various devices on the machine.

The following is a list of all the inputs and outputs on the machine, sorted by functionality.

B.1.1 AIR / PNEUMATIC INPUTS / OUTPUTS			
MACHINE AIR	MACHINE AIR ON 4030 SOL		THIS SOLENOID VALVE TURNS ON THE AIR SERVICE TO THE ENTIRE MACHINE. THIS SOLENOID IS ENERGIZED WHEN POWER IS APPLIED TO THE MACHINE.
	MACHINE AIR PRESSURE OK	I051-2	LOSS OF THIS SIGNAL CAUSES AN IMMEDIATE E-STOP.
SPINDLE SEAL	SPINDLE FRONT SEAL PRESSURIZATION AIR PRESSURE OK	I083-1	A CONSTANT PRESSURE IS MAINTAINED ACROSS THE SPINDLE FRONT SEAL TO KEEP THE SEAL CLEAR OF CONTAMINANTS. LOSS OF AIR PRESSURE SIGNAL CAUSES A MESSAGE ONLY TO BE POSTED.
	AIR TO ATTACHMENT AIR PRESSURE OK	I100-1	THIS INPUT IS ON TO CONFIRM PROPER AIR PRESSURE FOR SPINDLE LUBRICATION OF MOTORIZED SPINDLE UNITS. LOSS OF SIGNAL WHILE THE SPINDLE BEARING LUBRICATION PUMP MOTOR IS RUNNING CAUSES AN END OF BLOCK STOP, FOLLOWED BY A SPINDLE STOP. THE PUMP MOTOR IS STOPPED, AND A MESSAGE IS POSTED.
	RAM FACE BLOW OFF	Q104-0	THIS OUTPUT IS ENERGIZED DURING A SPINDLE UNIT DROP AND PICK CYCLE TO KEEP DEBRIS AWAY FROM THE RAM FACE.
MISC.	AIR BLAST RETENTION KNOB	Q104-2	THIS IS USED WHENEVER THE SPINDLE GRIPPER IS OPENED FOR A TOOL CHANGE. ALSO, WHEN AN M11 (AIR THROUGH SPINDLE) IS ENCOUNTERED, AIR IS DELIVERED THROUGH THE SPINDLE BY TURNING ON THIS SAME SOLENOID. THIS SOLENOID WILL REMAIN ON UNTIL AN M00 (PROGRAMMED STOP, UNCONDITIONAL), M05 (SPINDLE STOP), M09 (STOP COOLANT), M07 (EXTERNAL CUTTER LUBE), M08 (INTERNAL CUTTER LUBE), M30 (PROGRAM END, END OF TAPE) OR A RESET IS ENCOUNTERED.
	AIR ON TO ATTACHMENTS	Q100-1	THIS OUTPUT IS TURNED ON WHENEVER A SPINDLE UNIT REQUIRING AIR IS MOUNTED. THIS OUTPUT REMAINS ENERGIZED DURING E-STOP.
	AIR ON TO SPINDLE BEARING LUBE	Q104-3	THIS OUTPUT IS ENERGIZED WHEN A SPINDLE UNIT REQUIRING SPINDLE BEARING LUBRICATION IS MOUNTED ON THE HEAD. IT IS TURNED OFF WHEN THE SPINDLE UNIT IS REMOVED.
HEIDENHAIN SCALES	X-AXIS LEFT HEIDENHAIN AIR PRESSURE OK	I051-0	A CONSTANT PRESSURE IS MAINTAINED ACROSS THE AXES SCALES TO KEEP THE HEIDENHAIN SCALES CLEAR OF CONTAMINANTS.
	X-AXIS RIGHT HEIDENHAIN AIR PRESSURE OK	I051-1	LOSS OF AIR PRESSURE SIGNAL CAUSES A MESSAGE ONLY TO BE POSTED.
	Y-AXIS HEIDENHAIN AIR PRESSURE OK	I100-2	

	Z-AXIS HEIDENHAIN AIR PRESSURE OK	I100-4	
<b>B.1.2 AXIS CONTROL INPUTS / OUTPUTS</b>			
TRAVEL	OVERTRAVEL BYPASS	I090-3	DURING AXIS OVERTRAVEL RECOVERY, THE SPRING LOADED KEY SELECTOR SWITCH INPUT GOES HIGH TO INDICATE THE OPERATOR IS RECOVERING FROM AN AXIS OVERTRAVEL.
	NOT X-AXIS PLUS OVERTRAVEL	I041-0	THIS CORRESPONDING INPUT GOES LOW WHEN AN AXIS OVERTRAVEL OCCURS. AN IMMEDIATE E-STOP IS APPLIED. THE SWITCH IS ALSO INCLUDED IN THE HARD WIRED E-STOP STRING.
	NOT X-AXIS MINUS OVERTRAVEL	I041-1	
	NOT Y-AXIS PLUS OVERTRAVEL	I041-2	
	NOT Y-AXIS MINUS OVERTRAVEL	I041-3	
	NOT Z-AXIS PLUS OVERTRAVEL	I041-4	
	NOT Z-AXIS MINUS OVERTRAVEL	I041-5	
	NOT C-AXIS PLUS OVERTRAVEL	I041-6	
	NOT C-AXIS MINUS OVERTRAVEL	I041-7	
	NOT A-AXIS PLUS OVERTRAVEL	I042-0	
	NOT A-AXIS MINUS OVERTRAVEL	I042-1	
	PLUS OVERTRAVEL BYPASS	Q034-1	WHEN AXIS OVERTRAVEL RECOVERY PROCEDURES ARE FOLLOWED, THIS OUTPUT COMES ON TO TEMPORARILY BYPASS THE PLUS OVERTRAVEL CONDITION, AND ALLOW THE AXIS TO JOG IN THE MINUS DIRECTION.
	MINUS OVERTRAVEL BYPASS	Q034-2	WHEN AXIS OVERTRAVEL RECOVERY PROCEDURES ARE FOLLOWED, THIS OUTPUT COMES ON TO TEMPORARILY BYPASS THE MINUS OVERTRAVEL CONDITION, AND ALLOW THE AXIS TO JOG IN THE PLUS DIRECTION.
DRIVES	RACK #1 INFEED MODULE FAN RUNNING	I032-0	WHEN THIS INPUT GOES LOW AFTER THE MACHINE IS OUT OF E-STOP, AN ALARM MESSAGE IS POSTED, WARNING THAT THE INFEED MODULE MAY OVERHEAT. NO MACHINE INHIBIT IS GENERATED.
	RACK #2 INFEED MODULE FAN RUNNING	I032-1	
	RACK #3 INFEED MODULE FAN RUNNING	I032-2	
	RACK #4 INFEED MODULE FAN RUNNING	I032-3	
	RACK #5 INFEED MODULE FAN RUNNING	I032-4	
	X-AXIS AMPLIFIER FAN RUNNING	I032-5	IF THIS INPUT GOES LOW AFTER THE MACHINE IS OUT OF E-STOP, AN ALARM MESSAGE IS POSTED, WARNING THAT THE AMPLIFIER MAY OVERHEAT. NO MACHINE INHIBIT IS GENERATED.
	XT-AXIS AMPLIFIER FAN RUNNING	I032-6	
	XG-AXIS AMPLIFIER FAN RUNNING	I032-7	
	XGT-AXIS AMPLIFIER FAN RUNNING	I033-0	

Y-AXIS AMPLIFIER FAN RUNNING	I033-1	
YT-AXIS AMPLIFIER FAN RUNNING	I033-2	
SP1 SPINDLE AMPLIFIER FAN RUNNING	I033-4	
SP1A SPINDLE AMPLIFIER FAN RUNNING	I033-5	
A-AXIS AMPLIFIER FAN RUNNING	I033-6	
C-AXIS AMPLIFIER FAN RUNNING	I033-7	
RACK #1 INFEED CONTACTOR ENERGIZED	I034-0	THESE INPUTS ARE CHECKED WHEN THE MACHINE IS BEING RESET FROM E-STOP. IF THE CONTACTOR IS NOT ENERGIZED, THE MACHINE WILL GO BACK INTO E-STOP AND POST A MESSAGE, UNLESS ALL AXES ON THE CORRESPONDING RACK ARE BYPASSED.
RACK #2 INFEED CONTACTOR ENERGIZED	I034-1	
RACK #3 INFEED CONTACTOR ENERGIZED	I034-2	
RACK #4 INFEED CONTACTOR ENERGIZED	I034-3	
RACK #5 INFEED CONTACTOR ENERGIZED	I034-4	
RACK #1 MONITORING MODULE CONTACTOR ENERGIZED	I034-5	
X-AXIS DRIVE INHIBITED	I035-0	THESE INPUTS ARE CHECKED WHEN THE MACHINE IS BEING RESET FROM E-STOP. IF THE DRIVE IS INHIBITED, THE MACHINE GOES BACK INTO E-STOP AND POSTS A MESSAGE, UNLESS THE CORRESPONDING AXIS IS BYPASSED.
XT-AXIS DRIVE INHIBITED	I035-1	
XG-AXIS DRIVE INHIBITED	I035-2	
XGT-AXIS DRIVE INHIBITED	I035-3	
Y-AXIS DRIVE INHIBITED	I035-4	
YT-AXIS DRIVE INHIBITED	I035-5	
Z-AXIS DRIVE INHIBITED	I035-6	
ZT-AXIS DRIVE INHIBITED	I035-7	
SP1 SPINDLE DRIVE INHIBITED	I036-3	
SP1A SPINDLE DRIVE INHIBITED	I036-4	
A-AXIS DRIVE INHIBITED	I036-5	
C-AXIS DRIVE INHIBITED	I036-6	

Z-AXIS MOTOR FAN RUNNING	I040-0	IF THIS INPUT GOES LOW, AN ERROR MESSAGE IS POSTED WITH A WARNING THAT THE MOTOR MAY OVERHEAT. NO MACHINE INHIBIT OCCURS.
ZT-AXIS MOTOR FAN RUNNING	I040-1	
SP1 SPINDLE RESISTOR MODULE #1 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-0	IF THE PULSE RESISTOR MODULE PRE-WARNING FOR I2T SHUTDOWN SIGNAL GOES LOW ON ONE OF THE PULSE RESISTOR MODULES (INPUT TO PLC), A WARNING MESSAGE IS POSTED. IF THE PULSE RESISTOR MODULE PRE-WARNING FOR I2T SHUTDOWN SIGNAL GOES LOW ON TWO OR MORE OF THE ONE OF THE PULSE RESISTOR MODULES, AN IMMEDIATE SPINDLE STOP IS ISSUED, THE PULSE ENABLE TO BOTH SPINDLE DRIVE AMPLIFIERS ARE IMMEDIATELY REMOVED, AND AN E-STOP IS APPLIED.
SP1 SPINDLE RESISTOR MODULE #2 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-2	
SP1 SPINDLE RESISTOR MODULE #3 NOT PRE-WARNING FOR I*T SHUTDOWN	I044-4	
SP1A SPINDLE RESISTOR MODULE #1 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-0	
SP1A SPINDLE RESISTOR MODULE #2 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-2	
SP1A SPINDLE RESISTOR MODULE #3 NOT PRE-WARNING FOR I*T SHUTDOWN	I045-4	
SP1 SPINDLE RESISTOR MODULE #1 NOT FAULT	I044-1	
SP1 SPINDLE RESISTOR MODULE #2 NOT FAULT	I044-3	
SP1 SPINDLE RESISTOR MODULE #3 NOT FAULT	I044-5	
SP1A SPINDLE RESISTOR MODULE #1 NOT FAULT	I045-1	
SP1A SPINDLE RESISTOR MODULE #2 NOT FAULT	I045-3	
SP1A SPINDLE RESISTOR MODULE #3 NOT FAULT	I045-5	
SP1 SPINDLE VOLTAGE MODULE NOT FAULT	I039-0	IF THE VPM NOT FAULT SIGNAL GOES LOW, INDICATING THE VPM HAS BEEN APPLIED, AN IMMEDIATE SPINDLE STOP IS ISSUED, THE PULSE ENABLE TO BOTH SPINDLE DRIVE AMPLIFIERS ARE IMMEDIATELY REMOVED, AND AN E-STOP IS APPLIED.
SP1A SPINDLE VOLTAGE MODULE NOT FAULT	I039-1	
SP1 SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-0	
SP1 SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-1	

SP1 SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-2	
SP1A SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-3	
SP1A SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-4	
SP1A SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-5	
ENABLE X-AXIS DRIVES	Q032-0	
ENABLE Y-AXIS DRIVES	Q032-1	
ENABLE Z-AXIS DRIVES	Q032-2	THE CORRESPONDING OUTPUT IS TURNED ON TO ENABLE THE AXIS DRIVE AT THE APPROPRIATE TIME WHEN EXECUTING THE "COMING OUT OF E-STOP" ROUTINE.
ENABLE SP1 SPINDLE DRIVE	Q032-6	
ENABLE SP1A SPINDLE DRIVE	Q032-7	
ENABLE A-AXIS DRIVE	Q033-0	
ENABLE C-AXIS DRIVE	Q033-1	
INHIBIT SP1 SPINDLE RESISTOR MODULE #1	Q036-0	
INHIBIT SP1 SPINDLE RESISTOR MODULE #2	Q036-1	
INHIBIT SP1 SPINDLE RESISTOR MODULE #3	Q036-2	THE INHIBIT PULSE RESISTOR MODULE SIGNAL (OUTPUT FROM PLC) IS SET LOW TO ENABLE THE PULSE RESISTOR MODULE DURING NORMAL OPERATIONS.
INHIBIT SP1A SPINDLE RESISTOR MODULE #1	Q036-3	
INHIBIT SP1A SPINDLE RESISTOR MODULE #2	Q036-4	
INHIBIT SP1A SPINDLE RESISTOR MODULE #3	Q036-5	
DISABLE SPINDLE INFEEADS FOR VPM TESTING	Q037-0	
OPEN SP1 SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-1	THE VPM AND THE PULSE RESISTOR MODULES MUST BE TESTED PERIODICALLY IN ORDER TO ASSURE THEIR READINESS. THESE OUTPUTS ARE TURNED ON AT THE APPROPRIATE TIME DURING THE VPM AND THE PULSE RESISTOR MODULES TEST SEQUENCE.
OPEN SP1A SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-2	
RESET INFEED MODULES FROM VPM FAULTS	Q037-3	
X-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-2	WHEN AN E-STOP OCCURS, THESE OUTPUTS ARE TURNED OFF, A CONTACTOR DISENGAGES, WHICH SHORTS THE MOTOR LEADS TOGETHER, CREATING AN ELECTRONIC HOLDING BRAKE.
XT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-3	
XG-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-4	

	XGT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-5	
	Y-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-6	
	YT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-7	
	DISCONNECT X-AXIS MOTOR DYNAMIC BRAKING	Q035-0	
	DISCONNECT Y-AXIS MOTOR DYNAMIC BRAKING	Q035-1	
	AXES BRAKE CIRCUIT BREAKERS OK	I043-0	LOSS OF THIS SIGNAL CAUSES AN IMMEDIATE E-STOP. ALL BRAKES WILL IMMEDIATELY BE APPLIED.
	ENABLE AXES DRIVES & BRAKES	I043-1	THIS OUTPUT IS TURNED ON TO RELEASE THE AXIS BRAKES AT THE APPROPRIATE TIME WHEN EXECUTING THE "COMING OUT OF E-STOP" ROUTINE. E-STOP WILL IMMEDIATELY APPLY THE BRAKES.
	RELEASE Z-AXIS BRAKES	Q035-2	THIS OUTPUT IS TURNED ON TO RELEASE THE AXIS BRAKES AT THE APPROPRIATE TIME WHEN EXECUTING THE "COMING OUT OF E-STOP" ROUTINE. E-STOP WILL IMMEDIATELY APPLY THE BRAKES.
TEMPERATURE	NOT X-AXIS MOTOR OVER TEMPERATURE	I037-0	THIS CORRESPONDING INPUT GOES LOW WHEN AN AXIS OVER TEMPERATURE OCCURS. WHEN THE TORQUE MOTORS REACH A CRITICAL TEMPERATURE, THE CURRENT TO THE STATOR IS IMMEDIATELY SWITCHED OFF.
	NOT XT-AXIS MOTOR OVER TEMPERATURE	I037-1	
	NOT XG-AXIS MOTOR OVER TEMPERATURE	I037-2	
	NOT XGT-AXIS MOTOR OVER TEMPERATURE	I037-3	
	NOT Y-AXIS MOTOR OVER TEMPERATURE	I037-4	
	NOT YT-AXIS MOTOR OVER TEMPERATURE	I037-5	
	NOT A-AXIS MOTOR MAX OVERTEMP	I037-7	
	NOT C-AXIS MOTOR OVER TEMPERATURE	I038-2	
	NOT SP1 SPINDLE OVER TEMPERATURE	I038-3	
	NOT SP1A SPINDLE OVER TEMPERATURE	I038-4	
HOME	A-AXIS HOME	I080-6	THE A-AXIS HOME SWITCH TURNS ON WHEN THE A-AXIS IS AT THE HOME POSITION DURING A HOME REFERENCE CYCLE.
	C-AXIS HOME	I082-3	THE C-AXIS HOME SWITCH TURNS ON WHEN THE A-AXIS IS AT THE HOME POSITION DURING A HOME REFERENCE CYCLE.
<b>B.1.1 COOLANT SYSTEM INPUTS / OUTPUTS</b>			

FLOOD COOLANT SYSTEM	COOLANT FILTRATION SYSTEM RUNNING (NO FAULTS)	I053-0	THIS INPUT IS ON AFTER THE CUTTING COOLANT SYSTEM IS STARTED (REMOTE OR LOCAL), BOTH TANK LEVELS ARE AT PROPER LEVELS, INTERNAL CONVEYORS ARE NOT OVERLOADED, AND THE BACKWASH CONVEYOR IS RUNNING. LOSS OF THIS SIGNAL CAUSES AN IMMEDIATE STOP TO ALL COOLANT SYSTEM PUMP MOTORS, THE CONVEYOR MOTORS, AND TURNS OFF THE COOLANT FILTRATION SYSTEM REMOTE START.
	COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP MOTOR RUNNING	I053-1	THIS INPUT IS ON WHEN THE COOLANT HIGH PRESSURE PUMP MOTOR STARTER IS ENERGIZED, PROVIDING INTERNAL CUTTING COOLANT. LOSS OF THIS SIGNAL CAUSES THE COOLANT HIGH PRESSURE PUMP MOTOR TO STOP (THE START COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP - INTERNAL CUTTING COOLANT OUTPUT IS TURNED OFF), AND A MESSAGE IS POSTED. LOSS OF THIS SIGNAL WITH INTERNAL CUTTING COOLANT ACTIVE ADDITIONALLY FORCES A FEED HOLD, AND A MESSAGE IS POSTED.
	COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP MOTOR RUNNING	I053-2	THIS INPUT IS ON WHEN THE COOLANT LOW PRESSURE PUMP MOTOR STARTER IS ENERGIZED, PROVIDING EXTERNAL CUTTING COOLANT. LOSS OF THIS SIGNAL CAUSES THE COOLANT LOW PRESSURE PUMP MOTOR TO STOP (START COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP - EXTERNAL CUTTING COOLANT OUTPUT IS TURNED OFF), AND A MESSAGE IS POSTED. LOSS OF THIS SIGNAL WITH EXTERNAL CUTTING COOLANT ACTIVE ADDITIONALLY FORCES A FEED HOLD, AND A MESSAGE IS POSTED.
	COOLANT FILTRATION SYSTEM CHIP CONVEYORS RUNNING	I053-3	THIS INPUT IS ON WHEN THE MACHINE CHIP CONVEYORS MOTOR STARTERS ARE ENERGIZED (SIDE CONVEYORS AND CROSS CONVEYOR). WITH LOSS OF THIS SIGNAL, A MESSAGE ONLY IS POSTED. LOSS OF THIS SIGNAL DOES NOT TURN OFF THE COOLANT FILTRATION SYSTEM (E-STOP), DOES NOT STOP THE COOLANT SYSTEM HIGH PRESSURE PUMP OR THE CUTTING COOLANT SYSTEM LOW PRESSURE PUMP. LOSS OF THIS SIGNAL DOES NOT TURN OFF THE START COOLANT FILTRATION SYSTEM CHIP CONVEYORS. THE COOLANT FILTRATION SYSTEM CONTROLLER SHUTS OFF THE FAULTED CONVEYOR, AND THE NON-FAULTED CONVEYORS CONTINUE TO RUN.
	START COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP MOTOR	Q050-5	THIS OUTPUT IS TURNED ON TO START THE INTERNAL CUTTING COOLANT. THIS OUTPUT IS ENERGIZED WHEN INTERNAL COOLANT IS ACTIVATED WITH AN M-CODE OR FROM THE PUSHBUTTON ON THE OPERATOR CONSOLE. THIS OUTPUT IS TURNED OFF 2 MINUTES AFTER THE INTERNAL COOLANT REQUEST IS CANCELLED (THE TIME IS STORED IN A DATA REGISTER TO ALLOW FOR ADJUSTMENT). THIS PROCESS WILL PREVENT THE PUMP MOTOR FROM SHORT-CYCLING IF ANOTHER COOLANT REQUEST IS PENDING. THIS WILL ALSO PREVENT THE PUMP FROM EXPERIENCING EXTENDED PERIODS WITH A DEAD-HEAD PRESSURE. THIS OUTPUT IS TURNED OFF WITH AN E-STOP, COOLANT FILTRATION SYSTEM READY FAULT, OR HIGH PRESSURE COOLANT PUMP RUNNING FAULT. THIS OUTPUT IS NOT TURNED OFF WITH RESET, OR CHIP CONVEYOR RUNNING FAULT.

	START COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP MOTOR	Q050-6	<p>THIS OUTPUT IS TURNED ON TO START THE EXTERNAL CUTTING COOLANT.</p> <p>THIS OUTPUT IS ENERGIZED WHEN EXTERNAL COOLANT IS ACTIVATED WITH AN M-CODE OR FROM THE PUSHBUTTON ON THE OPERATOR CONSOLE.</p> <p>THIS OUTPUT IS TURNED OFF 2 MINUTES AFTER THE EXTERNAL COOLANT REQUEST IS CANCELLED (THE TIME IS STORED IN A DATA REGISTER TO ALLOW FOR ADJUSTMENT). THIS PROCESS WILL PREVENT THE PUMP MOTOR FROM SHORT-CYCLING IF ANOTHER COOLANT REQUEST IS PENDING. THIS WILL ALSO PREVENT THE PUMP FROM EXPERIENCING EXTENDED PERIODS WITH A DEAD-HEAD PRESSURE.</p> <p>THIS OUTPUT IS TURNED OFF WITH AN E-STOP, COOLANT FILTRATION SYSTEM READY FAULT, OR LOW PRESSURE COOLANT PUMP RUNNING FAULT. THIS OUTPUT IS NOT TURNED OFF WITH RESET, OR CHIP CONVEYOR RUNNING FAULT.</p>
	START COOLANT FILTRATION SYSTEM CHIP CONVEYORS	Q050-7	<p>THIS OUTPUT IS ENERGIZED TO START THE CHIP CONVEYORS. THIS OUTPUT IS TURNED ON WITH THE "CHIP CONV START" BUTTON ON THE MAIN OPERATOR CONSOLE.</p> <p>THIS OUTPUT IS TURNED OFF A WITH THE "CHIP CONV STOP" BUTTON ON THE MAIN OPERATOR CONSOLE, OR WITH AN E-STOP.</p> <p>A CHIP CONVEYOR FAULT, OR A COOLANT FILTRATION SYSTEM RUNNING FAULT, WILL NOT TURN OFF THE START COOLANT FILTRATION SYSTEM CHIP CONVEYORS. THE COOLANT FILTRATION SYSTEM CONTROLLER SHUTS OFF THE FAULTED CONVEYOR, AND THE NON-FAULTED CONVEYORS CONTINUE TO RUN.</p>
	EXTERNAL CUTTING COOLANT ON	Q061-0	<p>THIS SOLENOID VALVE IS ENERGIZED WHEN EXTERNAL CUTTING COOLANT IS REQUESTED, FROM THE PUSHBUTTON ON OPERATOR CONSOLE OR FROM AN M10 PROGRAMMED COMMAND.</p> <p>THE EXTERNAL COOLANT FLOW IS INTERRUPTED WHEN M00 (PROGRAM STOP), M05 (SPINDLE STOP), M09 (COOLANT OFF), M07-M12 (LUBE, COOLANT, AND AIR CODES), M30 (PROGRAM END), RESET, OR E-STOP ARE EXECUTED.</p>
	INTERNAL CUTTING COOLANT ON	Q061-1	<p>THIS SOLENOID VALVE IS ENERGIZED WHEN INTERNAL CUTTING COOLANT IS REQUESTED, FROM THE PUSHBUTTON ON OPERATOR CONSOLE OR FROM AN M12 PROGRAMMED COMMAND.</p> <p>THE INTERNAL COOLANT FLOW IS INTERRUPTED WHEN M00 (PROGRAM STOP), M05 (SPINDLE STOP), M09 (COOLANT OFF), M07-M12 (LUBE, COOLANT, AND AIR CODES), M30 (PROGRAM END), RESET, OR E-STOP ARE EXECUTED.</p>
	INTERNAL CUTTING COOLANT FLOW	PIW 408	<p>AFTER THE INTERNAL CUTTING COOLANT SOLENOID VALVE IS ENERGIZED, THIS ANALOG SIGNAL IS MONITORED. AUTOMATIC OPERATIONS CONTINUE AFTER FLOW IS ESTABLISHED.</p> <p>IF THIS SIGNAL DROPS BELOW A DEFINED LEVEL, LOGIC WILL GENERATE A FEED HOLD, FOLLOWED BY A SPINDLE STOP. A MESSAGE WILL BE POSTED.</p>
<b>B.1.3 MOTOR COOLING INPUTS / OUTPUTS</b>			
CHILLER	MOTOR CHILLER HIGH/LOW TEMP ALARM	I061-0	<p>AFTER THE CHILLER IS STARTED, IT RESPONDS WITH THIS SIGNAL.</p> <p>LOSS OF SIGNAL CAUSES A FEED HOLD, FOLLOWED BY A SPINDLE STOP, AND THEN AN E-STOP, AND A MESSAGE IS POSTED.</p>

	REMOTE START MOTOR CHILLER	Q061-4	THE CHILLER IS STARTED WITH THE MACHINE ON PUSHBUTTON AS THE MACHINE COMES OUT OF E-STOP. THE CHILLER IS STOPPED WITH AN E-STOP, OR WHEN A FAULT IN THE CHILLER SYSTEM IS DETECTED.
COOLING WATER FLOW	AXIS MOTOR RETURN COOLING BALL VALVE OPEN LS	I061-1	IF THIS SIGNAL IS HIGH, AN ALARM MESSAGE IS POSTED AND AN E-STOP IS GENERATED.
	X-AXIS MOTOR COOLING WATER FLOW MONITOR	I300- I301	
	XT-AXIS MOTOR COOLING WATER FLOW MONITOR	I302- I303	
	C-AXIS MOTOR COOLING WATER FLOW MONITOR	I410- I411	
	Y-AXIS MOTOR COOLING WATER FLOW MONITOR	I412- I413	AFTER THE COOLING WATER PUMP IS STARTED AND WATER FLOW IS ESTABLISHED, THESE ANALOG SIGNALS ARE MONITORED.
	YT-AXIS MOTOR COOLING WATER FLOW MONITOR	I414- I415	IF ANY OF THESE SIGNALS DROPS BELOW A DEFINED LEVEL, LOGIC WILL GENERATE A FEED HOLD, FOLLOWED BY A SPINDLE STOP, AND THEN AN E-STOP. A MESSAGE WILL BE POSTED.
	SPINDLE MOTOR COOLING WATER FLOW MONITOR	I424- I425	
	A-AXIS MOTOR COOLING WATER FLOW MONITOR	I426- I427	
	XG-AXIS MOTOR COOLING WATER FLOW MONITOR	I500- I501	
	XGT-AXIS MOTOR COOLING WATER FLOW MONITOR	I502- I503	
COOLING WATER TEMP	SPINDLE COOLING WATER INLET TEMPERATURE	I416- I417	THE TEMPERATURE OF THE WATER GOING INTO THE SPINDLE MOTOR IS MONITORED AND DISPLAYED.
	SPINDLE COOLING WATER OUTLET TEMPERATURE	I418- I419	THE TEMPERATURE OF THE WATER FLOWING OUT OF THE SPINDLE MOTOR IS MONITORED AND DISPLAYED.
<b>B.1.4 E-STOP INPUTS / OUTPUTS</b>			
E-STOP PUSHBUTTONS	MAIN CONTROL NOT E-STOP	I043-2	THIS INPUT GOES LOW WHEN THE E-STOP BUTTON IS PRESSED. THIS SWITCH IS ALSO INCLUDED IN THE HARD WIRED E-STOP STRING.
	TOOL CHANGER E-STOP	I061-4	THIS INPUT GOES LOW WHEN THE E-STOP BUTTON IS PRESSED. THIS SWITCH IS ALSO INCLUDED IN THE HARD WIRED E-STOP STRING.
	B-MPI PENDANT NOT E-STOP	I061-7	THIS INPUT GOES LOW WHEN THE E-STOP BUTTON IS PRESSED. THIS SWITCH IS ALSO INCLUDED IN THE HARD WIRED E-STOP STRING.
	E-STOP RESET	I090-2	THIS SIGNAL GOES HIGH TO CANCEL AN ALARM AND RESET THE LATCHED E-STOP CONDITION.
	OPERATOR PENDANT E-STOP	I090-4	THIS INPUT GOES LOW WHEN THE E-STOP BUTTON IS PRESSED. THIS SWITCH IS ALSO INCLUDED IN THE HARD WIRED E-STOP STRING.
	NOT CNC E-STOP REQUEST	Q034-0	THIS INPUT GOES LOW WHEN THE CNC LOGIC COMMANDS AN E-STOP. THIS CONTACT IS INCLUDED IN THE HARD WIRED E-STOP STRING.

<b>B.1.5 GATES &amp; INTERLOCKS INPUTS / OUTPUTS</b>			
<b>OP PLATFORM AISLE SIDE</b>	UNLOCK OPERATOR PLATFORM AISLE DOOR	I093-3	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT OPERATOR PLATFORM AISLE DOOR	I093-4	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE AUTO PERMIT POSITION.
	RESET OPERATOR PLATFORM AISLE DOOR	I093-5	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE GATE RESET POSITION.
	OPERATOR PLATFORM AISLE DOOR CLOSED	I093-7	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS DOOR IS CLOSED.
	UNLOCK OPERATOR PLATFORM AISLE DOOR	Q090-1	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS DOOR WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE DOOR.
	AUTO PERMIT OPERATOR PLATFORM AISLE DOOR	Q090-3	THIS LIGHT WILL ILLUMINATE WHEN THE DOOR IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
<b>OP PLATFORM FLOOR PLATE SIDE</b>	UNLOCK OPERATOR PLATFORM FLOOR PLATE DOOR	I093-0	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT OPERATOR PLATFORM FLOOR PLATE DOOR	I093-1	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE AUTO PERMIT POSITION.
	RESET OPERATOR PLATFORM FLOOR PLATE DOOR	I093-2	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS DOOR IS IN THE GATE RESET POSITION.
	OPERATOR PLATFORM FLOOR PLATE DOOR CLOSED	I093-6	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS DOOR IS CLOSED.
	UNLOCK OPERATOR PLATFORM FLOOR PLATE DOOR	Q090-0	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS DOOR WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE DOOR.
	AUTO PERMIT OPERATOR PLATFORM FLOOR PLATE DOOR	Q090-2	THIS LIGHT WILL ILLUMINATE WHEN THE DOOR IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
<b>PERIMETER GATE #1</b>	UNLOCK PERIMETER GATE #1 (SE)	I047-0	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #1 (SE)	I047-1	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #1 (SE)	I047-2	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	PERIMETER GATE #1 (SE) CLOSED	I047-6	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
	UNLOCK PERIMETER GATE #1 (SE)	Q037-4	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
	AUTO PERMIT PERIMETER GATE #1 (SE)	Q037-5	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.

<b>PERIMETER GATE #2</b>	UNLOCK PERIMETER GATE #2 (E)	I047-3	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #2 (E)	I047-4	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #2 (E)	I047-5	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	PERIMETER GATE #2 (E) CLOSED	I047-7	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
	UNLOCK PERIMETER GATE #2 (E)	Q037-6	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
<b>PERIMETER GATE #3</b>	AUTO PERMIT PERIMETER GATE #2 (E)	Q037-7	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
	UNLOCK PERIMETER GATE #3 (NE)	I050-0	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #3 (NE)	I050-1	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #3 (NE)	I050-2	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	PERIMETER GATE #3 (NE) CLOSED	I050-6	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
	UNLOCK PERIMETER GATE #3 (NE)	Q050-0	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
	AUTO PERMIT PERIMETER GATE #3 (NE)	Q050-1	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.

<b>PERIMETER GATE #4</b>	UNLOCK PERIMETER GATE #4 (NW)	I050-3	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #4 (NW)	I050-4	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #4 (NW)	I050-5	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	PERIMETER GATE #4 (NW) CLOSED	I050-7	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
	UNLOCK PERIMETER GATE #4 (NW)	Q050-2	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
<b>PERIMETER GATE #5</b>	AUTO PERMIT PERIMETER GATE #4 (NW)	Q050-3	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
	UNLOCK PERIMETER GATE #5 (W)	I052-0	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #5 (W)	I052-1	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #5 (W)	I052-2	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	PERIMETER GATE #5 (W) CLOSED	I052-6	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
<b>PERIMETER GATE #6</b>	UNLOCK PERIMETER GATE #5 (W)	Q051-0	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
	AUTO PERMIT PERIMETER GATE #5 (W)	Q051-1	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
	UNLOCK PERIMETER GATE #6 (SW)	I052-3	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT PERIMETER GATE #6 (SW)	I052-4	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET PERIMETER GATE #6 (SW)	I052-5	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
<b>OPERATOR CONSOLE</b>	PERIMETER GATE #6 (SW) CLOSED	I052-7	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED.
	UNLOCK PERIMETER GATE #6 (SW)	Q051-2	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
	AUTO PERMIT PERIMETER GATE #6 (SW)	Q051-3	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
	GATE OPEN IN ZONE #1	Q091-1	THIS LIGHT ON THE OPERATOR CONSOLE WILL ILLUMINATE WHEN ANY GATE IN ZONE #1 HAS BEEN OPENED, AND NOT RESET.
	GATE OPEN IN ZONE #2	Q091-2	THIS LIGHT ON THE OPERATOR CONSOLE WILL ILLUMINATE WHEN ANY GATE IN ZONE #2 HAS BEEN OPENED, AND NOT RESET.

<b>TOOL CHANGER</b>	TOOL CHANGER MANIPULATOR DOOR OPEN	Input to Tool Chg. PLC	THIS INPUT MUST BE ON, INDICATING THE TOOL CHANGER DOOR IS OPEN, TO ALLOW TOOL CHANGER MANIPULATOR MOTION.
	TOOL CHANGER MANIPULATOR DOOR CLOSED	Input to Tool Chg. PLC	THIS INPUT MUST BE ON, INDICATING THE TOOL CHANGER DOOR IS CLOSED, TO ALLOW AUTOMATIC OPERATIONS (ALLOW CYCLE START).
	OPEN TOOL CHANGER DOOR	Output from Tool Chg. PLC	THIS OUTPUT IS TURNED ON TO OPEN THE TOOL CHANGER DOOR.
	CLOSE TOOL CHANGER DOOR	Output from Tool Chg. PLC	THIS OUTPUT IS TURNED ON TO CLOSE THE TOOL CHANGER DOOR.
<b>TOOL LOAD PLATFORM GATE</b>	UNLOCK TOOL LOAD PLATFORM GATE	I051-3	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE UNLOCK POSITION.
	AUTO PERMIT TOOL LOAD PLATFORM GATE	I051-4	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE AUTO PERMIT POSITION.
	RESET TOOL LOAD PLATFORM GATE	I051-5	THIS INPUT COMES ON WHEN THE KEY SWITCH FOR THE ASSOCIATED ACCESS GATE IS IN THE GATE RESET POSITION.
	TOOL LOAD PLATFORM GATE CLOSED	I051-6	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS CLOSED. THE GATE MUST BE CLOSED TO ALLOW AUTOMATIC OPERATIONS OR X-AXIS MOTION.
	TOOL LOAD PLATFORM GATE OPENED	I051-7	THIS INPUT IS ON WHEN THE ASSOCIATED ACCESS GATE IS OPENED. THE GATE MUST BE OPEN TO ALLOW OPERATION OF THE TOOL CHANGER ROTARY DOOR.
	UNLOCK TOOL LOAD PLATFORM GATE	Q036-6	LOGIC WILL TURN THIS OUTPUT ON TO UNLOCK THE ACCESS GATE WHEN LOGIC DETECTS THE SELECTOR SWITCH IN THE "GATE UNLOCK" POSITION AND LOGIC INSURES THE MACHINE IS IN A SAFE STATE TO UNLOCK THE GATE.
	AUTO PERMIT TOOL LOAD PLATFORM GATE	Q036-7	THIS LIGHT WILL ILLUMINATE WHEN THE GATE IS CLOSED, AND THE SWITCH HAS BEEN MOVED TO "GATE RESET" AND THEN BACK TO "AUTO PERMIT", INDICATING AUTOMATIC MOTION CAN OCCUR WITHIN THE RESTRICTED AREA.
<b>B.1.6 HYDRAULICS INPUTS / OUTPUTS</b>			
<b>POWER UNIT</b>	HYDRAULIC RECIRCULATION PRESSURE OK	I091-0	A SHORT TIME AFTER THE HYDRAULIC PUMP MOTOR IS STARTED, THE HYDRAULIC PRESSURE OK IS MONITORED. LOSS OF THIS SIGNAL WILL CAUSE AN IMMEDIATE FEED HOLD ON THE MACHINE, STOP THE HYDRAULIC PUMP MOTOR, AND A MESSAGE WILL BE POSTED.
	NOT HYDRAULIC TANK LOW LEVEL	I091-1	IF THIS SIGNAL STAYS LOW FOR A PRESET PERIOD, A MESSAGE IS POSTED. CYCLE START OF A NEW PROGRAM IS INHIBITED, ANY ACTIVE PROGRAM IS UNAFFECTED.
	NOT HYDRAULIC TANK OVERTEMPERATURE	I091-2	IF THIS SIGNAL STAYS LOW FOR A PRESET PERIOD, A MESSAGE IS POSTED. CYCLE START OF A NEW PROGRAM IS INHIBITED, ANY ACTIVE PROGRAM IS UNAFFECTED.
	HYDRAULIC PRESSURE OK	I091-3	A SHORT TIME AFTER THE HYDRAULIC PUMP MOTOR IS STARTED, THE HYDRAULIC PRESSURE OK IS MONITORED. LOSS OF THIS SIGNAL WILL CAUSE AN IMMEDIATE FEED HOLD ON THE MACHINE, STOP THE HYDRAULIC PUMP MOTOR, AND A MESSAGE WILL BE POSTED.
	HYDRAULIC FILTER NOT DIRTY	I091-4	LOSS OF SIGNAL CAUSES A MESSAGE ONLY TO BE POSTED. CYCLE START IS INHIBITED.

	HYDRAULIC RECIRCULATION FILTER NOT DIRTY	I091-5	LOSS OF SIGNAL CAUSES A MESSAGE ONLY TO BE POSTED. CYCLE START IS INHIBITED.
	NOT HYDRAULIC TANK CRITICAL LOW LEVEL	I091-6	IF THIS SIGNAL STAYS LOW FOR A PRESET PERIOD, A MESSAGE IS POSTED. CYCLE START OF A NEW PROGRAM IS INHIBITED, ANY ACTIVE PROGRAM IS UNAFFECTED.
	NOT HYDRAULIC TANK CRITICAL OVERTEMPERATURE	I091-7	LOSS OF SIGNAL CAUSES A FEED HOLD, THEN THE MAIN HYDRAULIC PUMP MOTOR IS STOPPED (CAUSING E-STOP), AND A MESSAGE IS POSTED.
	HYDRAULIC PUMP MOTOR STARTER ENERGIZED	Q034-4	THE HYDRAULIC PUMP MOTOR IS STARTED WITH THE MACHINE ON PUSHBUTTON AS THE MACHINE COMES OUT OF E-STOP. THE HYDRAULIC MOTOR IS STOPPED WITH AN E-STOP, OR WHEN A FAULT IN THE HYDRAULIC SYSTEM IS DETECTED (LOSS OF PRESSURE, OVER TEMPERATURE, ETC).
C-AXIS CLAMPS	UNCLAMP C-AXIS	Q103-3	THIS SOLENOID IS ENERGIZED WHEN THE C-AXIS IS COMMANDED BY M-CODE TO UNCLAMP AND ENABLE THE C-AXIS.
	C-AXIS UNCLAMPED PRESSURE OK	I100-6	THIS INPUT IS ON WHILE THE C-AXIS IS UNCLAMPED. C-AXIS MOTION IS INHIBITED WHEN THIS SIGNAL IS LOW.
A-AXIS CLAMPS	CLAMP A-AXIS	Q102-0	M-CODES ARE USED TO COMMAND A-AXIS TO CLAMP OR UNCLAMP. THIS OUTPUT IS TURNED ON TO UNCLAMP THE A-AXIS AND TURNED OFF TO CLAMP THE A-AXIS. THIS OUTPUT IS USED IN CONJUNCTION WITH THE A-AXIS PRESSURE SELECT PROPORTIONAL VALVE TO DELIVER PROPER UNCLAMP PRESSURE.
	A-AXIS CLAMPED/UNCLAMPED PRESSURE	PIW 604	THIS SIGNAL IS MONITORED WHEN A SPINDLE UNIT WITH A-AXIS CLAMPS IS ATTACHED. THREE DIFFERENT ACCEPTABLE PRESSURE RANGES ARE USED: 1) A-AXIS CLAMPED 2) A-AXIS UNCLAMPED WITH HIGH PRESSURE 3) A-AXIS UNCLAMPED WITH LOW PRESSURE IF THIS SIGNAL FALLS OUTSIDE OF THE ACCEPTABLE PRESSURE RANGE FOR THE TYPE OF UNIT WHEN A-AXIS IS CLAMPED/UNCLAMPED, AN IMMEDIATE E-STOP OCCURS.
	A-AXIS CLAMPED PRESSURE OK	PIW 600	THIS SIGNAL IS MONITORED WHEN A SPINDLE UNIT WITH A-AXIS WORM DRIVE IS ATTACHED. TWO DIFFERENT ACCEPTABLE PRESSURE RANGES ARE USED: 1) LOW A-AXIS WORM DRIVE PRE-LOAD 2) HIGH A-AXIS WORM DRIVE PRE-LOAD IF THIS SIGNAL FALLS OUTSIDE OF THE ACCEPTABLE PRESSURE RANGE FOR THE COMMENDED A-AXIS PRE-LOAD, AN IMMEDIATE E-STOP OCCURS.
	A-AXIS CLAMP PRESSURE SELECT	Q302	THIS OUTPUT IS SET PER SPINDLE UNIT, TO DELIVER THE PROPER UNCLAMP PRESSURE FOR THE A-AXIS. THIS OUTPUT IS ALSO SET TO OBTAIN THE DESIRED PRE-LOAD FOR THE A-AXIS WORM DRIVE.
SPINDLE UNIT TOOL GRIPPER	TOOL GRIPPER UNCLAMPED/CLAMPED PRESSURE	I602-I603	THIS ANALOG INPUT MUST BE WITHIN AN ACCEPTABLE RANGE FOR THE TYPE OF SPINDLE UNIT MOUNTED ON THE RAM WHEN A TOOL IS LOADED IN THE UNIT. IF IT FALLS OUTSIDE OF THIS RANGE, AN IMMEDIATE FEEDHOLD WILL BE ISSUED. THIS WILL FEEDHOLD ANY ACTIVE TOOL CHANGE MOTION.
	TOOL GRIPPER PRESSURE	I606-I607	THIS INPUT VERIFIES THE PROPER PRESSURE IS SET TO OPEN THE SPINDLE UNIT TOOL GRIPPERS (BASED ON ACTIVE SPINDLE UNIT).
	UNCLAMP TOOL GRIPPER	Q102-1	THIS OUTPUT IS TURNED ON TO RELEASE A TOOL DURING A TOOL CHANGE. DEPENDING ON THE TYPE OF SU, THE TOOL GRIPPER PRESSURE SELECT PROPORTIONAL VALVE OUTPUT MUST ALSO BE SET ACCORDINGLY.

	TOOL GRIPPER PRESSURE SELECT PROPORTIONAL VALVE	Q300- Q301	THIS ANALOG OUTPUT SETS THE PROPER PRESSURE TO OPEN THE SU TOOL GRIPPERS. PRESSURE SETTING IS BASED ON WHICH SPINDLE UNIT IS MOUNTED.
SPINDLE UNIT CORNER GRIPPER	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6	THIS INPUT SHOULD BE OFF WHEN NO SU IS MOUNTED ON THE HEAD. THIS INPUT MUST BE ON BEFORE LOWERING THE RAM TO PICK A NEW SPINDLE UNIT. THIS INPUT MUST BE OFF BEFORE RAISING THE RAM TO DROP A SPINDLE UNIT. LOSS OF PROPER SIGNAL WILL CAUSE A FEEDHOLD.
	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7	THIS INPUT SHOULD BE ON WHEN A SU IS MOUNTED ON THE HEAD. LOSS OF THIS SIGNAL WITH A SU ATTACHED WILL CAUSE AN IMMEDIATE E-STOP.
	UNCLAMP CORNER GRIPPER (REDUNDANT)	Q103-0	THIS OUTPUT IS ENERGIZED ALONG WITH THE UNCLAMP CORNER GRIPPERS OUTPUT TO RELEASE THE SU FROM THE HEAD INTO AN EMPTY CRADLE.
	UNCLAMP CORNER GRIPPERS	Q103-1	THIS OUTPUT IS ENERGIZED ALONG WITH THE REDUNDANT UNCLAMP CORNER GRIPPERS OUTPUT TO RELEASE THE SU FROM THE HEAD INTO AN EMPTY CRADLE.
Z-AXIS COUNTERBALANCE	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE MONITOR TRANSDUCER	I608- I609	THIS ANALOG INPUT IS USED TO MONITOR THE Z-AXIS COUNTERBALANCE SYSTEM PRESSURE. LOSS OF PROPER VALVE OF THIS INPUT (BASED ON Z-AXIS POSITION) WILL FORCE A CONTROLLED E-STOP.
	Z-AXIS COUNTERBALANCE BLEED CIRCUIT ON	Q080-0	THIS SOLENOID IS ENERGIZED PERIODICALLY BASED ON A PRESET TIMER. THE SOLENOID REMAINS ENERGIZED FOR A PRESET AMOUNT OF TIME.
	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE CHARGING VALVE ON	Q100-2	THIS OUTPUT IS ENERGIZED WHEN THE Z-AXIS COUNTERBALANCE PRESSURE FALLS BELOW A PRESET LEVEL. THE OUTPUT IS TURNED OFF WHEN THE PRESSURE RISES ABOVE ANOTHER PRESET LEVEL.
<b>B.1.7 LUBRICATION INPUTS / OUTPUTS</b>			
AXIS LUBE	AXIS LUBRICANT LEVEL OK	I101-0	WHEN THIS SIGNAL GOES HIGH, A MESSAGE IS POSTED WITH NO MACHINE INHIBITS.
	AXIS LUBRICATION HIGH PRESSURE BLOWOUT	I101-1	THIS SIGNAL COMING ON WILL CAUSE LUBE PUMP OPERATIONS TO BE STOPPED AND AN ALARM TO BE POSTED. LOGIC WILL ISSUE A FEEDHOLD AND SPINDLE STOP. CYCLE START IS INHIBITED.
	AXIS LUBRICATION CYCLE SWITCH	I101-2	THIS INPUT MUST TOGGLE THREE (3) TIMES TO COMPLETE A FULL LUBE CYCLE.
	AXIS LUBRICATION PUMP ON	Q100-0	LOGIC ENERGIZED THIS OUTPUT TO START AN AXIS LUBE CYCLE. THIS OUTPUT REMAINS ENERGIZED UNTIL THE CYCLE SWITCH COMES ON OR UNTIL A LUBE FAULT OCCURS.

SU ATTACHMENT LUBE	TURN ON ATTACHMENT LUBE OIL	Q102-3	THIS OUTPUT IS ENERGIZED WHEN A SPINDLE UNIT REQUIRING SU RECIRCULATING LUBE (40 PSI) IS MOUNTED ON THE RAM. IT IS TURNED OFF WHEN THE SPINDLE UNIT IS PROGRAMMED TO BE REMOVED.
	TURN ON ATTACHMENT HYDRAULIC MOTOR	Q105-0	THIS OUTPUT IS ENERGIZED WHEN A SPINDLE UNIT REQUIRING SU RECIRCULATING LUBE (300 PSI) IS MOUNTED ON THE RAM, WHERE THE SYSTEM CONTAINED ENTIRELY INSIDE THE SU. IT IS TURNED OFF WHEN THE SPINDLE UNIT IS REMOVED.
	ATTACHMENT LUBE OIL PRESSURE OK	I100-0	THIS SWITCH IS MONITORED ONLY WHEN A SPINDLE UNIT REQUIRING SU RECIRCULATING LUBE IS MOUNTED ON THE RAM. ONCE THE SPINDLE UNIT IS ATTACHED, AND THE ATTACHMENT LUBE OIL OR ATTACHMENT HYDRAULIC MOTOR OIL OUTPUT IS ENERGIZED, THE PRESSURE SWITCH IS MONITORED. IF CORRESPONDING PRESSURE IS LOST, THE ATTACHMENT OIL OUTPUT IS DE-ENERGIZED, A FEED HOLD IS ISSUED, AND A FAULT MESSAGE IS DISPLAYED ON THE CRT.
	SPINDLE LUBE SCAVENGE PUMP MOTOR STARTER ENERGIZED	Q034-6	THIS OUTPUT IS ENERGIZED WHEN A SPINDLE UNIT REQUIRING SU RECIRCULATING LUBE (40 PSI) IS MOUNTED ON THE RAM. IT IS TURNED OFF WHEN THE SPINDLE UNIT IS REMOVED.
	SPINDLE LUBE PUMP PRIMING ON	Q080-2	THIS OUTPUT IS ENERGIZED WHEN THE SCAVENGE PUMP IS STARTED. IT REMAINS ON FOR APPROXIMATELY 10 SECOND, UNTIL THE PUMP IS PRIMED, AND THEN IS TURNED OFF.
	SU GREASE LUBE LOW LEVEL	I081-5	THIS INPUT IS MONITORED WHEN A SU WITH A GREASE INJECTION LUBE SYSTEM IS MOUNTED. IF THIS INPUT TURNS ON, LOGIC POSTS A MESSAGE FOR THE OPERATOR TO MANUALLY REFILL THE LUBE CYLINDER. LOGIC WILL INHIBIT ANY FUTURE CYCLE START, UNTIL THIS INPUT TURNS OFF.
	ACTIVATE SU GREASE LUBE	Q081-0	THIS OUTPUT IS ENERGIZED PERIODICALLY TO LUBE A SPINDLE UNIT THAT HAS A GREASE INJECTION SYSTEM. THIS SOLENOID IS TURNED ON AFTER A PRESET AMOUNT OF TIME, FOR A PRESET INTERVAL. THE INTERVAL AND DURATION IS SETTABLE PER SPINDLE UNIT.
SPINDLE BEARING LUBE	SPINDLE BEARING LUBRICATION LEVEL OK	I101-4	LOSS OF THIS SIGNAL INDICATES THE OIL LEVEL IN THE RESERVOIR TANK IS LOW. A FAULT REPORTED BY THE SPINDLE LUBRICATION PACKAGE WILL CAUSE AN END OF BLOCK STOP, FOLLOWED BY A SPINDLE STOP. A SPINDLE START INHIBIT WILL BE ENFORCED UNTIL THE FAULT IS CORRECTED AND THE ALARM IS RESET.
	SPINDLE BEARING LUBE SCAVENGE TANK OIL LEVEL NOT HIGH	I090-5	LOSS OF THIS SIGNAL INDICATES THE OIL LEVEL IN THE SCAVENGE TANK IS HIGH. A FAULT REPORTED BY THE SPINDLE LUBRICATION PACKAGE WILL CAUSE AN END OF BLOCK STOP, FOLLOWED BY A SPINDLE STOP. A SPINDLE START INHIBIT WILL BE ENFORCED UNTIL THE FAULT IS CORRECTED AND THE ALARM IS RESET.
	AIR ON TO SPINDLE BEARING LUBE	Q104-3	SPINDLE LUBE AIR SOLENOID IS "ON" ANY TIME SPINDLE IS COMMENDED TO RUN SPINDLE LUBE AIR SOLENOID IS TURNED "OFF" WHEN SPINDLE IS STOPPED AND THE ACTIVE LUBE CYCLE IS COMPLETED.
	SPINDLE BEARING LUBE SCAVENGE PUMP MOTOR STARTER	Q034-7	THIS PUMP MOTOR IS ENERGIZED WHENEVER THE AIR ON TO SPINDLE BEARING LUBE SOLENOID IS ACTIVE. IT REMAINS RUNNING APPROXIMATELY 1 MINUTE AFTER THE AIR ON TO SPINDLE BEARING LUBE SOLENOID IS DE-ENERGIZED. E-STOP WILL TURN OFF THESE PUMP MOTORS.
	SPINDLE LUBRICATION	Q080-1	THE SPINDLE LUBE OIL SOLENOID IS TURNED ON TO REFILL THE INJECTORS. THIS SOLENOID IS CYCLED BASED ON THE LUBE INTERVAL TIME AND THE PUMP DWELL TIME.

FRONT BEARING LUBE OIL TRANSDUCER #1	PIW 432	THESE ANALOG INPUTS FOR OIL AND AIR PRESSURES ARE MONITORED DURING THE C-AXIS / SPINDLE LUBE CYCLE AS DESCRIBED ABOVE IN THE C-AXIS / SPINDLE LUBE SECTION.
FRONT BEARING LUBE OIL TRANSDUCER #2	PIW 436	
FRONT BEARING LUBE AIR TRANSDUCER #1	PIW 434	
FRONT BEARING LUBE AIR TRANSDUCER #2	PIW 438	

**B.1.8 MISCELLANEOUS INPUTS / OUTPUTS**

MISC	CABINET AIR CONDITIONER #1 RUNNING	I043-3	THIS INPUT GOES LOW IF A FAULT IS DETECTED WITH THE AIR CONDITIONER. A MESSAGE ONLY IS POSTED.
	CABINET AIR CONDITIONER #2 RUNNING	I043-4	
	CABINET AIR CONDITIONER #3 RUNNING	I043-5	
	CABINET AIR CONDITIONER #4 RUNNING	I043-6	
	ENABLE RUN TIME METER	Q034-5	THIS METER TRACKS THE TOTAL ACCUMULATED TIME THAT CYCLE START MODE IS ACTIVE ON THE MACHINE.
	MACHINE OPERATING	Q051-5	GREEN - IF THIS LIGHT IS ON, THE MACHINE IS OPERATING WITH NO ALARMS
	MACHINE OPERATING - MINOR FAULT	Q051-6	AMBER – IF THIS LIGHT IS ON, THE MACHINE IS OPERATING WITH A WARNING ALARM (MINOR FAULT)
	MACHINE IN FAULT CONDITION	Q051-7	RED – IF THIS LIGHT IS ON, THE MACHINE HAS A CRITICAL FAULT CONDITION
	MESSAGE ALARM	Q091-0	A BEEPER IS USED TO INDICATE THAT A FAULT EXISTS. THE STANDARD SIEMENS ALARM CANCEL FUNCTION TURNS THE BEEPER OFF.
	AXIS PERMIT	I090-0	THIS KEY SELECTOR SWITCH MUST BE IN THE PERMIT POSITION TO ALLOW AXIS MOTION. THE KEY SWITCH IS REMOVABLE IN THE INHIBIT POSITION. IT PREVENTS ANYONE FROM MOVING THE AXIS DURING SERVICE OR TROUBLESHOOTING.
CURTAIN	SPINDLE PERMIT	I090-1	THIS KEY SELECTOR SWITCH MUST BE IN THE PERMIT POSITION TO ALLOW SPINDLE ROTATION. THE KEY SWITCH IS REMOVABLE IN THE INHIBIT POSITION. IT PREVENTS ANYONE FROM STARTING THE SPINDLE DURING SERVICE OR TROUBLESHOOTING.
	MIST COLLECTOR MOTOR STARTER ENERGIZED	Q033-7	THIS OUTPUT IS TURNED ON TO RUN THE MIST COLLECTOR MOTOR. IT IS TURNED ON AND OFF BY TOGGLING THE MIST COLLECTOR ON/OFF PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
	OPERATOR SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-0	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY OPEN.
	OPERATOR SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-1	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY CLOSED.
	TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-2	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY OPEN.

TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-3	THIS INPUT IS ON WHEN THE CURTAIN IS FULLY CLOSED.
OPEN OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q103-2	THIS OUTPUT IS TURNED ON TO OPEN THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE OPEN CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
CLOSE OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q105-1	THIS OUTPUT IS TURNED ON TO CLOSE THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE CLOSE CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
OPEN TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-2	THIS OUTPUT IS TURNED ON TO OPEN THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE OPEN CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.
CLOSE TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-3	THIS OUTPUT IS TURNED ON TO CLOSE THE CURTAIN. THE CURTAIN IS OPENED BY PRESSING THE CLOSE CURTAIN PUSHBUTTON ON THE MAIN OPERATOR CONSOLE.

**B.1.9 PENDANT INPUTS / OUTPUTS**

PNDT	B-MPI PENDANT ENABLED	I061-6	THIS INPUT IS ON WHEN THE B-MPI PENDANT IS ENABLED.
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**B.1.10 PROBE INPUTS / OUTPUTS**

TOOL PROBE	BROKEN TOOL PROBE HIGH SPEED BREAK	Q060-2	THIS OUTPUT IS TURNED ON BY A M142 CODE IN THE RENISHAW TOOL PROBE CYCLES AND TURNED OFF BY A M143 CODE.
	BROKEN TOOL PROBE LATCH MODE	Q060-3	THIS OUTPUT IS TURNED ON BY A M140 CODE IN THE RENISHAW TOOL PROBE CYCLES AND TURNED OFF BY A M141 CODE.
PART PROBE	PART PROBE BATTERY OK	I060-4	WHEN THE PART PROBE BATTERY OK INPUT TO THE PLC GOES LOW AND THE PROBE HAS BEEN TURNED ON, AN ALARM IS ISSUED TO SIGNAL THE OPERATOR THAT THE PROBE BATTERY IS LOW AND SHOULD BE CHANGED. THE PROBE WILL CONTINUE TO OPERATE FOR A SHORT PERIOD OF TIME UNDER THIS CONDITION.
	PART PROBE NOT ERROR	I060-5	WHEN THIS INPUT TO THE PLC GOES LOW, EITHER THE PROBE IS OUT OF RANGE FROM THE RECEIVER OR A HARDWARE ERROR HAS OCCURRED. IF THIS HAPPENS, AND THE PROBE HAS BEEN LOADED ONTO THE HEAD, THEN AN ALARM IS ISSUED THAT WILL CAUSE AN IMMEDIATE FEEDHOLD.
	SELECT PART PROBE	Q034-3	
	ENABLE PART PROBE	Q060-1	THIS OUTPUT IS PULSED ON, THEN OFF, TO ACTIVATE THE PROBE WHEN A M72 (PROBE ENABLE) IS ISSUED. THIS OUTPUT IS PULSED ON AND OFF TO DEACTIVATE THE PROBE WHEN A M73 (PROBE DISABLE) IS ISSUED.

**B.1.11 SPINDLE & SPINDLE UNIT INPUTS / OUTPUTS**

SUID	SU ID 1	I080-0	THESE INPUTS ARE USED TO DECODE THE SPINDLE UNIT PIN CODING. THIS NUMBER MUST MATCH THE PROGRAMMED SPINDLE UNIT NUMBER.
	SU ID 2	I080-1	
	SU ID 4	I080-2	
	SU ID 8	I080-3	
SU CORNER GRIPPERS	SPINDLE UNIT ATTACHED #1	PIW 444	THESE TWO ANALOG INPUTS VERIFY A SPINDLE UNIT IS ATTACHED TO THE RAM. IF EITHER INPUT GOES OUT OF ITS INDIVIDUAL RANGE WHILE A SPINDLE UNIT IS ATTACHED, AN IMMEDIATE E-STOP IS ISSUED. THE ALLOWABLE RANGE IS DETERMINED DURING MACHINE COMMISSIONING, AND IS STORED IN A DATA TABLE. THIS IS A SINGLE MACHINE SETTING, NOT A PER SPINDLE UNIT SETTING.
	SPINDLE UNIT ATTACHED #2	PIW 446	

	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6	THIS INPUT SHOULD BE OFF WHEN NO SU IS MOUNTED ON THE HEAD. THIS INPUT MUST BE OFF BEFORE LOWERING THE RAM TO PICK A NEW SPINDLE UNIT. THIS INPUT MUST BE OFF BEFORE RAISING THE RAM TO DROP A SPINDLE UNIT.
	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7	THIS INPUT SHOULD BE ON WHEN A SU IS MOUNTED ON THE HEAD. LOSS OF THIS SIGNAL WITH A SU ATTACHED WILL CAUSE AN IMMEDIATE E-STOP.
	UNCLAMP CORNER GRIPPER (REDUNDANT)	Q103-0	THIS OUTPUT IS ENERGIZED ALONG WITH THE UNCLAMP CORNER GRIPPERS OUTPUT TO RELEASE THE SU FROM THE HEAD INTO AN EMPTY CRADLE.
	UNCLAMP CORNER GRIPPER (REDUNDANT)	Q103-1	THIS OUTPUT IS ENERGIZED ALONG WITH THE REDUNDANT UNCLAMP CORNER GRIPPERS OUTPUT TO RELEASE THE SU FROM THE HEAD INTO AN EMPTY CRADLE.
SU TOOL GRIPPERS	SU TOOL GRIPPER PISTON RETRACTED	I081-1	THIS INPUT WILL BE ON WHEN THE SPINDLE UNIT TOOL GRIPPER IS CLOSED (WITH OR WITHOUT A TOOL), AND THE PISTON PUSHING THE GRIPPER IS RETRACTED. THIS INPUT MUST BE ON TO ALLOW SPINDLE ROTATION.
	TOOL GRIPPER ORIENT	I081-0	THIS INPUT IS USED FOR ORIENTING THE TOOL IN SPINDLE UNITS THAT HAVE GEARING THAT IS NOT A 1:1 RATIO.
	SU TOOL GRIPPER OPEN	I081-2	THIS INPUT WILL BE ON WHEN THE SPINDLE UNIT TOOL GRIPPER IS FULLY OPENED. IF THIS INPUT IS ON AND THE TOOL GRIPPER CLOSED INPUT IS ALSO ON, THIS INDICATES THAT THE GRIPPER IS CLOSED WITH A TOOL.
	SU TOOL GRIPPER CLOSED	I081-3	THIS INPUT WILL BE ON WHEN THE SPINDLE UNIT TOOL GRIPPER IS CLOSED (WITH OR WITHOUT A TOOL).
	SU TOOL GRIPPER CLOSED WITHOUT TOOL	I081-4	THIS INPUT WILL BE ON WHEN IF THE SPINDLE UNIT TOOL GRIPPER IS CLOSES WITHOUT A TOOL.
	SU DRAWBAR (TOOL GRIPPER POSITION)	I404-I405	THIS ANALOG INPUT IS USED ON SOME SPINDLE UNITS GRIPPER POSITION INDICATION. THE TYPE OF INDICATOR SWITCHES USED MUST BE IDENTIFIED IN THE SPINDLE UNIT DATA TABLE.
	TOOL GRIPPER UNCLAMPED / CLAMPED PRESSURE	I602-I603	THIS ANALOG PRESSURE SWITCH MONITORS TOOL GRIPPER PRESSURE TO CONFIRM GRIPPERS ARE OPEN OR CLOSED.
	UNCLAMP TOOL GRIPPER	Q102-1	THIS OUTPUT IS TURNED ON TO RELEASE A TOOL DURING A TOOL CHANGE. DEPENDING ON THE TYPE OF SU, THE SELECT TOOL GRIPPER HIGH PRESSURE OR SELECT TOOL GRIPPER LOW PRESSURE OUTPUT MUST ALSO BE ENERGIZED AT THE SAME TIME.
	TOOL GRIPPER PRESSURE SELECT PROPORTIONAL VALVE	Q300-Q301	THIS ANALOG OUTPUT SETS THE PROPER PRESSURE TO OPEN THE SU TOOL GRIPPERS. PRESSURE SETTING IS BASED ON WHICH SPINDLE UNIT IS MOUNTED.
SPINDLE IN SU VIBRATION	SPINDLE VIBRATION LEVEL HIGH	I082-0	WHEN THIS SIGNAL GOES HIGH, A MESSAGE ONLY IS POSTED.
	SPINDLE VIBRATION LEVEL EXCESSIVE	I082-1	WHEN THIS SIGNAL GOES HIGH, A FEED HOLD IS ISSUED, FOLLOWED BY A SPINDLE STOP.
	SPINDLE VIBRATION MONITOR FAULT	I082-2	WHEN THIS SIGNAL GOES LOW, A FEED HOLD IS ISSUED, FOLLOWED BY A SPINDLE STOP.
	SPINDLE VIBRATION	I402-I403	THE PLC DISPLAYS THE SPINDLE VIBRATION ON THE LOG SUB-SCREEN.
SPINDLE IN RAM VIBRATION	SP1 SPINDLE VIBRATION LEVEL HIGH	I080-5	WHEN THIS SIGNAL GOES HIGH, A MESSAGE ONLY IS POSTED.
	SP1 SPINDLE VIBRATION LEVEL EXCESSIVE	I080-6	WHEN THIS SIGNAL GOES HIGH, A FEED HOLD IS ISSUED, FOLLOWED BY A SPINDLE STOP.

	SP1 SPINDLE VIBRATION MONITOR FAULT	I080-7	WHEN THIS SIGNAL GOES LOW, A FEED HOLD IS ISSUED, FOLLOWED BY A SPINDLE STOP.
	SP1 SPINDLE VIBRATION	I420-I421	THE PLC DISPLAYS THE SPINDLE VIBRATION ON THE LOG SUB-SCREEN.
MISC	SPINDLE IN POSITION TO UNCLAMP A-AXIS	I080-7	WHEN A SPINDLE UNIT IS EQUIPPED WITH THIS SWITCH, THIS INPUT MUST BE ON TO ALLOW AN A-AXIS UNCLAMP.
	SPINDLE UNIT BEARING OVERTEMP	I400-I401	THE PLC LOGIC DISPLAYS THE SPINDLE BEARING TEMPERATURE ON THE LOG SUB-SCREEN. WHEN THE TEMPERATURE REACHES A WARNING LEVEL (55° C) AN ALARM MESSAGE IS POSTED. IF THE TEMPERATURE REACHES 60° C, THEN A CUT FREE E-STOP IS DONE.
	SPINDLE MOTOR FRONT BEARING TEMPERATURE (IN RAM)	I428-I429	THE PLC LOGIC DISPLAYS THE SPINDLE BEARING TEMPERATURE ON THE LOG SUB-SCREEN. WHEN THE TEMPERATURE REACHES A WARNING LEVEL (55° C) AN ALARM MESSAGE IS POSTED. IF THE TEMPERATURE REACHES 60° C, THEN A CUT FREE E-STOP IS DONE.

### B.1.12 MAGNETIC CHUCKS INPUTS / OUTPUTS

	MAGNETIC CHUCKS ZONE 1 MAGNETIZED	I042-4	Magnets in zone #1 must be magnetized to permit a Cycle Start when the machine is in Zone #1, M23 active. Magnets in both zones must be magnetized to permit a Cycle Start when the machine is in both zones, M24 active.
	MAGNETIC CHUCKS ZONE 1 DEMAGNETIZED	I042-5	Used for diagnostic purposes only.
	MAGNETIC CHUCKS ZONE 2 MAGNETIZED	I042-6	Magnets in zone #2 must be magnetized to permit a Cycle Start when the machine is in zone #2, M24 active. Magnets in both zones must be magnetized to permit a Cycle Start when the machine is in both zones, M24 active.
	MAGNETIC CHUCKS ZONE 2 DEMAGNETIZED	I042-7	Used for diagnostic purposes only.
	ENABLE MAGNETIC CHUCKS ZONE 1	Q033-5	When the machine is in zone #2, M24 active, magnets in zone #1 are enabled. (Magnet control must be enabled to allow magnets to be magnetized or demagnetized.) When the machine is in both zones, M22 active, both sets of magnets are enabled when the gate interlock indicates a gate is open.
	ENABLE MAGNETIC CHUCKS ZONE 2	Q033-6	When the machine is in zone #1, M23 active, magnets in zone #2 are enabled. When the machine is in both zones, M22 active, both sets of magnets are enabled when the gate interlock indicates a gate is open.

## B.2 INPUT/OUTPUT VALUES

The following is a comprehensive list of all inputs/outputs, sorted by address, identifying the specific category where the input/out is applied.

CATEGORY	DESCRIPTION	ADDR
axis control	RACK #1 INFEED MODULE FAN RUNNING	I032-0
axis control	RACK #2 INFEED MODULE FAN RUNNING	I032-1
axis control	RACK #3 INFEED MODULE FAN RUNNING	I032-2
axis control	RACK #4 INFEED MODULE FAN RUNNING	I032-3
axis control	RACK #5 INFEED MODULE FAN RUNNING	I032-4
axis control	X-AXIS AMPLIFIER FAN RUNNING	I032-5
axis control	XT-AXIS AMPLIFIER FAN RUNNING	I032-6
axis control	XG-AXIS AMPLIFIER FAN RUNNING	I032-7
axis control	XGT-AXIS AMPLIFIER FAN RUNNING	I033-0
axis control	Y-AXIS AMPLIFIER FAN RUNNING	I033-1
axis control	YT-AXIS AMPLIFIER FAN RUNNING	I033-2
axis control	SP1 SPINDLE AMPLIFIER FAN RUNNING	I033-4
axis control	SP1A SPINDLE AMPLIFIER FAN RUNNING	I033-5
axis control	A-AXIS AMPLIFIER FAN RUNNING	I033-6
axis control	C-AXIS AMPLIFIER FAN RUNNING	I033-7
axis control	RACK #1 INFEED CONTACTOR ENERGIZED	I034-0
axis control	RACK #2 INFEED CONTACTOR ENERGIZED	I034-1
axis control	RACK #3 INFEED CONTACTOR ENERGIZED	I034-2
axis control	RACK #4 INFEED CONTACTOR ENERGIZED	I034-3
axis control	RACK #5 INFEED CONTACTOR ENERGIZED	I034-4
axis control	RACK #1 MONITORING MODULE CONTACTOR ENERGIZED	I034-5
axis control	X-AXIS DRIVE INHIBITED	I035-0
axis control	XT-AXIS DRIVE INHIBITED	I035-1
axis control	XG-AXIS DRIVE INHIBITED	I035-2
axis control	XGT-AXIS DRIVE INHIBITED	I035-3
axis control	Y-AXIS DRIVE INHIBITED	I035-4
axis control	YT-AXIS DRIVE INHIBITED	I035-5
axis control	Z-AXIS DRIVE INHIBITED	I035-6
axis control	ZT-AXIS DRIVE INHIBITED	I035-7
axis control	SP1 SPINDLE DRIVE INHIBITED	I036-3
axis control	SP1A SPINDLE DRIVE INHIBITED	I036-4
axis control	A-AXIS DRIVE INHIBITED	I036-5
axis control	C-AXIS DRIVE INHIBITED	I036-6
axis control	NOT X-AXIS MOTOR OVER TEMPERATURE	I037-0
axis control	NOT XT-AXIS MOTOR OVER TEMPERATURE	I037-1
axis control	NOT XG-AXIS MOTOR OVER TEMPERATURE	I037-2
axis control	NOT XGT-AXIS MOTOR OVER TEMPERATURE	I037-3
axis control	NOT Y-AXIS MOTOR OVER TEMPERATURE	I037-4
axis control	NOT YT-AXIS MOTOR OVER TEMPERATURE	I037-5
axis control	NOT A-AXIS MOTOR MAX OVERTEMP	I037-7
axis control	NOT C-AXIS MOTOR OVER TEMPERATURE	I038-2
axis control	NOT SP1 SPINDLE OVER TEMPERATURE	I038-3

CATEGORY	DESCRIPTION	ADDR
axis control	NOT SP1A SPINDLE OVER TEMPERATURE	I038-4
axis control	SP1 SPINDLE VOLTAGE MODULE NOT FAULT	I039-0
axis control	SP1A SPINDLE VOLTAGE MODULE NOT FAULT	I039-1
axis control	X-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-2
axis control	XT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-3
axis control	XG-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-4
axis control	XGT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-5
axis control	Y-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-6
axis control	YT-AXIS MOTOR DYNAMIC BRAKING DISCONNECTED	I039-7
axis control	Z-AXIS MOTOR FAN RUNNING	I040-0
axis control	ZT-AXIS MOTOR FAN RUNNING	I040-1
axis control	NOT X-AXIS PLUS OVERTRAVEL	I041-0
axis control	NOT X-AXIS MINUS OVERTRAVEL	I041-1
axis control	NOT Y-AXIS PLUS OVERTRAVEL	I041-2
axis control	NOT Y-AXIS MINUS OVERTRAVEL	I041-3
axis control	NOT Z-AXIS PLUS OVERTRAVEL	I041-4
axis control	NOT Z-AXIS MINUS OVERTRAVEL	I041-5
axis control	NOT C-AXIS PLUS OVERTRAVEL	I041-6
axis control	NOT C-AXIS MINUS OVERTRAVEL	I041-7
axis control	NOT A-AXIS PLUS OVERTRAVEL	I042-0
axis control	NOT A-AXIS MINUS OVERTRAVEL	I042-1
magnets	MAGNETIC CHUCKS ZONE 1 MAGNETIZED	I042-4
magnets	MAGNETIC CHUCKS ZONE 1 DEMAGNETIZED	I042-5
magnets	MAGNETIC CHUCKS ZONE 2 MAGNETIZED	I042-6
magnets	MAGNETIC CHUCKS ZONE 2 DEMAGNETIZED	I042-7
axis control	AXES BRAKE CIRCUIT BREAKERS OK	I043-0
axis control	ENABLE AXES DRIVES & BRAKES	I043-1
e-stop	MAIN CONTROL NOT E-STOP	I043-2
misc	CABINET AIR CONDITIONER #1 RUNNING	I043-3
misc	CABINET AIR CONDITIONER #2 RUNNING	I043-4
misc	CABINET AIR CONDITIONER #3 RUNNING	I043-5
misc	CABINET AIR CONDITIONER #4 RUNNING	I043-6
axis control	SP1 SPINDLE RESISTOR MODULE #1	I044-0
axis control	SP1 SPINDLE RESISTOR MODULE #1	I044-1
axis control	SP1 SPINDLE RESISTOR MODULE #2	I044-2
axis control	SP1 SPINDLE RESISTOR MODULE #2	I044-3
axis control	SP1 SPINDLE RESISTOR MODULE #3	I044-4
axis control	SP1 SPINDLE RESISTOR MODULE #3	I044-5
axis control	SP1A SPINDLE RESISTOR MODULE #1	I045-0
axis control	SP1A SPINDLE RESISTOR MODULE #1	I045-1
axis control	SP1A SPINDLE RESISTOR MODULE #2	I045-2
axis control	SP1A SPINDLE RESISTOR MODULE #2	I045-3
axis control	SP1A SPINDLE RESISTOR MODULE #3	I045-4
axis control	SP1A SPINDLE RESISTOR MODULE #3	I045-5
axis control	SP1 SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-0
axis control	SP1 SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-1
axis control	SP1 SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-2
axis control	SP1A SPINDLE VOLTAGE MODULE #2 NOT FAULT	I046-3
axis control	SP1A SPINDLE VOLTAGE MODULE #3 NOT FAULT	I046-4
axis control	SP1A SPINDLE VOLTAGE MODULE #4 NOT FAULT	I046-5

CATEGORY	DESCRIPTION	ADDR
gates	UNLOCK PERIMETER GATE #1 (SE)	I047-0
gates	AUTO PERMIT PERIMETER GATE #1 (SE)	I047-1
gates	RESET PERIMETER GATE #1 (SE)	I047-2
gates	UNLOCK PERIMETER GATE #2 (E)	I047-3
gates	AUTO PERMIT PERIMETER GATE #2 (E)	I047-4
gates	RESET PERIMETER GATE #2 (E)	I047-5
gates	PERIMETER GATE #1 (SE) CLOSED	I047-6
gates	PERIMETER GATE #2 (E) CLOSED	I047-7
gates	UNLOCK PERIMETER GATE #3 (NE)	I050-0
gates	AUTO PERMIT PERIMETER GATE #3 (NE)	I050-1
gates	RESET PERIMETER GATE #3 (NE)	I050-2
gates	UNLOCK PERIMETER GATE #4 (NW)	I050-3
gates	AUTO PERMIT PERIMETER GATE #4 (NW)	I050-4
gates	RESET PERIMETER GATE #4 (NW)	I050-5
gates	PERIMETER GATE #3 (NE) CLOSED	I050-6
gates	PERIMETER GATE #4 (NW) CLOSED	I050-7
air / pneumatic	X-AXIS LEFT HEIDENHAIN AIR PRESSURE OK	I051-0
air / pneumatic	X-AXIS RIGHT HEIDENHAIN AIR PRESSURE OK	I051-1
air / pneumatic	MACHINE AIR PRESSURE OK	I051-2
gates	UNLOCK PERIMETER GATE #5 (W)	I052-0
gates	AUTO PERMIT PERIMETER GATE #5 (W)	I052-1
gates	RESET PERIMETER GATE #5 (W)	I052-2
gates	UNLOCK PERIMETER GATE #6 (SW)	I052-3
gates	AUTO PERMIT PERIMETER GATE #6 (SW)	I052-4
gates	RESET PERIMETER GATE #6 (SW)	I052-5
gates	PERIMETER GATE #5 (W) CLOSED	I052-6
gates	PERIMETER GATE #6 (SW) CLOSED	I052-7
coolant	COOLANT FILTRATION SYSTEM RUNNING (NO FAULTS)	I053-0
coolant	COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP MOTOR RUNNING	I053-1
coolant	COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP MOTOR RUNNING	I053-2
coolant	COOLANT FILTRATION SYSTEM CHIP CONVEYORS RUNNING	I053-3
misc	OPERATOR SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-0
misc	OPERATOR SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-1
misc	TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR OPEN	I060-2
misc	TOOL CHANGE SIDE ENCLOSURE CURTAIN DOOR CLOSED	I060-3
probe	PART PROBE #1 BATTERY OK	I060-4
probe	NOT PART PROBE #1 ERROR	I060-5
cooling	MOTOR CHILLER HIGH/LOW TEMP ALARM	I061-0
cooling	AXES MOTOR RETURN COOLING BALL VALVE OPEN	I061-1
e-stop	TOOL CHANGER E-STOP	I061-4
pendant	B-MPI PENDANT ENABLED	I061-6
e-stop	B-MPI PENDANT NOT E-STOP	I061-7
spindle	SU ID (1)	I080-0
spindle	SU ID (2)	I080-1
spindle	SU ID (4)	I080-2
spindle	SU ID (8)	I080-3
hydraulics	A-AXIS CLAMPED	I080-4
hydraulics	A-AXIS UNCLAMPED	I080-5

CATEGORY	DESCRIPTION	ADDR
axis control	A-AXIS HOME	I080-6
spindle	SPINDLE IN POSITION TO UNCLAMP A-AXIS	I080-7
spindle	TOOL GRIPPER ORIENT	I081-0
spindle	SP3 SPINDLE TOOL GRIPPER PISTON RETRACTED	I081-1
spindle	SU TOOL GRIPPER OPEN	I081-2
spindle	SU TOOL GRIPPER CLOSED	I081-3
spindle	SU TOOL GRIPPER CLOSED WITHOUT TOOL	I081-4
lubrication	SU GREASE LUBE LOW LEVEL	I081-5
spindle	SPINDLE VIBRATION LEVEL HIGH	I082-0
spindle	SPINDLE VIBRATION LEVEL EXCESSIVE	I082-1
spindle	SPINDLE VIBRATION MONITOR FAULT	I082-2
axis control	C-AXIS HOME	I082-3
spindle	SP1 SPINDLE MOTOR VIBRATION LEVEL HIGH	I082-5
spindle	SP1 SPINDLE MOTOR VIBRATION LEVEL EXCESSIVE	I082-6
spindle	SP1 SPINDLE MOTOR VIBRATION MONITOR FAULT	I082-7
air / pneumatic	SPINDLE FRONT SEAL PRESSURIZATION AIR PRESSURE OK	I083-1
axis	AXIS PERMIT	I090-0
spindle	SPINDLE PERMIT	I090-1
e-stop	E-STOP RESET	I090-2
axis control	OVERTRAVEL BYPASS	I090-3
e-stop	OPERATOR PENDANT E-STOP	I090-4
lubrication	SPINDLE BEARING LUBE SCAVENGE TANK OIL LEVEL NOT HIGH	I090-5
hydraulics	HYDRAULIC RECIRCULATION PRESSURE OK	I091-0
hydraulics	NOT HYDRAULIC TANK LOW LEVEL	I091-1
hydraulics	NOT HYDRAULIC TANK OVERTEMPERATURE	I091-2
hydraulics	HYDRAULIC PRESSURE OK	I091-3
hydraulics	HYDRAULIC FILTER NOT DIRTY	I091-4
hydraulics	HYDRAULIC RECIRCULATION FILTER NOT DIRTY	I091-5
hydraulics	NOT HYDRAULIC TANK CRITICAL LOW LEVEL	I091-6
hydraulics	NOT HYDRAULIC TANK CRITICAL OVERTEMPERATURE	I091-7
gates	UNLOCK OPERATOR PLATFORM WORK FLOOR GATE	I093-0
gates	AUTO PERMIT OPERATOR PLATFORM WORK FLOOR GATE	I093-1
gates	RESET OPERATOR PLATFORM WORK FLOOR GATE	I093-2
gates	UNLOCK OPERATOR PLATFORM SHOP FLOOR GATE	I093-3
gates	AUTO PERMIT OPERATOR PLATFORM SHOP FLOOR GATE	I093-4
gates	RESET OPERATOR PLATFORM SHOP FLOOR GATE	I093-5
gates	OPERATOR PLATFORM WORK FLOOR GATE CLOSED	I093-6
gates	OPERATOR PLATFORM SHOP FLOOR GATE CLOSED	I093-7
lubrication	ATTACHMENT LUBRICATION OIL PRESSURE OK	I100-0
air / pneumatic	AIR TO ATTACHMENT AIR PRESSURE OK	I100-1
air / pneumatic	Y-AXIS HEIDENHAIN AIR PRESSURE OK	I100-2
air / pneumatic	Z-AXIS HEIDENHAIN AIR PRESSURE OK	I100-4
hydraulics	C-AXIS UNCLAMPED PRESSURE OK	I100-6
lubrication	AXIS LUBRICANT LEVEL OK	I101-0
lubrication	AXIS LUBRICATION HIGH PRESSURE BLOWOUT	I101-1
lubrication	AXIS LUBRICATION CYCLE SWITCH	I101-2
lubrication	SPINDLE BEARING LUBRICANT LEVEL OK	I101-4
hydraulics	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6
spindle	CORNER GRIPPER UNCLAMPED PRESSURE OK	I101-6
hydraulics	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7

CATEGORY	DESCRIPTION	ADDR
spindle	CORNER GRIPPER CLAMPED PRESSURE OK	I101-7
gates	UNLOCK TOOL LOAD PLATFORM GATE	I062-0
gates	AUTO PERMIT TOOL LOAD PLATFORM GATE	I062-1
gates	RESET TOOL LOAD PLATFORM GATE	I062-2
gates	TOOL LOAD PLATFORM GATE CLOSED	I062-3
gates	TOOL LOAD PLATFORM GATE OPENED	I062-4
gates	UNLOCK TOOL LOAD PLATFORM GATE	Q060-6
gates	AUTO PERMIT TOOL LOAD PLATFORM GATE	Q060-7
cooling	X-AXIS MOTOR COOLING WATER FLOW MONITOR	I300-I301
cooling	XT-AXIS MOTOR COOLING WATER FLOW MONITOR	I302-I303
spindle	SPINDLE BEARING OVERTEMP	I400-I401
spindle	SPINDLE VIBRATION MONITOR	I402-I403
spindle	SU DRAWBAR	I404-I405
coolant	INTERNAL CUTTING COOLANT FLOW	I408-I409
cooling	C-AXIS MOTOR COOLING WATER FLOW MONITOR	I410-I411
cooling	Y-AXIS MOTOR COOLING WATER FLOW MONITOR	I412-I413
cooling	YT-AXIS MOTOR COOLING WATER FLOW MONITOR	I414-I415
cooling	SPINDLE COOLING WATER INLET TEMPERATURE	I416-I417
cooling	SPINDLE COOLING WATER OUTLET TEMPERATURE	I418-I419
spindle	SP1 SPINDLE MOTOR VIBRATION MONITOR	I420-I421
cooling	SPINDLE MOTOR COOLING WATER FLOW MONITOR	I424-I425
cooling	A-AXIS MOTOR COOLING WATER FLOW MONITOR	I426-I427
spindle	SP1 SPINDLE MOTOR FRONT BEARING TEMPERATURE	I428-I429
lubrication	FRONT BEARING LUBE TRANSDUCER #1	I432-I433
lubrication	FRONT BEARING LUBE TRANSDUCER #2	I434-I435
lubrication	FRONT BEARING LUBE TRANSDUCER #3	I436-I437
lubrication	FRONT BEARING LUBE TRANSDUCER #4	I438-I439
cooling	XG-AXIS MOTOR COOLING WATER FLOW MONITOR	I500-I501
cooling	XGT-AXIS MOTOR COOLING WATER FLOW MONITOR	I502-I503
hydraulics	A-AXIS CLAMPED PRESSURE OK	I600-I601
hydraulics	TOOL GRIPPER UNCLAMPED/CLAMPED PRESSURE OK	I602-I603
spindle	TOOL GRIPPER UNCLAMPED/CLAMPED PRESSURE OK	I602-I603
hydraulics	A-AXIS UNCLAMPED/CLAMPED PRESSURE OK	I604-I605
hydraulics	TOOL GRIPPER PRESSURE	I606-I607
hydraulics	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE MONITOR TRANSDUCER	I608-I609
axis control	ENABLE X-AXIS DRIVES	Q032-0
axis control	ENABLE Y-AXIS DRIVES	Q032-1
axis control	ENABLE Z-AXIS DRIVES	Q032-2
axis control	ENABLE SP1 SPINDLE DRIVE	Q032-6
axis control	ENABLE SP1A SPINDLE DRIVE	Q032-7
axis control	ENABLE A-AXIS DRIVE	Q033-0
axis control	ENABLE C-AXIS DRIVE	Q033-1
magnets	ENABLE MAGNETIC CHUCKS ZONE 1	Q033-5
magnets	ENABLE MAGNETIC CHUCKS ZONE 2	Q033-6
misc	MIST COLLECTOR MOTOR STARTER ENERGIZED	Q033-7
e-stop	NOT CNC E-STOP REQUEST	Q034-0
axis control	PLUS OVERTRAVEL BYPASS	Q034-1
axis control	MINUS OVERTRAVEL BYPASS	Q034-2
probe	SELECT PART PROBE #1	Q034-3

CATEGORY	DESCRIPTION	ADDR
hydraulics	HYDRAULIC PUMP MOTOR STARTER ENERGIZED	Q034-4
misc	ENABLE RUN TIME METER	Q034-5
lubrication	SPINDLE LUBE SCAVENGE PUMP MOTOR STARTER ENERGIZED	Q034-6
lubrication	SPINDLE BEARING LUBE SCAVENGE PUMP MOTOR STARTER ENERGIZED	Q034-7
axis control	DISCONNECT X-AXIS MOTOR DYNAMIC BRAKING	Q035-0
axis control	DISCONNECT Y-AXIS MOTOR DYNAMIC BRAKING	Q035-1
axis control	RELEASE Z-AXIS BRAKES	Q035-2
axis control	INHIBIT SP1 SPINDLE RESISTOR MODULE #1	Q036-0
axis control	INHIBIT SP1 SPINDLE RESISTOR MODULE #2	Q036-1
axis control	INHIBIT SP1 SPINDLE RESISTOR MODULE #3	Q036-2
axis control	INHIBIT SP1A SPINDLE RESISTOR MODULE #1	Q036-3
axis control	INHIBIT SP1A SPINDLE RESISTOR MODULE #2	Q036-4
axis control	INHIBIT SP1A SPINDLE RESISTOR MODULE #3	Q036-5
axis control	DISABLE SPINDLE INFEEDS FOR VPM TESTING	Q037-0
axis control	OPEN SP1 SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-1
axis control	OPEN SP1A SPINDLE POWER CIRCUITS FOR VPM TESTING	Q037-2
axis control	RESET INFEED MODULES FROM VPM FAULTS	Q037-3
gates	UNLOCK PERIMETER GATE #1 (SE)	Q037-4
gates	AUTO PERMIT PERIMETER GATE #1 (SE)	Q037-5
gates	UNLOCK PERIMETER GATE #2 (E)	Q037-6
gates	AUTO PERMIT PERIMETER GATE #2 (E)	Q037-7
gates	UNLOCK PERIMETER GATE #3 (NE)	Q050-0
gates	AUTO PERMIT PERIMETER GATE #3 (NE)	Q050-1
gates	UNLOCK PERIMETER GATE #4 (NW)	Q050-2
gates	AUTO PERMIT PERIMETER GATE #4 (NW)	Q050-3
coolant	START COOLANT FILTRATION SYSTEM HIGH PRESSURE PUMP MOTOR	Q050-5
coolant	START COOLANT FILTRATION SYSTEM LOW PRESSURE PUMP MOTOR	Q050-6
coolant	START COOLANT FILTRATION SYSTEM CHIP CONVEYORS	Q050-7
gates	UNLOCK PERIMETER GATE #5 (W)	Q051-0
gates	AUTO PERMIT PERIMETER GATE #5 (W)	Q051-1
gates	UNLOCK PERIMETER GATE #6 (SW)	Q051-2
gates	AUTO PERMIT PERIMETER GATE #6 (SW)	Q051-3
misc	MACHINE OPERATING	Q051-5
misc	MACHINE OPERATING - MINOR FAULT	Q051-6
misc	MACHINE IN FAULT CONDITION	Q051-7
probe	ENABLE PART PROBE #1	Q060-1
probe	BROKEN TOOL PROBE HIGH SPEED BREAK	Q060-2
probe	BROKEN TOOL PROBE LATCH MODE	Q060-3
coolant	EXTERNAL CUTTING COOLANT ON	Q061-0
coolant	INTERNAL CUTTING COOLANT ON	Q061-1
cooling	REMOTE START MOTOR CHILLER	Q061-4
cooling	SET MOTOR CHILLER TO SET POINT CONTROL	Q061-5
hydraulics	Z-AXIS COUNTERBALANCE BLEED CIRCUIT ON	Q080-0
lubrication	SPINDLE LUBRICATION	Q080-1
lubrication	SPINDLE LUBE PUMP PRIMING ON	Q080-2
lubrication	ACTIVATE SU LUBE	Q081-0
gates	UNLOCK OPERATOR PLATFORM WORK FLOOR GATE	Q090-0

CATEGORY	DESCRIPTION	ADDR
gates	UNLOCK OPERATOR PLATFORM SHOP FLOOR GATE	Q090-1
gates	AUTO PERMIT OPERATOR PLATFORM WORK FLOOR GATE	Q090-2
gates	AUTO PERMIT OPERATOR PLATFORM SHOP FLOOR GATE	Q090-3
misc	MESSAGE ALARM	Q091-0
gates	GATE OPEN IN ZONE #1	Q091-1
gates	GATE OPEN IN ZONE #2	Q091-2
lubrication	AXIS LUBRICATION PUMP ON	Q100-0
hydraulics	Z-AXIS COUNTERBALANCE SYSTEM PRESSURE CHARGING VALVE ON	Q100-2
hydraulics	CLAMP A-AXIS	Q102-0
hydraulics	UNCLAMP TOOL GRIPPER	Q102-1
spindle	UNCLAMP TOOL GRIPPER	Q102-1
lubrication	TURN ON ATTACHMENT LUBRICATION OIL	Q102-3
hydraulics	UNCLAMP CORNER GRIPPER (REDUNDANT)	Q103-0
spindle	UNCLAMP CORNER GRIPPER (REDUNDANT)	Q103-0
hydraulics	UNCLAMP CORNER GRIPPERS	Q103-1
spindle	UNCLAMP CORNER GRIPPERS	Q103-1
misc	OPEN OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q103-2
hydraulics	UNCLAMP C-AXIS	Q103-3
air / pneumatic	RAM FACE BLOW OFF	Q104-0
air / pneumatic	AIR ON TO ATTACHMENTS	Q104-1
air / pneumatic	AIR BLAST RETENTION KNOB	Q104-2
air / pneumatic	AIR ON TO SPINDLE BEARING LUBE	Q104-3
lubrication	TURN ON ATTACHMENT HYDRAULIC MOTOR	Q105-0
misc	CLOSE OPERATOR SIDE ENCLOSURE CURTAIN DOOR	Q105-1
misc	OPEN TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-2
misc	CLOSE TOOL CHANGER SIDE ENCLOSURE CURTAIN DOOR	Q105-3
hydraulics	TOOL GRIPPER PRESSURE SELECT	Q300-Q301
spindle	TOOL GRIPPER PRESSURE SELECT	Q300-Q301
hydraulics	A-AXIS CLAMP PRESSURE SELECT	Q302-Q303



## **APPENDIX C - TOOL CAROUSEL COMMUNICATIONS**



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**C.1 EXCHANGE DATA DEFINITION****C.1.1 DATA SENT FROM MACHINE PLC TO TOOL MAGAZINE PLC**

<b>Byte offset</b>	<b>Bit 7</b>	<b>Bit 6</b>	<b>Bit 5</b>	<b>Bit 4</b>	<b>Bit 3</b>	<b>Bit 2</b>	<b>Bit 1</b>	<b>Bit 0</b>
+ 0	Message header							
+ 1								
+2	Message data word 0							
+3								
+4	Message data word 1							
+5								
+6	Message data word 2							
+7								
+8	Message data word 3							
+9								
+10	Message data word 4							
+11								
+12	Message handler							
+13								
+14							Reset fault	
+15				Tool exchange area free				
+16				Wait to enable manual mode	Acknowledged to enable manual mode		Acknowledged to receive	Request to send
+17	Machine tool change request							
+18	Machine tool change request (Negative copy)							
+19								
+20								
+21	Spindle Unit							
+22								
+23	Comm watchdog							

## C.1.2 DATA SENT FROM ATC PLC TO MACHINE PLC

Byte offset	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
+ 0	Message header							
+ 1								
+2	Message data word 0							
+3								
+4	Message data word 1							
+5								
+6	Message data word 2							
+7								
+8	Message data word 3							
+9								
+10	Message data word 4							
+11								
+12	Message Handler							
+13								
+14					Gates closed	In auto mode	Not in fault	In power on
+15			Load place 1 occupied	Tool arm retracted				
+16	Gripper toward spindle closed	Gripper toward spindle opened			Request manual mode		Acknowledge to receive	Request to send
+17	Machine tool change request status							
+18	Machine tool change request status (negative copy)							
+19								
+20								
+21	Reserved for tool changer messages Not implemented right now							
+22								
+23	Comm watchdog							

## **C.2 MESSAGES COMMUNICATION**

### **C.2.1 MESSAGE HANDSHAKE**

When sending a message, either the Machine or the Tool Changer PLC must before fill the whole message (byte +0 to +13) and then set the request to send “Request to send” bit +16.0. After detecting the request to send, the receive partner on the other side reads the sender message (byte +0 to +13) and set it’s own acknowledge to receive “Acknowledge to receive” bit 16.1. The sender detects the acknowledge bit and resets the request to send “Request to send” bit +16.0. The receiver detects that the request to receive has cleared and clears the acknowledge to receive “Acknowledge to receive” bit 16.1.

### **C.2.2 UNAMBIGUOUS ANSWER CHECK**

The messages sent from one of the partners (from now referred to as A) require answers from the other partner (from now referred as B). In order to avoid mistakes, it is vital for A to know that the answer received from B matches his request and is not the answer to another message. To prevent this ambiguity, the Handler field has been created. Every time that A sends a message, he fills the handler field with an incremental number. When B answers, he should put the same value in the answer Handler field.

The range for the Handler is different between the machine and the ATC. Each new message send by the machine that requires an answer from the ATC will have an Handler between 10000 and 19999. Vice versa, each new message sent by the ATC that requires an answer from the machine, will have a Handler between 20000 and 29999.

### **C.2.3 MESSAGES SENT FROM MACHINE PLC TO TOOL CHANGER PLC**

<b>Header #</b>	<b>Header name</b>
1001	Preselect tool
1002	Unload all the tools from the buffers
1003	Load tool
1004	Unload tool
1005	Move tool
1011	Magazine pocket found
1012	Tool table updated
1013	Places info result

#### C.2.4 MESSAGES SENT FROM TOOL CHANGER TO MACHINE PLC

Header #	Header name
1101	Tool preselected
1102	All tools unloaded from buffers
1103	Tool loaded
1104	Tool unloaded
1105	Tool moved
1111	Find free magazine pocket for a tool
1112	Update tool table
1113	Request places info

#### C.2.5 UNITS FOR THE MESSAGES

The Siemens Tool Management use the term “magazine/place” to represent every location. Depending on a specific configuration, the magazine numbers can change. In order to avoid these changes, we can abstract from the Tool Management definition and use a constant paradigm to communicate with the tool magazine.

Unit #	Unit description
1	Tool magazine floor 1
2	Tool magazine floor 2
3	Tool magazine floor 3
4	Tool magazine floor 4
100	Tool robot (1 place)
101	Tool arm grippers (2 places or 4 places)
102	Load/Unload pockets (Up to 2 places)

### **C.2.6 TOOL PRESELECTION**

The tool changer should preselect the tool for next tool change. If a tool is already present in the arm grippers or in the robot, the tool changer should first put this tool back in the magazine and then preselect the tool

<b>SENDER</b>	Machine
<b>HEADER</b>	1001 Preselect tool
<b>DATA WORD 0</b>	Source unit
<b>DATA WORD 1</b>	Source place
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	
<b>SENDER</b>	ATC
<b>HEADER</b>	1101 Tool preselected
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error) Errors list: -1 Process busy -5 Execution error
<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

### **C.2.7 UNLOAD ALL THE TOOLS FROM THE BUFFERS**

The machine asks the tool changer to put all the tools that are in the buffers (arm grippers and robot) back in the magazine. To find a suitable pocket in the magazine, the tool changer should send message 1003 to the machine.

<b>SENDER</b>	Machine
<b>HEADER</b>	1002 Unload all the tools from the buffers
<b>DATA WORD 0</b>	
<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	
<b>SENDER</b>	ATC
<b>HEADER</b>	1102 All tools unloaded from buffers
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error)
<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

### C.2.8 TOOL LOAD

The operator put the tool into load/unload pocket and then through the Siemens Tool Management requests to load a new tool. The machine forwards this request at the ATC

<b>SENDER</b>	Machine
<b>HEADER</b>	1003 Load tool
<b>DATA WORD 0</b>	Destination unit
<b>DATA WORD 1</b>	Destination place
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

<b>SENDER</b>	ATC
<b>HEADER</b>	1103 Tool loaded
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error)
<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

### C.2.9 TOOL UNLOAD

The operator through the Siemens Tool Management selects a tool to unload from the magazine. The machine forwards the request at the ATC

<b>SENDER</b>	Machine
<b>HEADER</b>	1004 Unload tool
<b>DATA WORD 0</b>	Source unit
<b>DATA WORD 1</b>	Source place
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

<b>SENDER</b>	ATC
<b>HEADER</b>	1104 Tool unloaded
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error)

<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

### C.2.10 MOVE TOOL

With this message, the machine PLC is able to relocate a tool between two tool exchanger locations.

<b>SENDER</b>	Machine
<b>HEADER</b>	1005 Move tool
<b>DATA WORD 0</b>	Source unit
<b>DATA WORD 1</b>	Source place
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

<b>SENDER</b>	ATC
<b>HEADER</b>	1105 Tool moved
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error)
<b>DATA WORD 1</b>	
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

### C.2.11 FIND FREE MAGAZINE POCKET

When the tool changer should move a tool into a magazine pocket, it should first ask the machine for a suitable pocket.

<b>SENDER</b>	ATC
<b>HEADER</b>	1111 Find free magazine pocket for a tool
<b>DATA WORD 0</b>	Current tool unit
<b>DATA WORD 1</b>	Current tool place
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

<b>SENDER</b>	Machine	
<b>HEADER</b>	1011 Magazine pocket found	
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error) Errors list:	
	-1	Process busy The tool server is already processing a previous request from the tool magazine therefore can not accomplish a new one
	-2	Invalid tool actual location The tool actual location specified is not valid
	-3	Tool Management Error The tool server has encountered an error processing the request
	-4	Free location not found There aren't any free location in the tool magazine suitable for the specified tool
<b>DATA WORD 1</b>	Found unit	
<b>DATA WORD 2</b>	Found place	
<b>DATA WORD 3</b>		
<b>DATA WORD 4</b>		

### C.2.12 UPDATE THE TOOL TABLE

In order to keep the tool table updated, every time that the tool changer moves a tool between two places, it should notify the machine.

<b>SENDER</b>	ATC	
<b>HEADER</b>	1112 Update tool table	
<b>DATA WORD 0</b>	Source unit	
<b>DATA WORD 1</b>	Source place	
<b>DATA WORD 2</b>	Destination unit	
<b>DATA WORD 3</b>	Destination place	
<b>DATA WORD 4</b>		

<b>SENDER</b>	Machine	
<b>HEADER</b>	1012 Tool table updated	
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error) Errors list:	
	-1	Process busy The tool server is already processing a previous request from the tool magazine therefore can not accomplish a new one
	-2	Invalid tool source location The specified tool source location is not valid
	-3	Invalid tool target location The specified tool target location is not valid

	-4	Tool Management Error The tool server has encounter an error processing the request
<b>DATA WORD 1</b>		
<b>DATA WORD 2</b>		
<b>DATA WORD 3</b>		
<b>DATA WORD 4</b>		

### C.2.13 PLACE STATUS INFO

This message lets the tool changer PLC query the machine tool table to find if a specific place is free. If a tool is in one of the requested places, the tool number is reported at the tool changer. If the place is free, 0 is reported.

<b>SENDER</b>	ATC
<b>HEADER</b>	1113 Request places info
<b>DATA WORD 0</b>	Optional unit (Should be 0 if not needed)
<b>DATA WORD 1</b>	Optional place (Should be 0 if not needed)
<b>DATA WORD 2</b>	
<b>DATA WORD 3</b>	
<b>DATA WORD 4</b>	

<b>SENDER</b>	Machine
<b>HEADER</b>	1013 Place info result
<b>DATA WORD 0</b>	Result ( 1 = OK, < 0 Error) Errors list: -1 Process busy The tool server is already processing a previous request from the tool magazine therefore can not accomplish a new one -2 Invalid optional unit location The specified optional unit location is not valid -3 Tool Management Error The tool server has encounter an error processing the request
<b>DATA WORD 1</b>	Tool number in optional unit/place (-1 if unit place not specified)
<b>DATA WORD 2</b>	Tool number in robot gripper (unit100, place 1)
<b>DATA WORD 3</b>	Tool number in exchange arm gripper (unit101, place 1)
<b>DATA WORD 4</b>	Tool number in exchange arm gripper (unit101, place 2)

### C.3 TOOL EXCHANGE BETWEEN MACHINE AND ATC

To perform the tool change, the machine needs to take control of the tool magazine exchange arm. For this purpose, the “machine tool change request” has been provided. The machine is the master. It first asks for control at the tool changer, and when that has been granted, it starts to control the tool changer arm. The machine writes “machine tool change request” (byte +17) and reads the magazine reply in “machine tool change request status” (byte +17). Both the machine and the ATC, write a bit inverted copy of their byte +17 at byte +18.

Addr	Machine bit	ATC bit
+17.0	ReqStartToolChange The machine request control of the exchange arm	AckStartToolChange The control of the exchange arm has been transferred at the machine
+17.1	ReqPreparePickUp Request to move the exchange arm at the position to start a tool pick up	AckPreparePickUp The tool change arm is in position to start a tool pick up
+17.2	ReqPrepareDeposit Request to move the exchange arm at the position to start a tool deposit	AckPrepareDeposit The tool change arm is in position to start a tool deposit
+17.3	ReqPrepareDepositPickUp Request to move the exchange arm at the position to start a tool deposit/pick up	AckPrepareDepositPickUp The tool change arm is in position to start a tool deposit/pick up
+17.4	ReqRetractFinish Request to retract the tool exchange arm back in the tool magazine after the tool change	AckRetractFinish The tool exchange arm has been retracted in the tool magazine
+17.5	ReqSwapGrippers Request to turn the tool magazine grippers of 180 degree	AckSwapGrippers The grippers has been turned
+17.6	ReqOpenGriperTowardSp Request to open the tool magazine gripper toward the spindle	AckOpenGriperTowardSp The tool magazine gripper toward the spindle is open
+17.7	ReqCloseGripperTowardSP Request to close the tool magazine gripper toward the spindle	AckCloseGripperTowardSP The tool magazine gripper toward the spindle is close

To gain control, the machine should set bit +17.0. As soon as possible, the tool magazine sets +17.0 and then the machine is in control of the exchange arm until it reset his +17.0.

When the machine is in control of the exchange arm, the tool magazine cannot perform any other task.

## C.4 INFORMATION BITS BETWEEN MACH. AND TL CHANGER

### C.4.1 BITS FROM ATC PLC TO MACHINE PLC

<b>BIT ADDR.</b>	<b>DESCRIPTION</b>
+14.0	In power on The ATC is switched on
+14.1	Not in fault When this bit is set, no critical fault are active on the ATC. If the ATC is also in automatic mode is ready to execute commands from the machine. When this bit is low, the tool magazine can just be operated in manual mode. An explicit ATC fault reset from the operator is needed to clear the fault.
+14.2	In auto mode ATC is in automatic mode. Any manual operation is forbidden
+14.3	Gates closed The gates between the tool changer and the machine are closed.
+15.4	Tool arm retracted The ATC grippers are retracted. The tool changer arm is not invading the tool exchange area
+15.5	Load place 1 occupied There is a tool on the load/unload place #1
+16.0	Request to send
+16.1	Acknowledge To receive
+16.3	Request manual mode
+16.6	Gripper toward spindle opened The ATC exchange gripper toward the spindle is open
+16.7	Gripper toward spindle closed The ATC exchange gripper toward the spindle is closed

### C.4.2 BITS FROM MACHINE PLC TO ATC PLC

<b>BIT ADDR.</b>	<b>DESCRIPTION</b>
+15.5	Tool exchange area free The machine informs ATC that the tool exchange area is free.
+16.0	Request to send
+16.1	Acknowledge To receive
+16.3	Acknowledge to enable manual mode
+16.4	Wait to enable manual mode

## C.5 MISCELLANEOUS FUNCTIONS

### C.5.1 COMMUNICATION WATCHDOG

The machine writes a random number into the “Comm watchdog” field (byte +12) and starts the watch dog timer. As soon as the tool exchanger sees the new value, it should copy it in his “Comm watchdog” field and reset his watchdog timer. When the machine sees that the tool changer has copied the same value, it will reset the machine watchdog timer and the process will restart from the beginning.

### C.5.2 MACHINE INFLUENCE OVER ATC MANUAL FUNCTION ENABLE

The machine has the power to delay the ATC to enter into manual mode. Every time that the operator requests the ATC to switch into manual mode, the ATC performs some internal checks to decide if is safe and the right time to switch mode. After this, the ATC should request permission at the machine to enable the manual mode switch over with the bit +16.3 “Request manual mode”. The machine can allow the ATC to switch, with the bit +16.3 “Acknowledge to enable manual mode” or delay it with the bit +16.4 “Wait to enable manual mode”

### C.5.3 MULTIPLE SPINDLE UNIT HANDLING

The tool changer is able to serve several, different, spindle units. The ATC has a wrist on the gripper arm that makes it able to exchange tools with horizontal and vertical spindle units. The position of the gripper arm axis can be set for each spindle unit. To get the ATC to move to the proper exchange position, the machine writes to byte +20, the current Spindle Unit mounted on the ram.

### C.5.4 MANUAL RECOVERY FROM A TOOL EXCHANGE INTERRUPTION

If an error occurs during a tool exchange between the machine and the ATC, the first attempt to recover the situation is done by executing Task 2. If after the execution of Task 2 the robot is not in a safe state, a manual intervention of the operator is needed.

The goal for the operator is to clear the tool exchange area from the machine and ATC. To achieve this goal, the operator should first move the machine away from tool exchange area and afterwards retract the ATC arm. If there is a tool stuck between the spindle tool gripper and the ATC, before moving the machine, the operator should evaluate which is the safest place to leave the tool.

If the spindle tool gripper and ATC gripper nearest the spindle are both closed, the machine is in feedhold. Therefore to move the machine away from the tool change area, at least one of the grippers should be open. It is the responsibility of the operator to choose the right gripper to open.

When at least one of the grippers is open, the operator in JOG mode should retract the machine from the tool exchange area. Subsequently, the operator through the ATC manual interface, must jog back the exchange arm.

Finally, when the tool exchange area is clear, the operator should verify the consistency between the Siemens Tool Management table and actual status of the tools in the buffers (both ATC buffers and machine buffers).

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