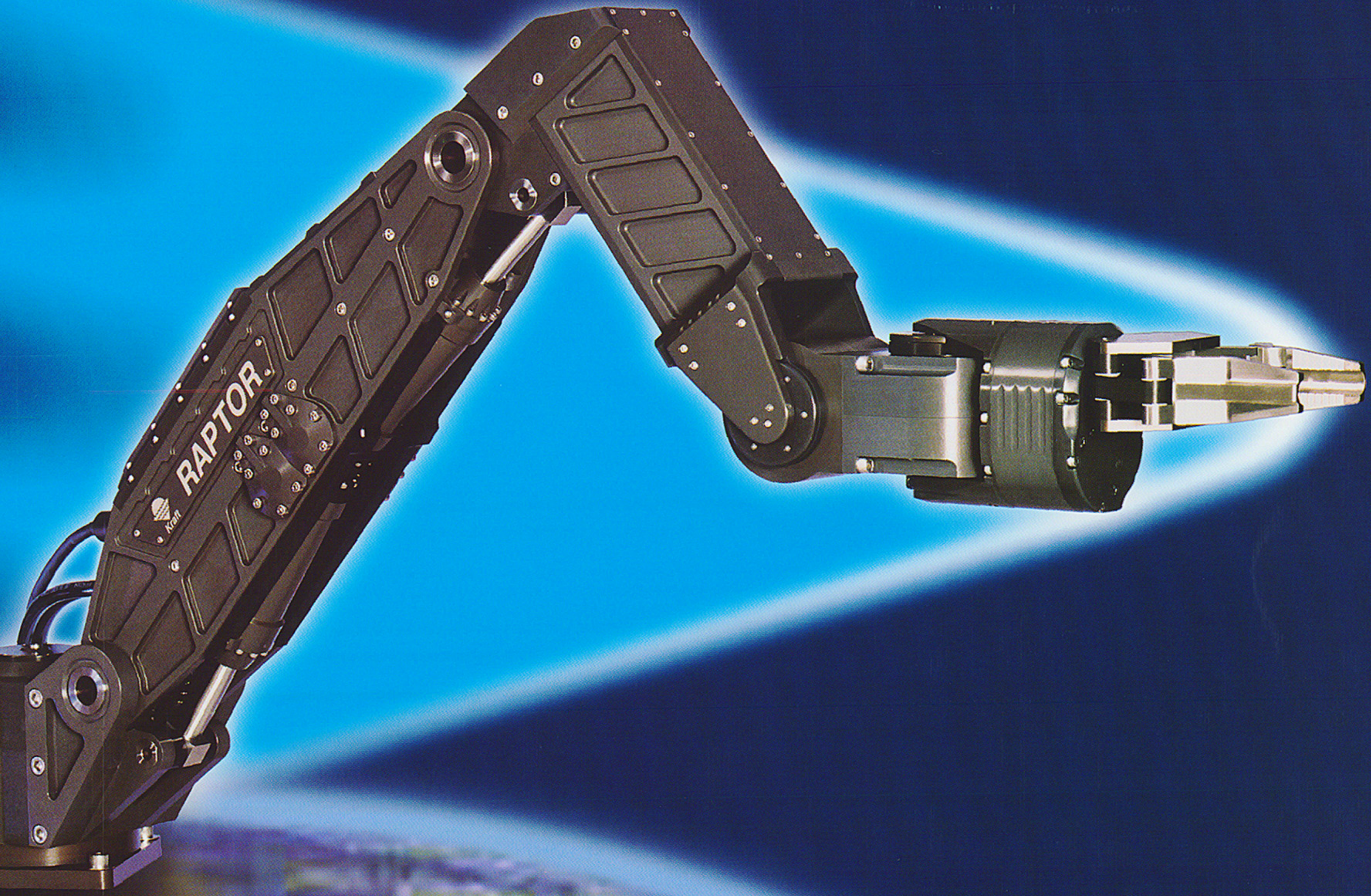
RAPTOR

MANIPULATOR SYSTEM MANUAL



Kraft TeleRobotics INC.

RAPTOR

Manipulator System Manual

003-5008-10

Rev 0

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1 General Information

1.1 INTRODUCTION

Kraft TeleRobotics thanks you for selecting our *Raptor* manipulator system. The *Raptor's* rugged construction and quality components offer the reliability demanded by the harshest operating environments. If after reading this manual you should have any questions or comments, our Technical Support Department is eager to serve you. Kraft TeleRobotics is fully committed to your satisfaction as a customer.

This manual contains, installation, operation, and maintenance instructions for the Kraft *Raptor* manipulator system. It describes both hardware and software operating features of the system and the interface options that are available.

Two copies of this manual are supplied with each system. One hard copy is supplied in a 3-ring binder and the other is provided on CD-ROM. This manual is divided into five indexed sections. These sections are:

1. GENERAL INFORMATION
2. INSTALLATION
3. OPERATION
4. MAINTENANCE
5. PARTS LIST

1.2 EQUIPMENT DESCRIPTION

Raptor is a general purpose, master/slave, teleoperated manipulator system designed for reliable operation undersea or in other "hostile" environments. Operating as a position controlled, closed-loop servo system, movements introduced at the master control arm by the operator are duplicated by the slave manipulator allowing an operator to perform complex work tasks from a safe remote location. With optional force feedback, the forces acting upon the distant manipulator are reflected back to the operator through a force reflecting master. This capability allows the remote operator to perform tasks that may otherwise be impossible without the dimension of feeling force feedback provides.

The following is a list of major system components for the standard *Raptor* system. These components are illustrated in Figure 1-1.

- *Raptor* 7-function slave manipulator arm

-Operator control unit with Kraft mini-master®

- KMC 9100 electronics chassis including:

  Twisted-pair, coax or fiber optic telemetry

- Servo driver module

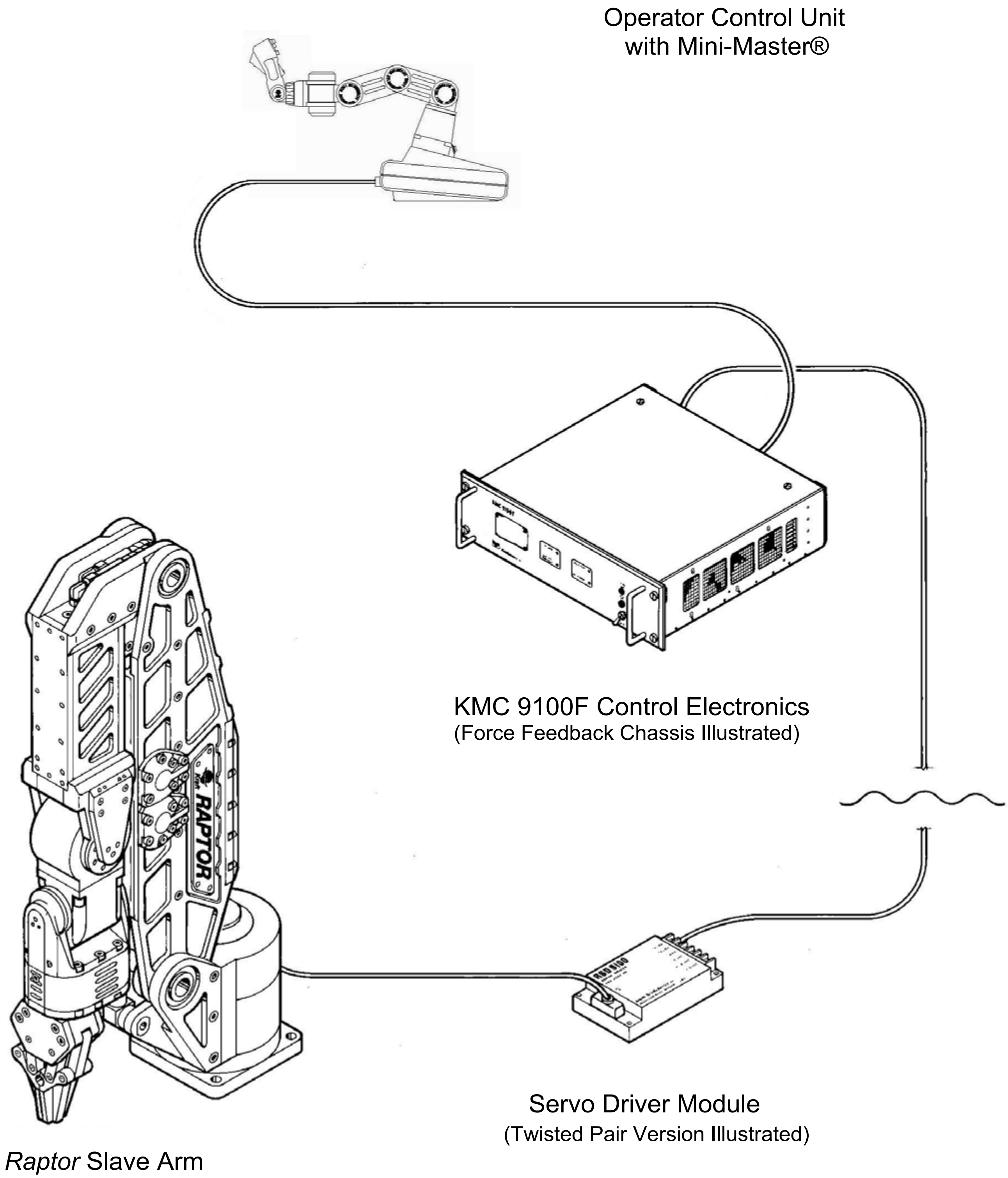


Figure 1-1 Major components of the *Raptor* manipulator system

1.2.1 *Raptor* Slave Arm

The *Raptor* manipulator is a microprocessor controlled electro-hydraulic device with a total of seven actuated functions (Figure 1-2). The manipulator's performance envelope (Figure 1-3) allows for either left or right hand operation. Figure 1-4 provides basic outline dimensions of the manipulator arm.

The slave manipulator's basic structure is hard anodized 6061-T6 aluminum with an impregnated Teflon protective coating. The use of this alloy for the structural elements of the manipulator allows most field repairs or modifications to occur without any knowledge of special materials or machining practices. All non-aluminum hardware is corrosion resistant stainless steel or a composite material. Coatings, hoses, and other materials were selected for the UV/saltwater environment found offshore.

The manipulator is completely sealed for submersion in sea water with proper attention paid to the elimination of galvanic coupling and the associated problems of corrosion. The manipulator arm is divided into two basic actuated sections. An upper arm section that provides the primary motions of shoulder azimuth, shoulder elevation and elbow pivot, and a forearm section that provides wrist pitch, wrist yaw, and wrist rotate motions (Figure 1-5).

In addition to these six degrees-of-freedom, a parallel jaw type gripper with force control is provided as the standard end effector. Four fingered intermeshing jaws are available as an option (Figure 1-6). Both jaw configurations can grip 3/4" diameter T-handles as shown in Figure 1-7. Kraft's unique method of controlling the jaws, allows the operator to vary both the rate of closure and the amount of grip force. Proportionally variable control of gripper force has proven to be superior to the typical constant rate type of jaw control.

Motive force is supplied by seven hydraulic actuators. All the hydraulic actuators are designed and manufactured by Kraft TeleRobotics. The upper arm section of the manipulator includes a rotary actuator for 275 degrees of shoulder azimuth, a linear actuator for 120 degrees of shoulder elevation, and a linear actuator that provides 130 degrees of elbow pivot. The forearm section includes a rotary actuator for 200 degrees of wrist pitch, a rotary actuator for 200 degrees of wrist yaw, a piston type hydraulic motor that provides 360 degrees of continuous wrist rotation, and a linear actuator that opens and closes the jaws.

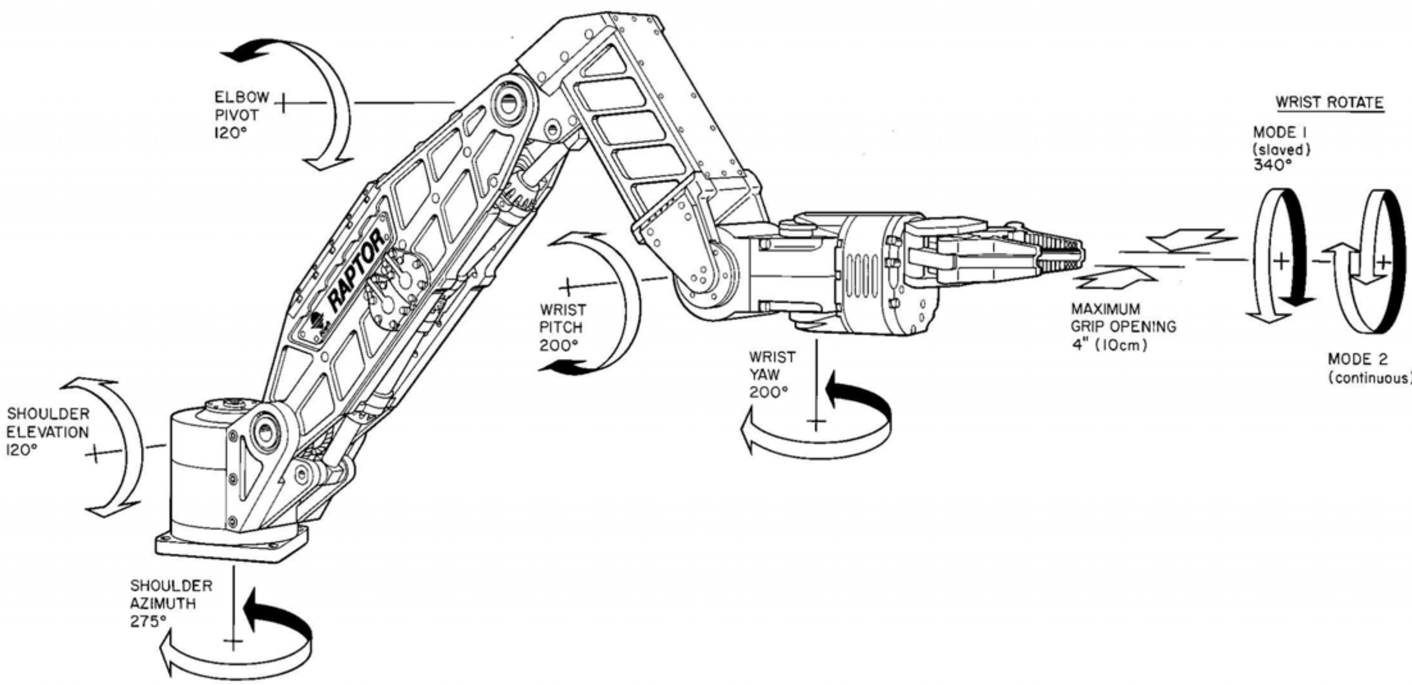
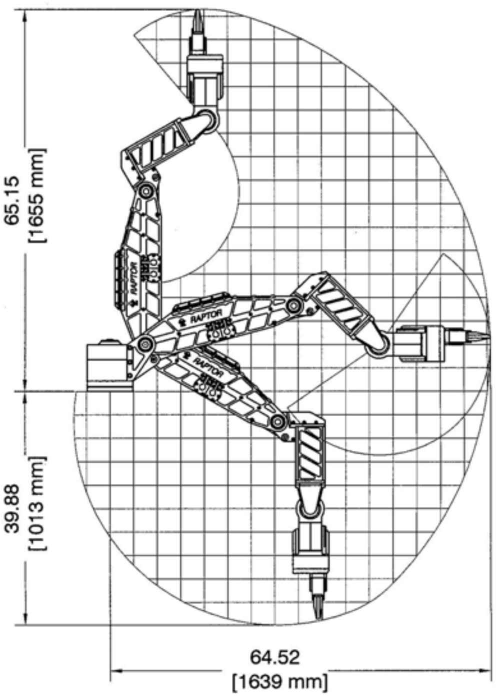


Figure 1-2 Axis Identification and Travel

SIDE VIEW



Grid Scale: One block = 4"

PLAN VIEW

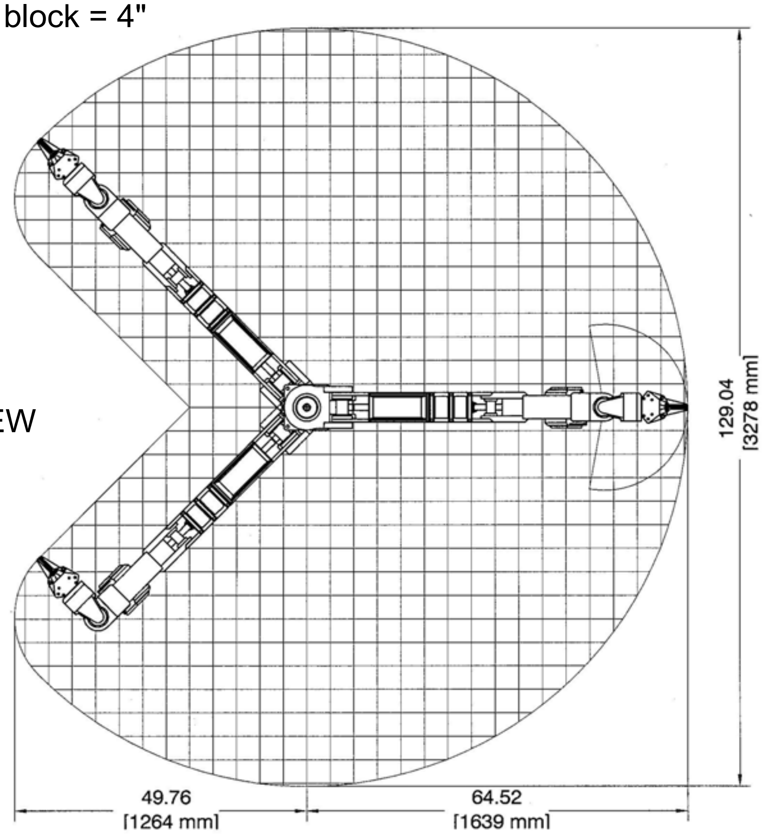


Figure 1-3 *Raptor* Performance Envelope

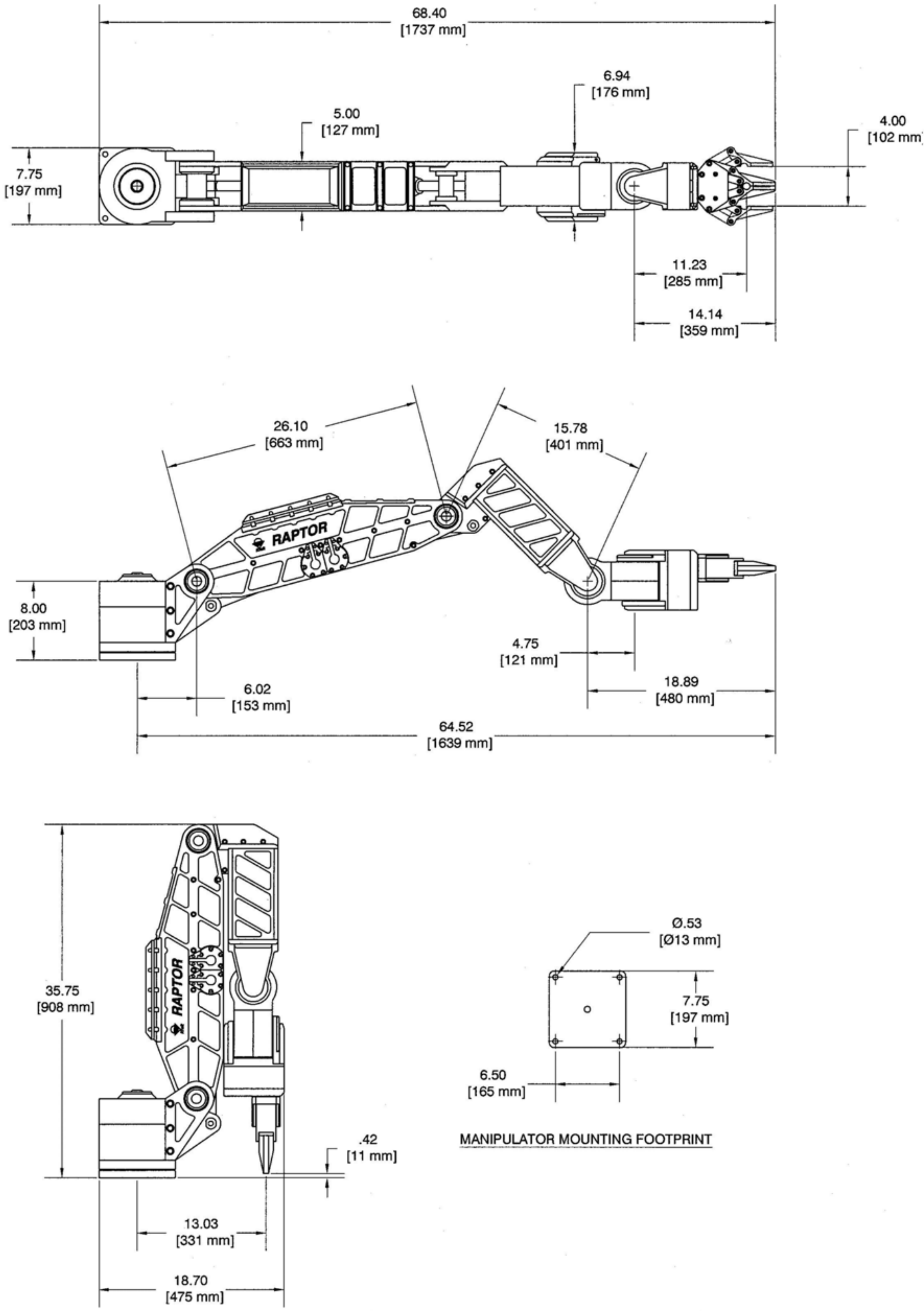


Figure 1-4 *Raptor* Outline Drawing

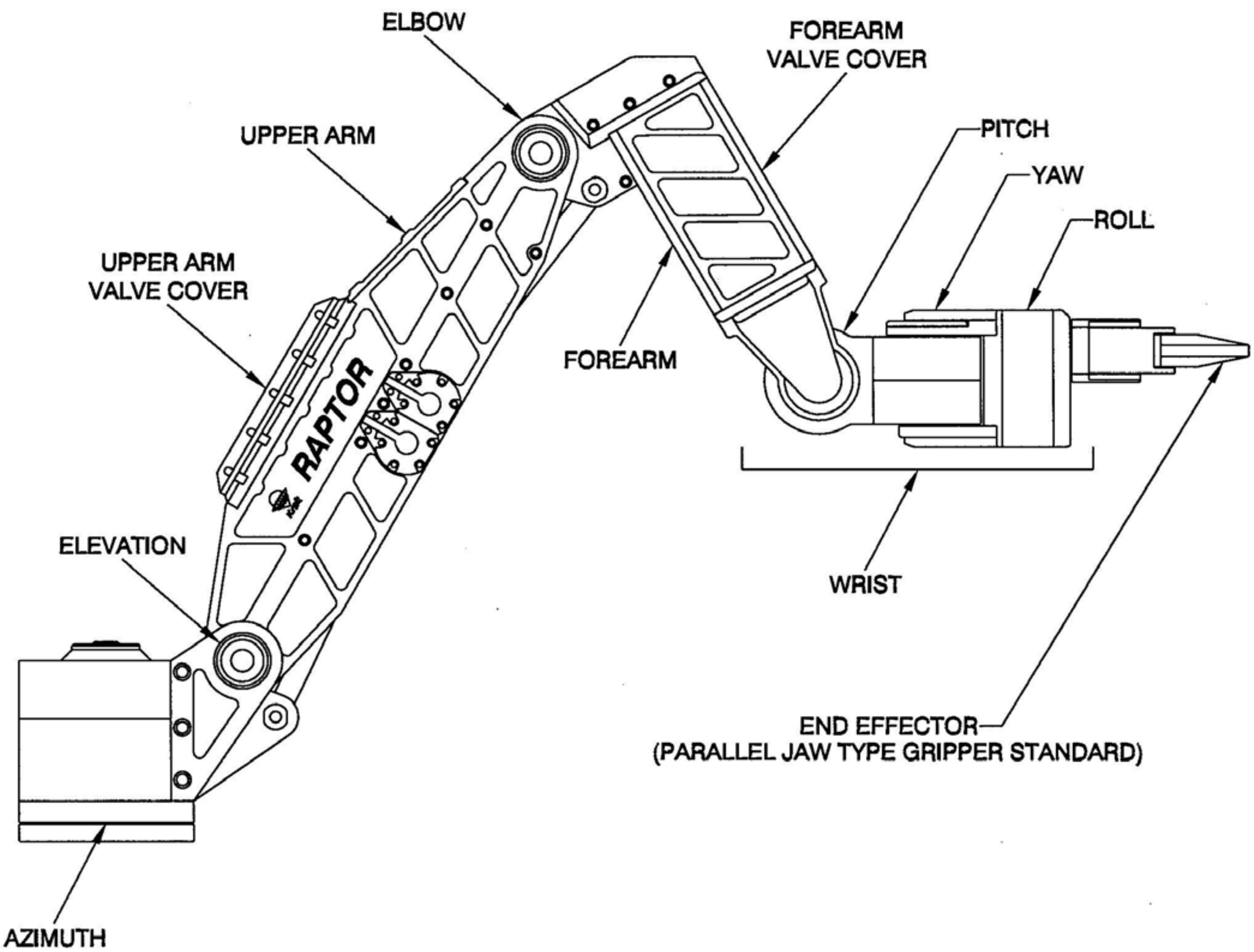
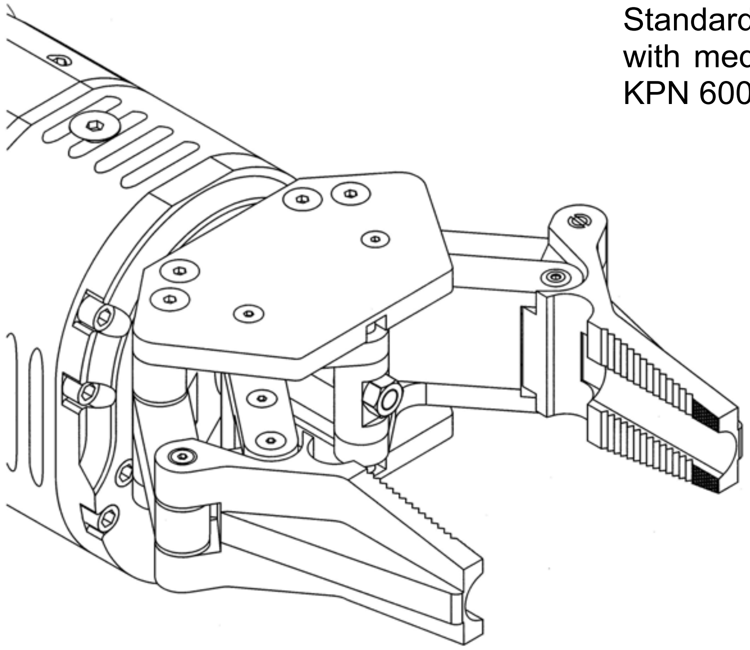


Figure 1-5 *Raptor* Slave Arm - Member Identification

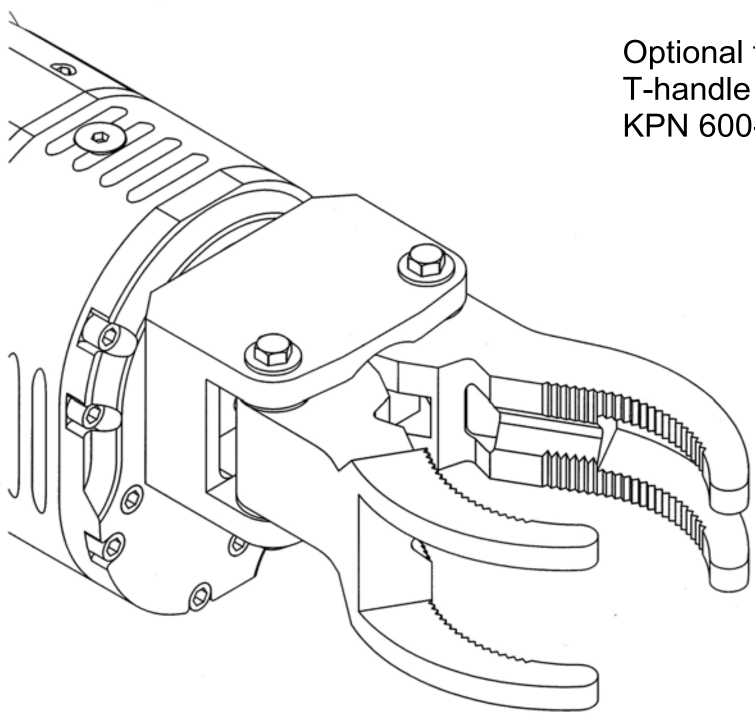
1.2.1 Slave Arm (continued)

Each actuator is controlled by a hydraulic servo valve. All servo valves are packaged as an integral part of the manipulator, with hydraulic manifolds located in the upper arm, and forearm sections. In addition to servo valves, the upper arm manifold includes a pressure reducing valve and a solenoid valve. The solenoid valve is used to switch hydraulic power to the manipulator on and off, while the integral pressure reducing valve allows operation from a primary supply pressure of up to 3000 PSI. Hydraulic oil is supplied to the manipulator via two hose connections at the upper arm manifold. The wrist pitch, wrist yaw, wrist roll, and gripper actuators are all internally ported to the hydraulic manifold in the forearm section. Internal porting within the wrist assembly eliminates the need for hydraulic hoses. Hydraulic hoses, although well suited to many tasks, are less than desirable in a wrist assembly that can both pitch and yaw 200 degrees.

Valve covers on the upper arm, and forearm sections of the manipulator provide quick, easy access to all valving without disassembly of the arm. The pressure compensated oil filled volumes within the *Raptor* manipulator are completely isolated from the working hydraulic portions of the arm. Separating the pressure compensation oil from the working hydraulic oil allows the arm to be operated for test purposes with the valve covers removed. Isolating the pressure compensation oil also protects electrical components within the arm from any contaminates that may have entered the working hydraulic oil.

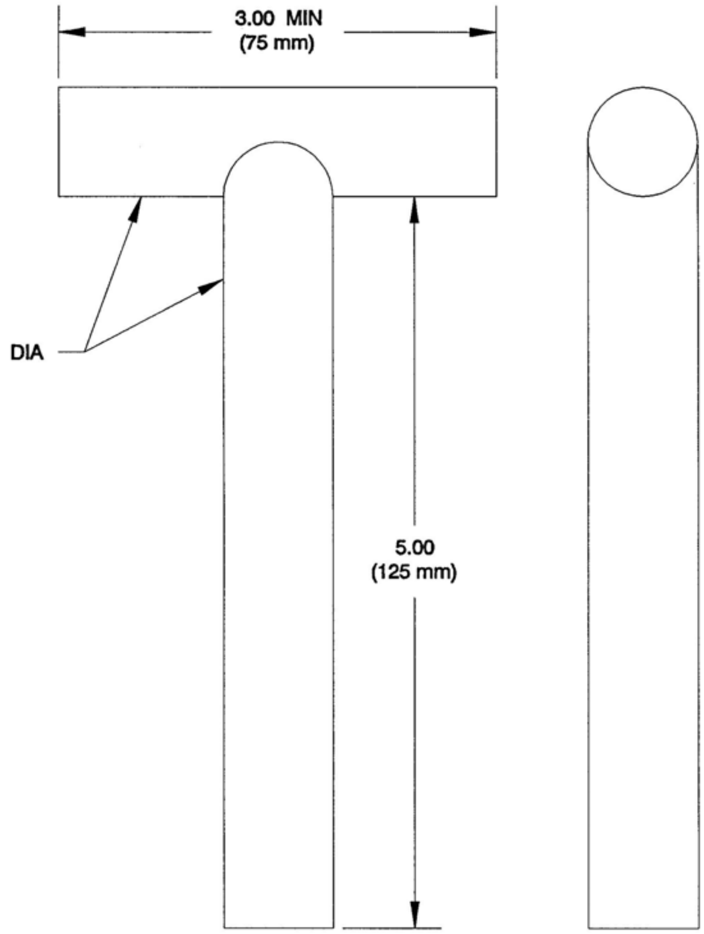


Standard parallel acting T-handle jaws with medium serrations and knurled tip
KPN 600-0133-02 (3/4" T-Handle)



Optional four fingered intermeshing T-handle jaws
KPN 600-0272-01 (3/4" T-Handle)

Figure 1-6 *Raptor* Jaw Configurations



	CLASS 1	CLASS 2	TOL
DIA INCH	.75	1.25	±.03
DIA (mm)	(20)	(30)	±.2

NOTE:
MATERIAL IS 75,000 PSI (520 MPa)
MIN YIELD STRENGTH.

Figure 1-7 T-Handle Tool Interface

1.2.2 Master Controller

The Kraft mini-master® controller (Figure 1-8), (Figure 1-9) is compact in size, yet it allows the operator to control complex manipulator motions in a comfortable and intuitive manner. The master is kinematically similar to the slave arm with six spatially correspondent control functions. The mini-master® is designed for comfortable left-hand or right-hand operation.

The hand grip can be rotated and locked into three different positions. The operator is able to choose the most suitable position for a given mounting option or manipulative task. These positions provide for either a joystick, pistol-grip, or stylus mode of operation as shown in Figure 1-10.

Dual trigger switches in the hand grip provide proportional control of gripper closure force at the slave arm. Conveniently located pushbutton switches on the pistol grip provide the operator with direct access to core manipulator functions for faster arm operation (Figure 1-11). These switches control wrist rotate mode (continuous/slaved), grip lock, and the halt/index function. Additionally, a spring centered rocker switch provides proportionally variable rate control of wrist rotate, when in the continuous wrist mode. Four LED indicators are integrated into the master for high visibility during operation. The LED lamps indicate manipulator hydraulics on/off, grip lock on/off, continuous/slave wrist rotate mode, and halt/index on/off.

The force feedback mini-master® provides scaled manipulator forces to the operator. Electric actuators on the individual joints of the master respond to the forces acting upon the manipulator arm, providing force feedback to the operator. Both the static and dynamic forces acting upon the distant manipulator are reflected back to the operator via actuators on the shoulder azimuth, shoulder elevation, elbow pivot, wrist pitch and wrist yaw joints. This force information greatly improves operator awareness allowing the operator to complete tasks of much greater complexity.

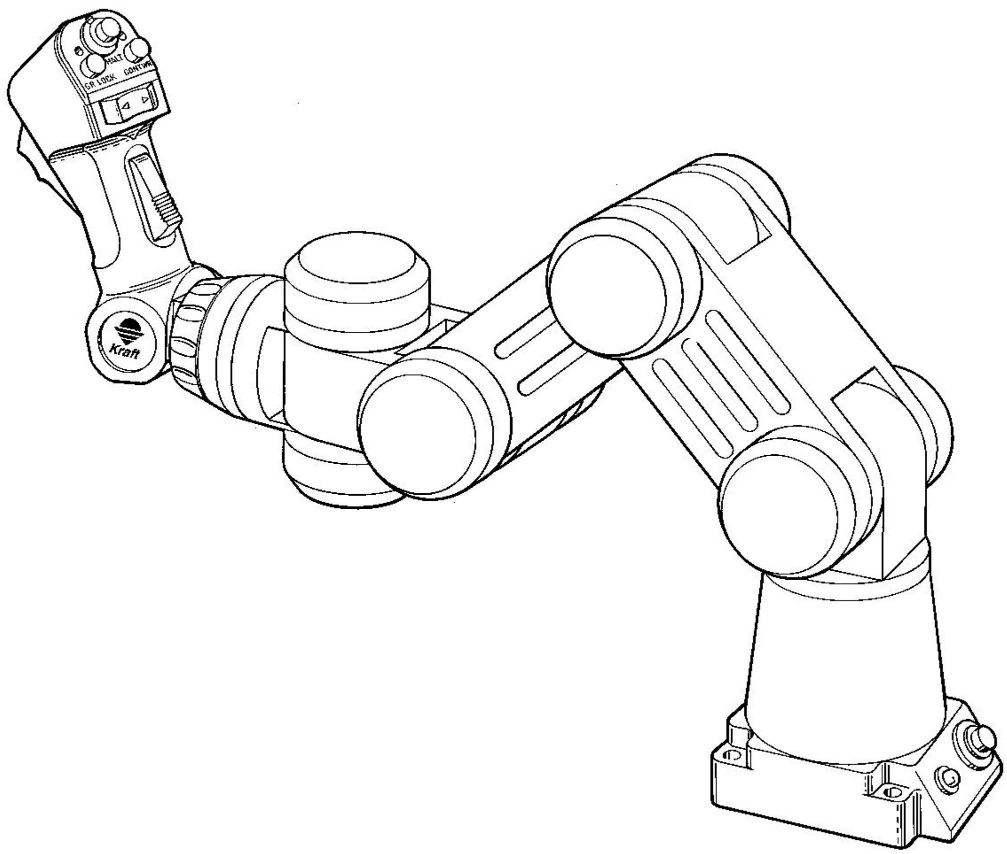


Figure 1-8 Kraft Mini-Master®

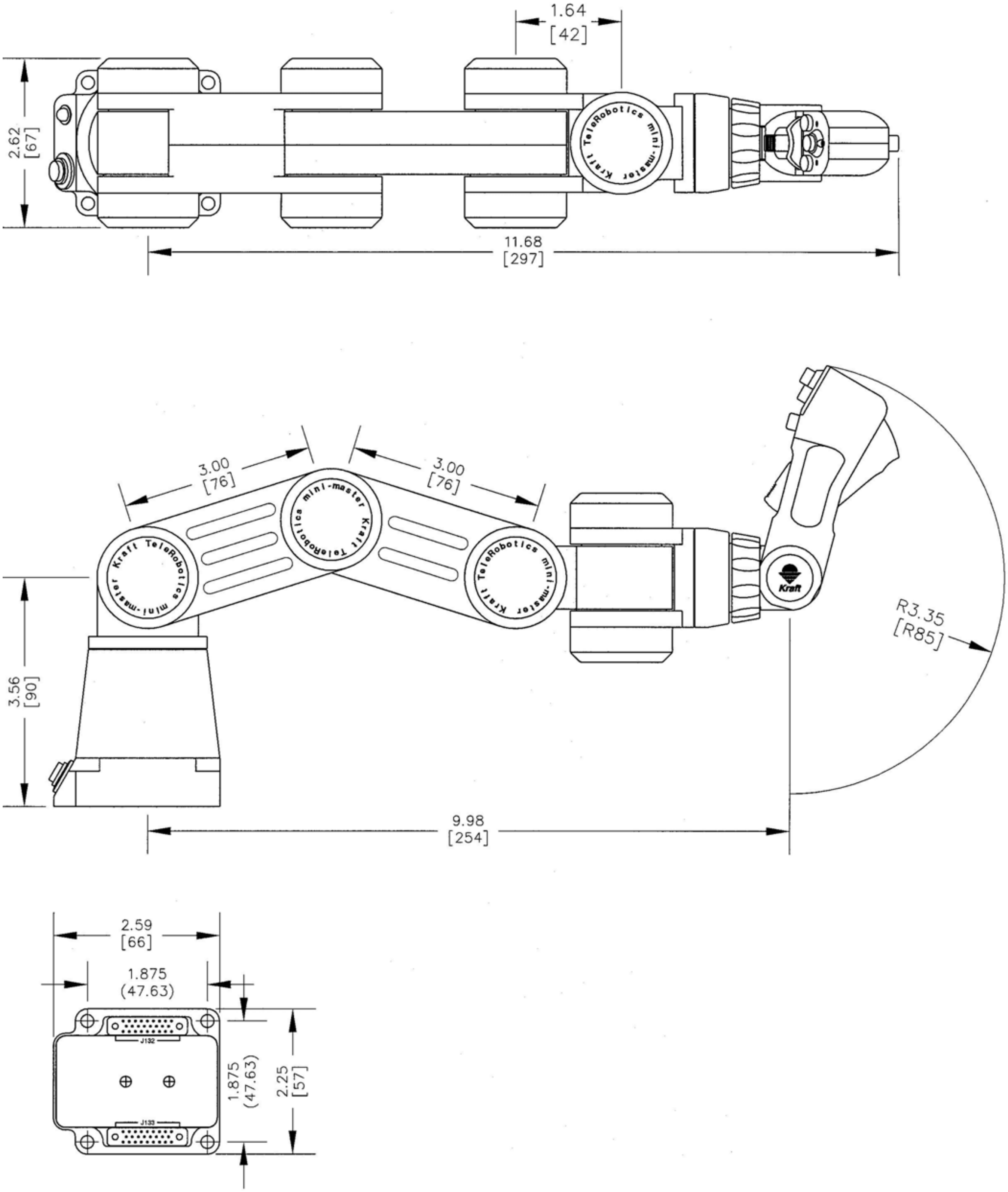
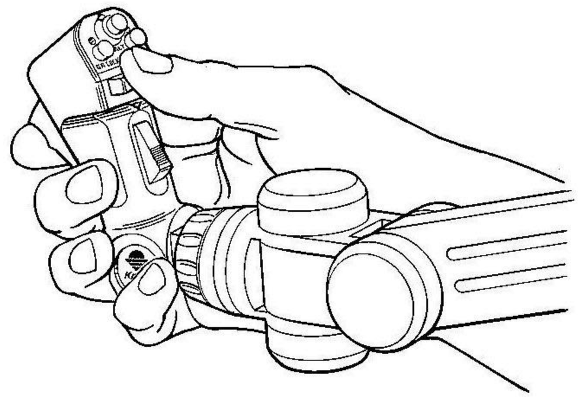
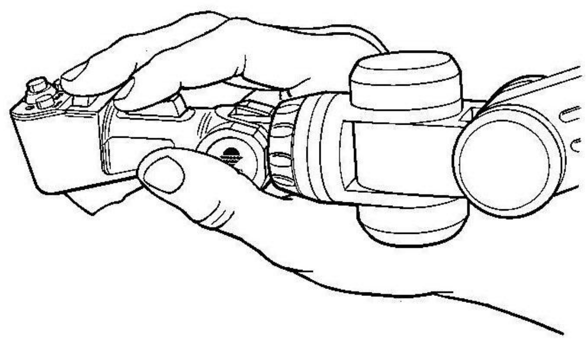


Figure 1-9 mini-master® outline drawing

Joystick Mode of Operation



Stylus Mode of Operation



Pistol-Grip Mode of Operation

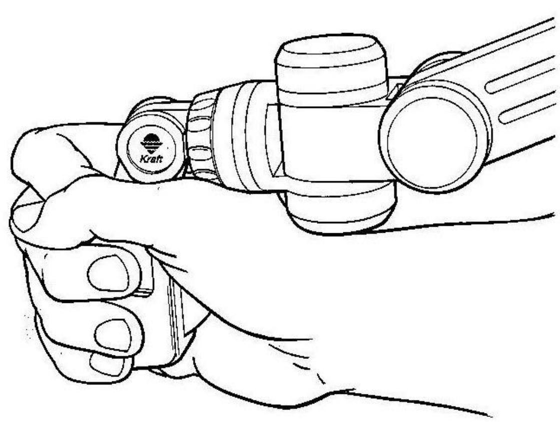


Figure 1-10 mini-master® hand grip positions

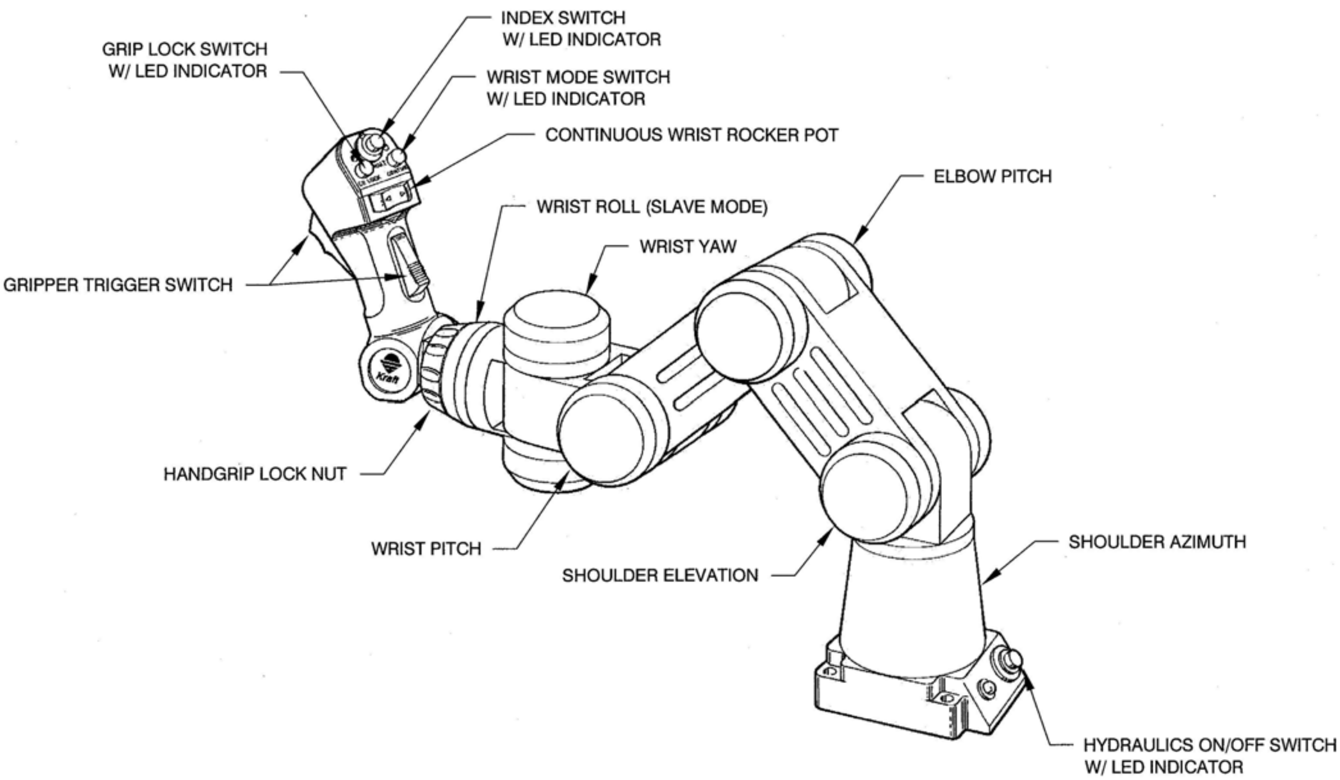


Figure 1-11 mini-master® - Features and Controls

1.2.3 KMC 9100 Control Electronics

The KMC 9100 is a microprocessor based control system designed to provide the electronic control and telemetry functions necessary for operation of the *Raptor* seven function manipulator. The KMC 9100 control system offers maximum capability with minimum complexity.

The KMC 9100 System Features:

- Force feedback
- Automatic manipulator stow function
- Automatic manipulator deploy function
- Automatic self test
- Automatic calibration mode
- Programmable task execution

The manipulator control system consists of the following major components:

1. An enclosed 19 inch EIA rack mount master electronics chassis (Figure 1-12). This chassis houses the encapsulated master controller interface unit (MCIU) module which is the primary "computing engine" for the manipulator system in all configurations. Additionally, this chassis houses the torque motor driver electronics for powering the electric actuators on the force feedback master.

2. An operator control unit with keypad and display provides the means to enter and display data. This is the operator's interface to the control electronics for commanding those capabilities not controlled directly by the master control arm.

3. An encapsulated Remote Servo Driver module (RSD) that is typically located near the manipulator. The RSD module interfaces directly to the manipulator, receiving its command signals from the distant KMC 9100 chassis. Communication between these two stations is accomplished over a variety of customer specified signal medium including twisted wire pair, coax cable, optical fiber, or RF modem.

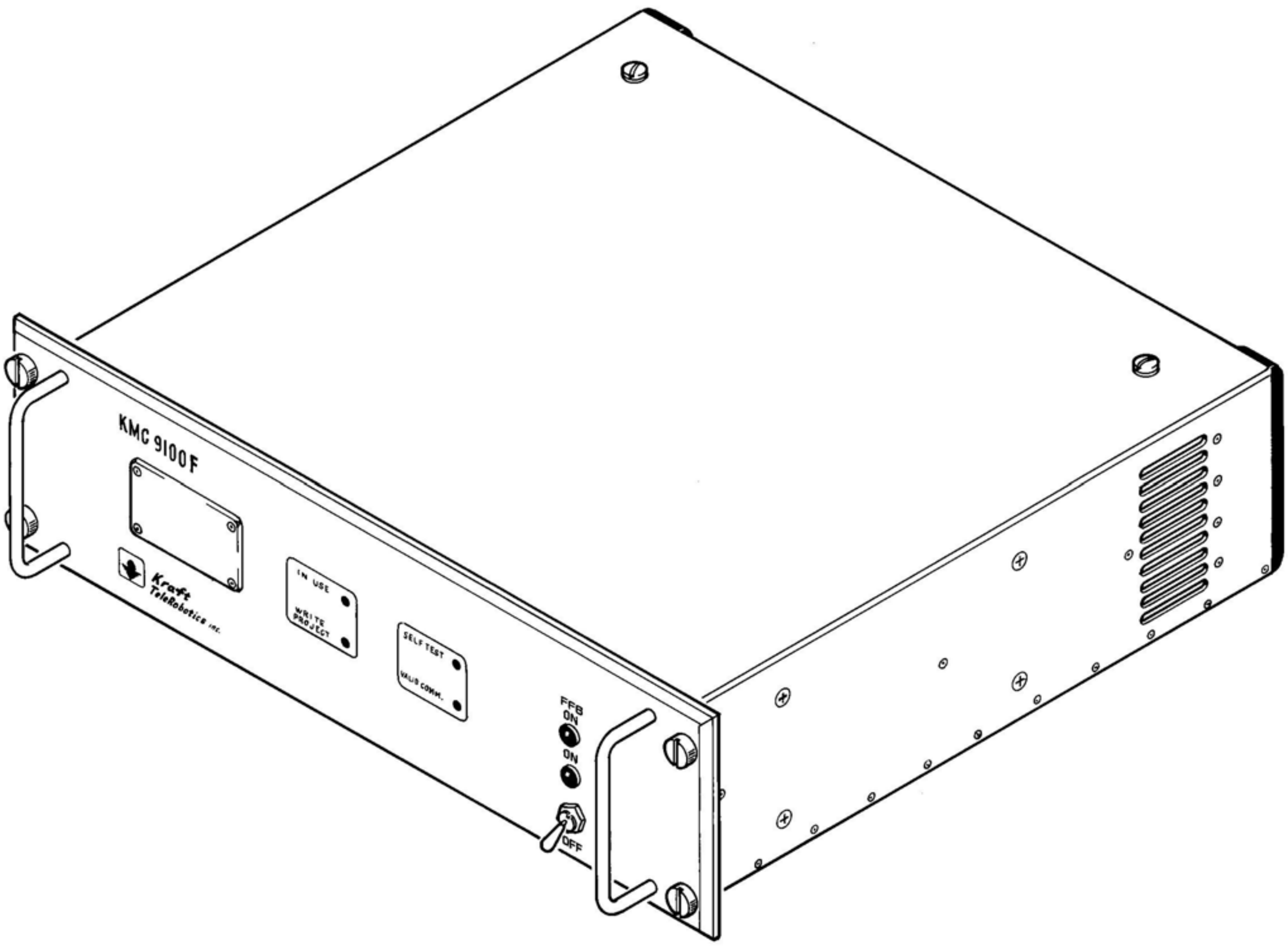


Figure 1-12 KMC 9100 F force feedback electronics chassis.

The design strategy of the control system locates the computing power in the rack mount KMC 9100 chassis, allowing the RSD module, which is typically less accessible, to be small in size and of optimum reliability. The system is "software driven" with most operations performed by the execution of a program. This allows for the greatest flexibility in that only software need be changed to add capabilities to the system. Straight forward command entries allow the operator to quickly gain confident control of the system's numerous computer enhanced capabilities. These capabilities include:

Scaled motion - the ability to scale down master-to-slave relative motion ratio for precise end-effector control.

Indexed motion - the ability to offset master position relative to slave for operator comfort.

Constrained motion - the ability to establish boundaries or individual joint motion restrictions within software to prevent impact with peripheral equipment.

Task recall - the ability to "teach" the manipulator a routine or sequence and save it for execution at a later time.

1.2.4 Operator Control Unit (OCU)

In its standard configuration the mini-master® is mounted to a compact, portable, operator control unit (OCU) (Figure 1-13) that can be placed on nearly any surface for operation.
The OCU includes a console, which serves as a platform from which one or two mini-master® controllers can be operated, and a keypad with display. The optional dual mini-master® OCU includes a second keypad and display to support simultaneous operation of both a left and right hand mini-master®.

The OCU communicates directly with the KMC 9100 electronics chassis to display system information and allow the operator to select various operating options.

The console features a 4 line by 20 character vacuum fluorescent display (VFD) providing high brightness, wide operating temperature range and a wide viewing angle. Four user-selectable intensities of display brightness are available.

The console includes a 30-key sealed membrane type keypad as shown in Figure 1-14. All keys are backlit for use in low or no ambient light conditions. An audio beeper provides audible key response and will sound each time a key is depressed. Refer to the Operation section of this manual for detailed information regarding individual key functions.

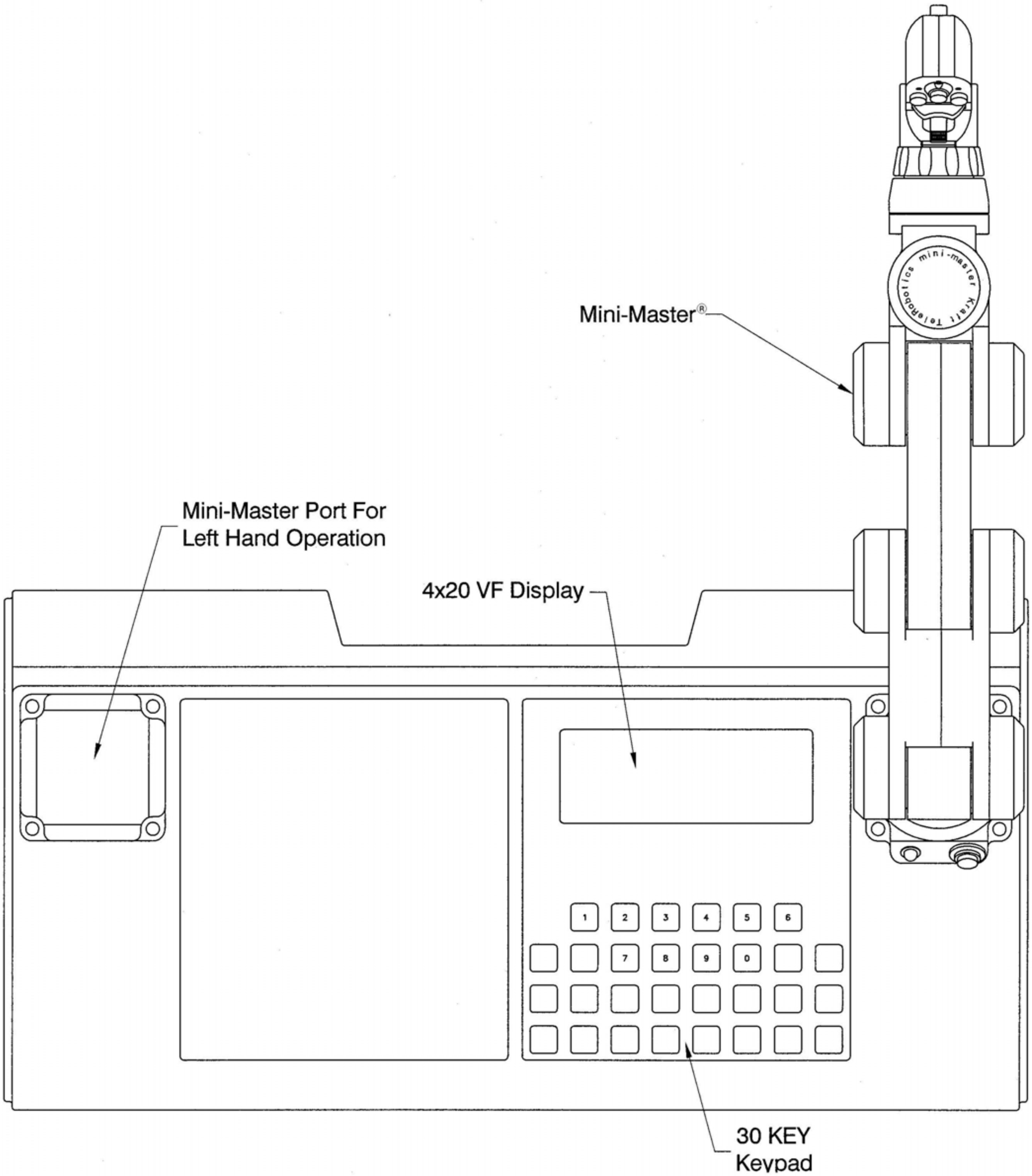


Figure 1-13 Operator Control Unit

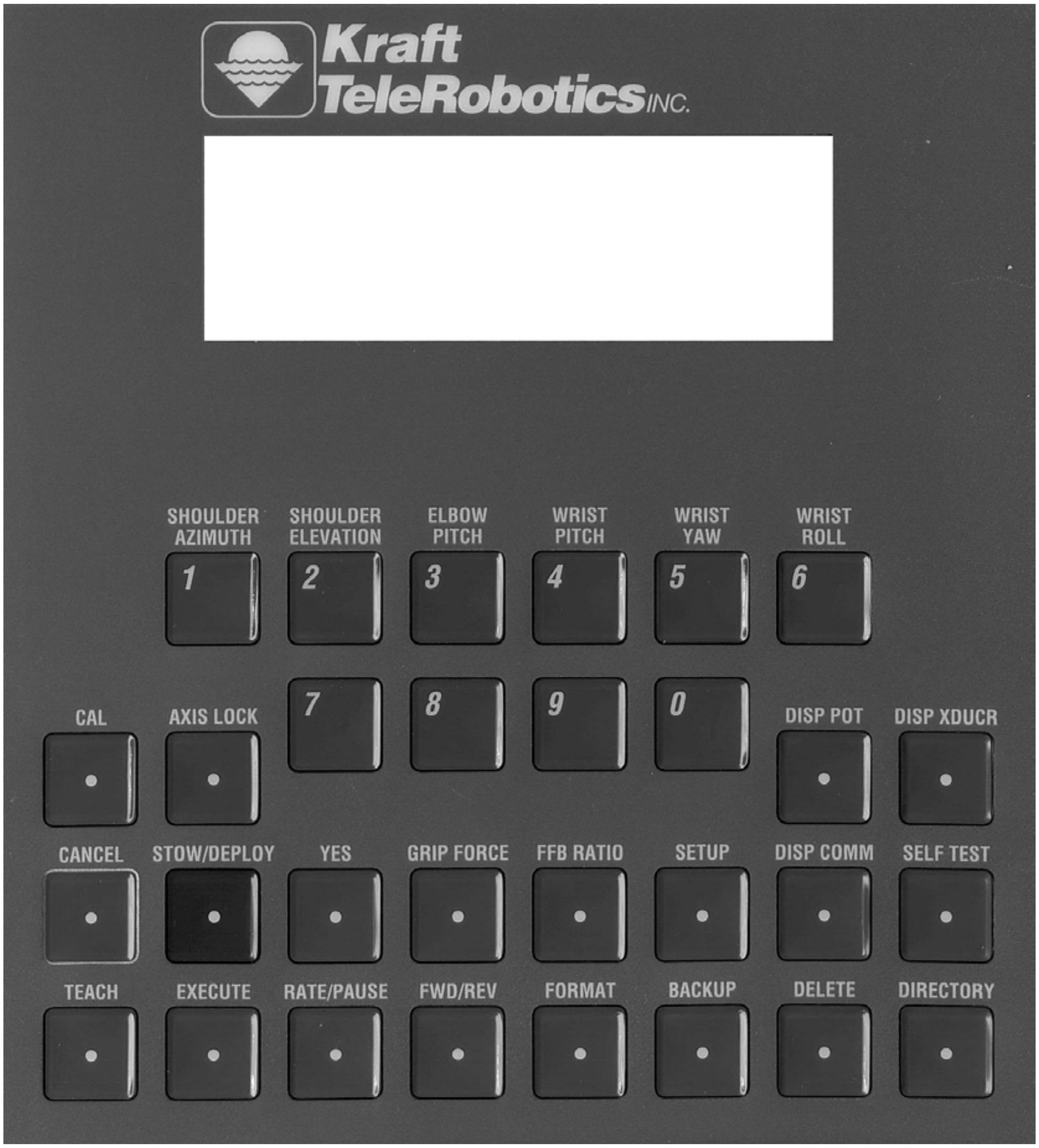


Figure 1-14 OCU Keypad and display

1.2.5 RSD Module Configurations

The following paragraphs describe the telemetry options available for the *Raptor* control system. The RSD modules for each telemetry option are illustrated Figure 1-15.

Twisted Pair Telemetry

Twisted pair telemetry (RS-485) is the standard configuration. The KMC 9100 master electronics chassis is equipped with a twisted pair Communication Interface Module (CIM-T) for communication with a twisted pair Remote Servo Driver module (RSD-T). Communication is possible over a shielded twisted pair for distances in excess of 4000 feet.

Fiber Optic Telemetry

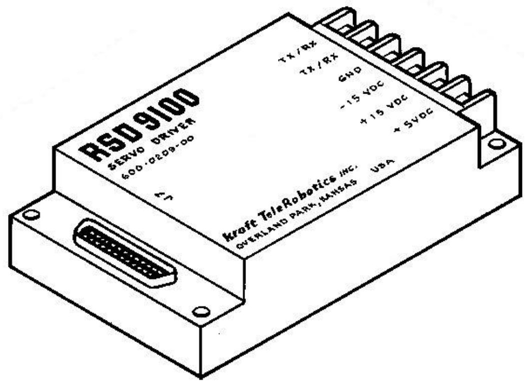
This configuration uses the CIM-F and RSD-F fiber optic modules to provide a complete fiber optic telemetry system (excluding the fiber cable). The CIM-F module in the control chassis and the RSD-F module are each equipped with two SMA type fiber optic connectors. Communication is possible for distances exceeding 13,000 feet.

Coax Cable Telemetry

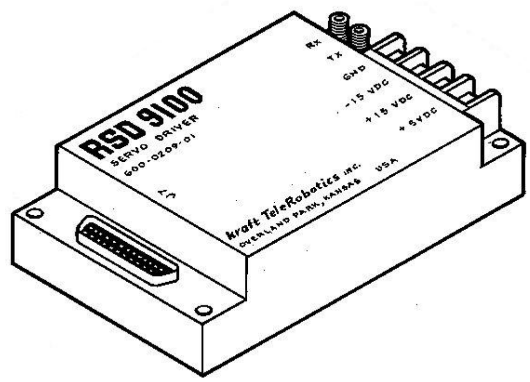
This configuration uses the CIM-C and RSD-C coax modules to provide the user with an SMA type coax cable connection at both the rack mount chassis and the RSD module. These modules differ from the CIM-T and RSD-T only in the type of connector provided. Communication is possible for distances in excess of 4000 feet.

RF Modem Telemetry

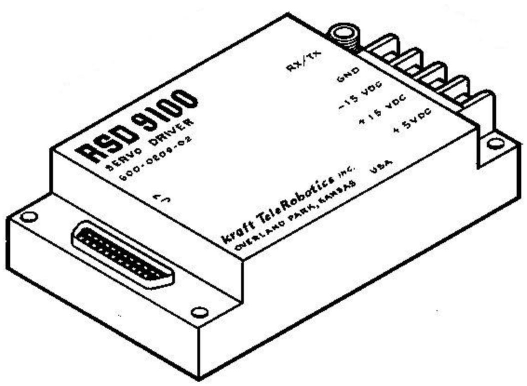
This unique capability allows remote operation of the slave manipulator via a radio frequency (RF) telemetry link. Advanced digital wireless technology provides an encrypted secure data link, with a high degree of resistance to any type of jamming or interference.



RSD-T Remote Servo Driver Module
(Twisted Pair Interface)



RSD-F Remote Servo Driver Module
(Fiber Optic Interface)



RSD-C Remote Servo Driver Module
(Coax Cable Interface)

Figure 1-15 Remote Servo Driver (RSD) Modules. Type T, C, and F

1.2.6 Software Identification

To assist the operator or maintenance personnel, a software version, origination date, system ID number and serial number is embedded within each system's firmware. This information is displayed whenever the self test function is invoked by depressing the [TEST] key. The format of the I.D. code is shown below.

VER 05.06 3/23/06
COPYRIGHT (C) 1987-2006

SERIAL# __ __ __ __

SID# __ __ __ __ __ __ __ __ __ __

The systems unique serial and ID numbers will appear on the third screen of the selftest routine.

1.3 STANDARD EQUIPMENT LIST

The following is a list of the standard manipulator system components inclusive of all electrical, electronic, hydraulic and mechanical hardware.

Description	Part Number
Raptor Manipulator - Slave Arm	
Non Force Feedback	700-9060-00
Force Feedback	700-9061-00
Master Controller	
Non Force Feedback (right hand)	700-9057-00
Non Force Feedback (left hand)	700-9058-00
Force Feedback (right hand)	700-9041-00
Force Feedback (left hand)	700-9043-00
mini-master ®	700-9075-00

Rack Mount Chassis Electronics System

KMC 9100 - Non Force Feedback System

CIM-T	700-9044-10
CIM-F	700-9044-12
CIM-C	700-9044-14

KMC 9100 F - Force Feedback System

CIM-T	700-9039-10
CIM-F	700-9039-12
CIM-C	700-9039-14

KMC 9100 MCIU - Controller Module (Installed in KMC 9100 / KMC 9100F chassis)	600-0208-10

Telemetry Module
(Installed in KMC 9100 / KMC 9100F chassis)

CIM-T Communication Interface Module (Twisted Pair Interface)	600-0207-00
CIM-F Communication Interface Module (Fiber Optic Interface)	600-0207-01
CIM-C Communication Interface Module (Coax Cable Interface)	600-0207-02

Remote Servo Driver Modules

RSD-T Remote Servo Driver Module (Twisted Pair Interface)	600-0209-00
RSD-F Remote Servo Driver Module (Fiber Optic Interface)	600-0209-01
RSD-C Remote Servo Driver Module (Coax Cable Interface)	600-0209-02

Cable Assemblies

KMC 9100	
Master Interface Cable	326-0016-25
KMC 9100	
Detachable AC Cord	326-0017-02
KMC 9100 F	
Y - Adapter Cable	326-0032-00
Master Interface Cable	326-0033-00
KMC 9100-F	
Detachable AC Cord	326-0019-02

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1.4 OPTIONAL EQUIPMENT LIST

Fiberoptic Telemetry System

Wireless R.F. Telemetry System

Remote Servo Driver Enclosure:

for RSD-T Remote Servo Driver Module
(Twisted Pair Interface)

for RSD-F Remote Servo Driver Module
(Fiber Optic Interface)

for RSD-C Remote Servo Driver Module
(Coax Cable Interface)

Force Sensor on Gripper
(Force Feedback System Only)

220 Vac 50 Hz Power Supply
(Force Feedback System Only)

Integral Electrical Power Unit with RSD Module

Intermeshing T-Handle Jaws

Class 1 Field Maintenance Spares Kit

Sub sea electronics bottle

1.5 SYSTEM SPECIFICATIONS

1.5.1 *RAPTOR* Slave Manipulator

Degrees freedom-of-motion .... 6 plus gripper

Maximum reach .... 64.5 inches

Lift capacity .... 200 lbs

Jaw closure force .... 300 lbs

Wrist torque .... 100 ft lbs

Stowed height .... 35.75 inches

Weight in air .... 165 lbs

Weight in sea water .... 98 lbs

Joint Motion	Total Angular Excursion (degrees)	Angular Slew Rate (degrees)
Shoulder Azimuth	275	80/sec.
Shoulder Elevation	120	65/sec.
Elbow Pivot	120	50/sec.
Wrist Pitch	200	100/sec.
Wrist Yaw	200	100/sec.
Wrist Rotate (slaved mode)	340	330/sec.
Wrist Rotate (continuous mode)	Variable to	55 rpm max.

1.5.1 Slave Manipulator (continued)

Hydraulic Power Requirements:

Operating pressure .... 2000 PSI*

Flow requirement .... 5 GPM (19 liters/min)

Filtration .... 25 micron absolute

Pressure line connection .... No. 6 JIC

Return line connection .... No. 6 JIC

* Note: The manipulator incorporates an integral pressure regulating valve set at 2000 psi. The system can be connected to a 2000-3000 psi hydraulic source.

Operating fluid requirement: The Raptor manipulator can be operated on a variety of hydraulic oils. Both MIL-H-5606 (aircraft hydraulic fluid) and Shell, Tellus Oil 32 are both excellent choices. Consult factory regarding the use of other fluids.

Electrical Connection: The slave manipulator incorporates a bulkhead connector receptacle (Brantner & Associates SeaCon MIN-M-37-FCR) located at the upper arm manifold near the base. This bulkhead connector receptacle interfaces with a customer furnished interconnect cable, with a Brantner & Associates SeaCon MIN-M-37-CCP mating connector at one end.

The manipulator base incorporates a square 4 bolt mounting flange with a 7 3/4 inch footprint. The bolt pattern is 6 1/2 inches square with through holes for 1/2 inch mounting bolts. (Reference Figure 1-4)

1.5.2 Mini-Master® Controller

Degrees-of-freedom 6

Maximum reflected force in fully extended position .... 4 lbs. (17.8N)

Weight .... 2.8 lbs. (1.27kg)

Joint Sensor .... Conductive Plastic Potentiometers

Actuators .... Electric, Direct Drive

Jaw trigger spring rate .... Front 8 oz.
Rear 1 lb.

Electrical Power Requirements:

Maximum Peak (all actuators full on) .... 385 watts
Typical Operating .... 150 watts
Quiescent .... 20 watts

Environmental:

Operating temperature range .... 0 deg. C to +35 deg. C
Storage temperature range .... -20 deg. C to +70 deg. C
Humidity .... 5% to 95% RH non condensing

Joint Motion	Total Angular Excursion (degrees)
Shoulder Azimuth (SA)	180
Shoulder Elevation (SE)	120
Elbow Pivot (EL)	110
Wrist Pitch (WP)	180
Wrist Yaw (WY)	180
Wrist Roll (WR)	120

1.5.3 KMC 9100-F Control Electronics (Standard 19" rack mount chassis)

Dimensions:

Height .... 5.25 in
Width .... 19.0 in
Depth (no connector allowance)
Including handle projection .... 18.0 in
Excluding handle projection .... 16.5 in

Weight .... 30 lbs nominal

Environment (Operating):

Temperature .... 32 - 120 deg F
Humidity .... 95% RH non condensing

Power Requirements:

Wattage .... 875 watts max.
Frequency .... 47 - 63 Hz
Voltage .... 105 - 125 VAC

Fusing .... 1A/250V and 15A/250V normal blow

Front Panel Controls .... Power on/off switch

Front Panel Indicators .... Power On
FFB On
Valid Comm
Self Test

1.5.4 RSD Remote Servo Driver module

Dimensions:

Length ....5.0 in
Width ....3.0 in
Height ....1.0 in

Weight ....1.5 lbs
Electrical Connectors:

Power connector .... (4) Terminal Block
Signal connector (twisted pair) .... (2) Terminal Block
Manipulator connection .... 25 contact Male D-Subminiature Mil-C-24308
Mating connector .... 25 contact Female D-Subminiature Mil-C-24308

Environmental:

Temperature .... 0-70 deg. C (extended temperature range available)
Humidity .... 95% RH non condensing

Communication Signal:

Type .... Synchronous, Bi-phase Mark, Half Duplex, 2 wire differential balanced line

Data rate .... 125K baud

Cable requirements .... 1 pair, twisted shielded (per EIA RS-485)

Power Requirements:

+12Vdc + or - 5%	350mA max
-12Vdc + or - 5%	350mA max
+5Vdc + or - 5%	400mA max
+24Vdc + or - 5% (solenoid valve power)	1 Amp max

Communication Options:

Fiber Optic
Coax Cable
RF Modem

2 Installation

2.1 GENERAL INFORMATION

The *Raptor* manipulator system is shipped as three major components: the manipulator, the master controller and the control electronics. The entire system configuration, including all ordered options, is recorded as part of the final test and inspection report included in the maintenance section of this manual. A packing list accompanies the equipment and it should be checked for accuracy during the unpacking process.

2.2 SHIPPING WEIGHTS AND MEASURES

Component	Shipping Weight	Dimensions
Manipulator	245 lbs (112 Kg)	53x26x16 in (135x66x40 cm)
Operator Control Unit	28 lbs (11.4 Kg)	23x16x13 in (58x40x33 cm)
Electronics	75 lbs (34 Kg)	29x25x13 in (74x64x33 cm)

2.3 REPORTING SHIPPING DAMAGES AND SHORTAGES

If there are any signs of damage to the containers, do not sign the Bill of Lading until damage has been assessed and noted on the bill. The claims department of the carrier should be notified immediately so they can send a representative to verify and assess any damage. Damage claim forms should be submitted promptly. Photographs should be taken and retained or submitted with the claim. Check the total number of containers or cartons against the packing list. If all the items are not accounted for or there is some doubt about the equipment, contact Kraft TeleRobotics immediately.

2.4 UNPACKING AND HANDLING

2.4.1 Manipulator

The manipulator (slave) is shipped in a reusable, air transportable container meeting ATA specification 300. A floating pallet with air damped cushioning devices supports the manipulator within the container and provides shock protection in transit. The container, pallet, and other packing material should be retained for reshipment of the equipment.

The manipulator should be transported to the installation site in the shipping container. To remove the manipulator:

1. Set container upright as shown in Figure 2-1 before opening.

2. Remove safety wire from container latches to open door. Pull manipulator out of case using the hand hole in the pallet and remove the foam cap.

3. The manipulator can be rigged for lifting by use of the hollow elbow pivot pin as shown in Figure 2-2.

To re-pack the manipulator for shipment:

1. Place the manipulator in the fully upright, stowed position (shoulder elevation cylinder rod extended, elbow cylinder rod retracted).

2. Rotate the manipulator at the shoulder azimuth joint 45 degrees clockwise or counter clockwise from the normally front facing position. This allows access to the four mounting bolts in the base of the manipulator. Cap all hydraulic lines.

Note: The manipulator should be positioned as described above while the arm is still operational and can be moved using the master controller.

3. Secure the base of the manipulator to the shipping pallet using four 1/2" bolts and nuts.

4. Place foam padding between the upper arm and forearm sections, place the protective plastic bag over the entire arm, and then fit the custom foam cap over the top of the arm where the elbow bends.

5. Slide the manipulator into the shipping container with the pallet hand hole facing outward and latch the container closed.

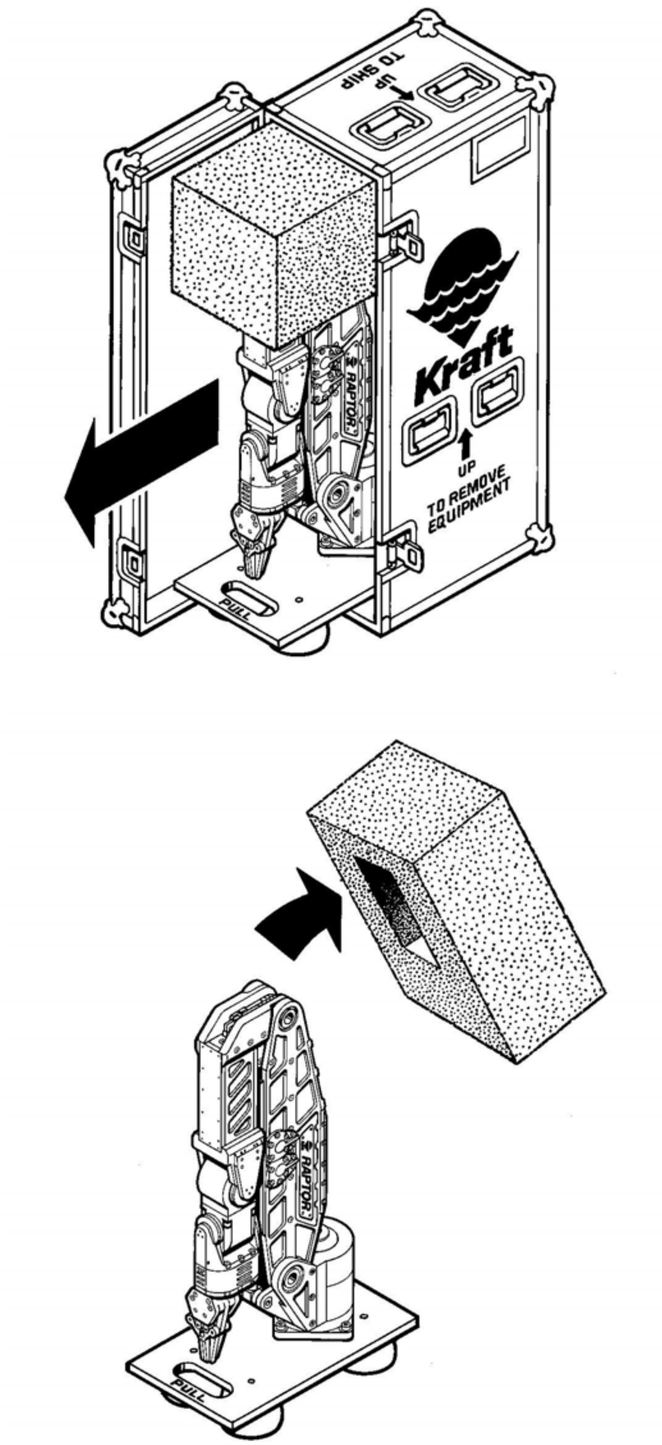


Figure 2-1 Unpacking the *Raptor* Slave Arm

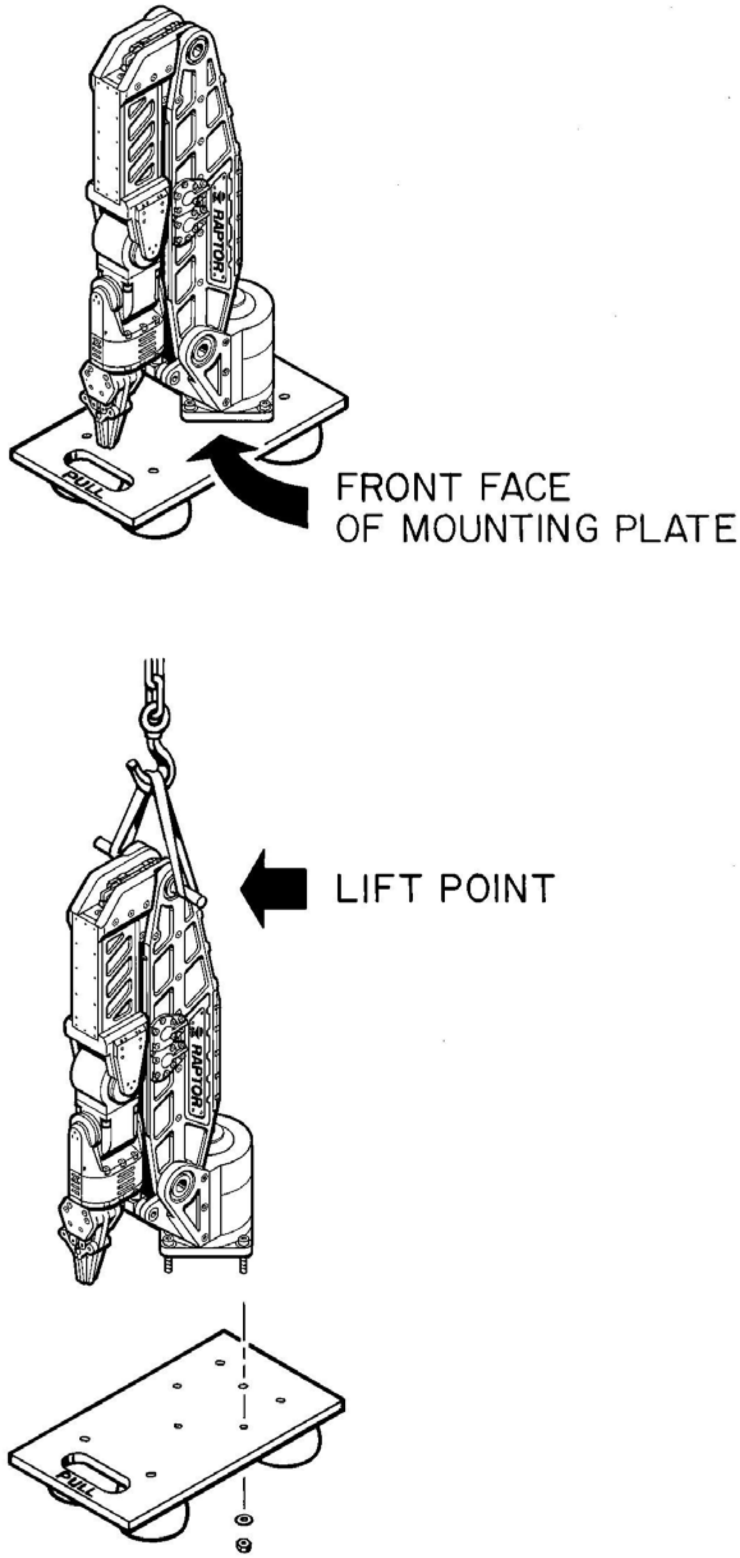


Figure 2-2 Lifting the *Raptor* Slave Arm

2.4.2 Master

The master is an instrument quality piece of hardware that should be handled with care. Support the master with one hand to keep it from rotating when lifting or carrying the operator control unit,.

2.4.3 Electronics

There are no special requirements for the unpacking of the KMC 9100 electronics system beyond the normal care given any electronic equipment. The RSD module shipped with the system will be enclosed in an antistatic bag to prevent damage from static charges during handling. This bag should be retained in the event that shipping of a module becomes necessary. When removing an electronics module from its anti static bag for installation, care should be taken to avoid exposure to high voltage static charges as damage to internal components could result.

2.5 MANIPULATOR INSTALLATION REQUIREMENTS

It is beyond the scope of this manual to present a discussion of work envelope orientation, camera placement, and other considerations which are vehicle/system dependent and influenced by the type of work or task to be performed. The manipulator performance envelope and other installation drawings should be studied to determine manipulator placement. Kraft TeleRobotics will provide assistance by reviewing installation plans and making recommendations to insure optimum performance of the manipulator system. It should be noted that Figure 1-3 shows the maximum or full performance envelope of the manipulator. The performance envelope may be characterized as necessary, using the "single axis" calibration feature of the KMC 9100 system, to impose electronic limits of travel or "stops" for each individual joint to prevent impact with the vehicle frame or other equipment. For additional information refer to the calibration section of this manual.

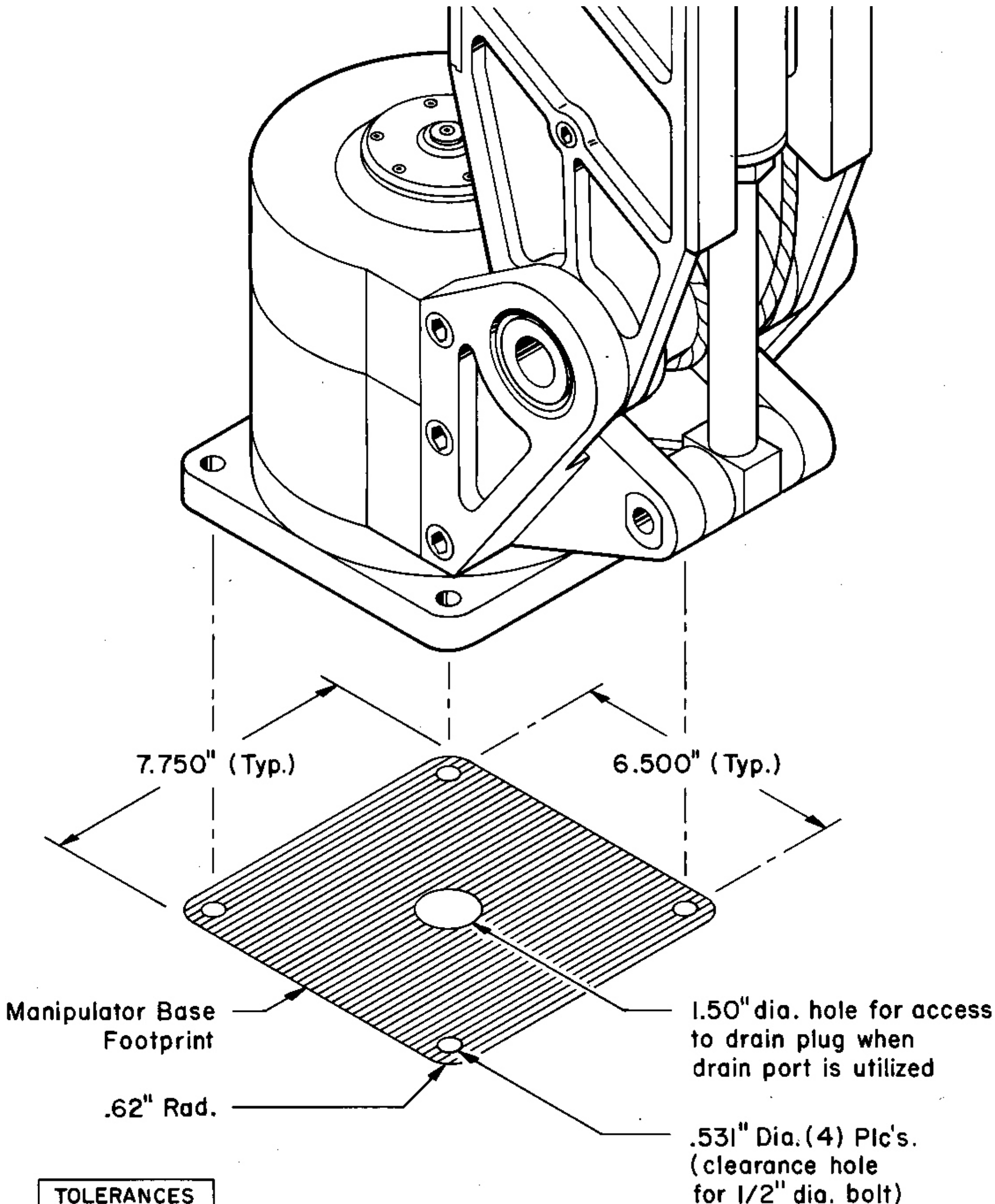
2.5.1 Mechanical

The manipulator is spot mounted to a vehicle or platform using (4) 1/2-13 UNC-2A socket head cap screws, having a minimum tensile strength of 35,000 lbs., and 4 nylon insert-type lock nuts. If conventional type hex nuts are substituted, they should be installed using Loctite 242 or the equivalent. The companion surface should be flat within .001" and have a hole providing access to the plug in the base plate of the manipulator as shown in Figure 2-3. The bottom of the manipulator mounting plate and the companion mounting surface should be wiped clean before setting the manipulator in place. The socket cap screws should be inserted through the manipulator side of the mounting plate first so that the nuts are tightened from the back side of the receiving mounting surface. To prevent damage to the manipulator's protective coating, the head of the socket cap screw should be kept from rotating with a hex key while tightening the nuts. Fasteners should be tightened to a torque value of 500 inch lbs. The socket head cap screws and nuts used to secure the manipulator to the pallet when shipped are suitable to use for installation.

2.5.2 Primary Hydraulic Connections

The *Raptor* manipulator requires a hydraulic power source that will provide hydraulic pressures up to 1500 PSI and flows up to 5 GPM. The manipulator's hydraulic supply and return connections are No.6 SAE 37 degree flared tube fittings and are labeled "P" and "R" on the valve manifold (Figure 2-4). Connecting lines should be 3/8" I.D. flexible hose with an adequate service loop to provide strain relief. The lines should be cleaned and flushed prior to connecting to the manipulator.

A solenoid valve is incorporated into the manipulator manifold high pressure passage to switch hydraulic power to the manipulator on and off. The valve must be controlled by the KMC 9100 system for the manipulator to function properly and safely. A diode is installed at the solenoid to prevent damage to the servo driver module due to inductive kickback. In addition to the solenoid valve a pressure reducing valve is incorporated into the upper arm manifold to maintain a 1500 psi operating pressure for the manipulator when connected to higher system pressures. This valve is rated for 3000 psi maximum inlet pressure with an outlet adjustment range of 100 to 3000 psi. The valve is factory set at 1500 psi. Adjustment of the pressure reducing valve is not required or recommended. This valve also acts as a relief valve providing overload protection for the manipulator. If a hydraulic cylinder or actuator is pushed back mechanically, the valve opens and regulates secondary system flow to tank like a relief valve to maintain the desired 1500 psi operating pressure.



TOLERANCES
.xx = ±.010
.xxx = ±.005

Figure 2-3 *Raptor* Slave Arm Mounting Surface

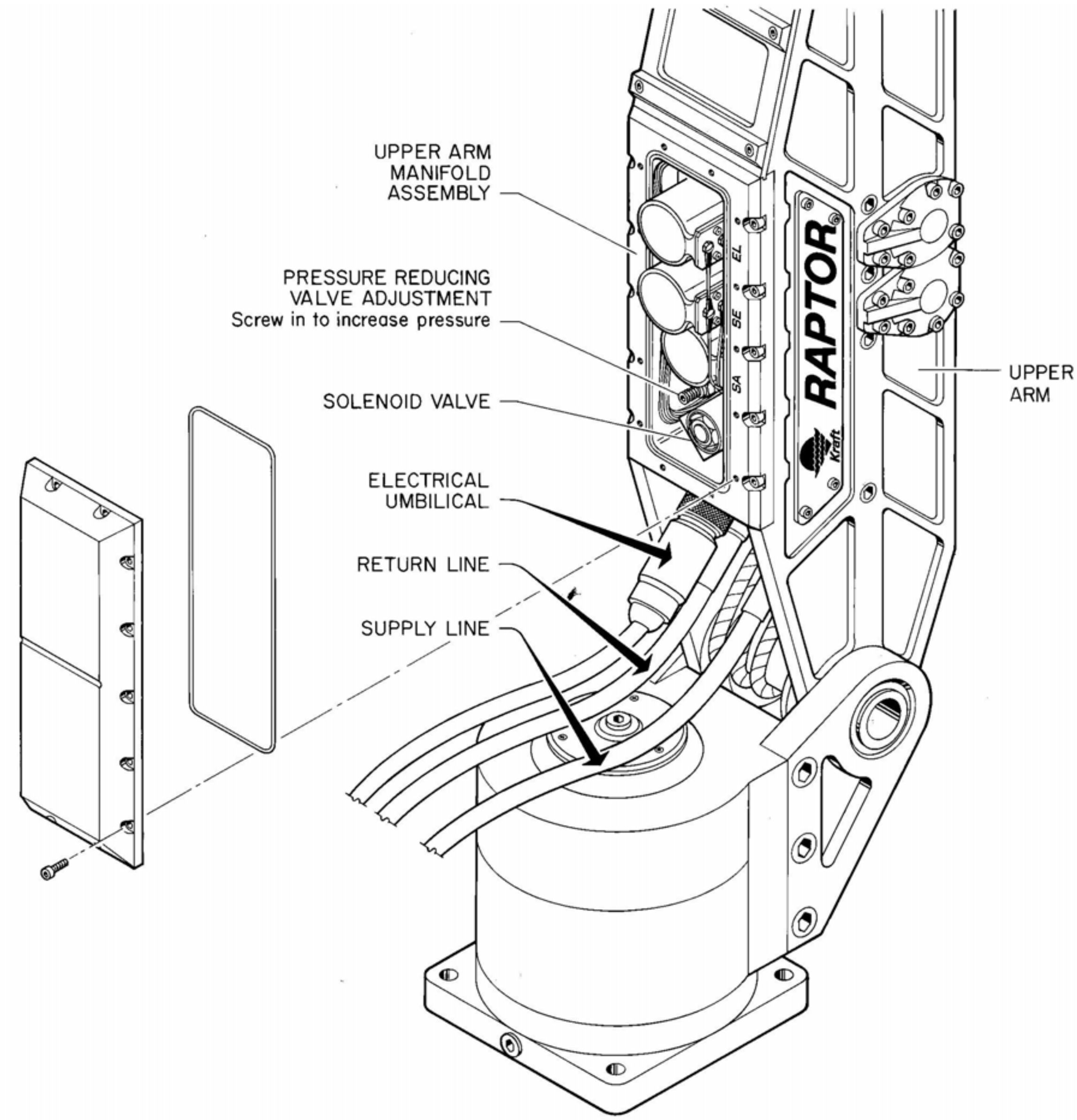


Figure 2-4 *Raptor* Slave Arm Electrical and Hydraulic Connections

2.5.3 Pressure Compensation

For use undersea the *Raptor* manipulator must be capable of withstanding the external pressure of the water at its intended depth of operation. All voids or airspaces within the manipulator must be filled with hydraulic fluid and pressure compensated to prevent collapse of these volumes when the manipulator is submerged. Pressure compensation of the manipulator for deep submergence use is accomplished by connecting this passive hydraulic fluid system to a customer furnished compensator. The compensator device is generally a rolling diaphragm type cylinder. One end of the cylinder is open to seawater while the other end is filled with hydraulic fluid. The diaphragm piston provides a moving interface between the compensating fluid and seawater. Ambient pressure acting on the seawater side of the piston provides pressure compensation to the fluid volumes in the manipulator. Additionally, a spring acting on the seawater side of the diaphragm piston provides a positive compensation pressure over and above ambient sea pressure to prevent seawater from leaking into the manipulator.
It is not necessary to provide pressure compensation in applications where the Raptor slave arm will not be submerged underwater.

2.5.3.1 Compensator Installation

Pressure compensated volumes within the *Raptor* slave arm are shown in Figure 2-5. All compensated volumes within the manipulator are commonly connected by the hoses and drilled passageways used for routing of wires within the arm. The compensation system is isolated from the manipulators working fluid and requires a separate connection to a compensator. Pressure compensation must be provided to keep the entire hydraulic system 5 to 10 PSI above ambient pressure.

There are two ports provided in the base plate of the azimuth actuator. Either port is suitable for connection of the compensator line. If desired, the auxiliary port can then serve as a dedicated fill or drain port.

Connection to the manipulator is made by removing one of the two hollow hex plugs in the base plate (Figure 2-5) and connecting hose or rigid tubing from the compensating system to the No. 4 SAE straight thread O-ring port (7/16-20 UNF-2A thread).

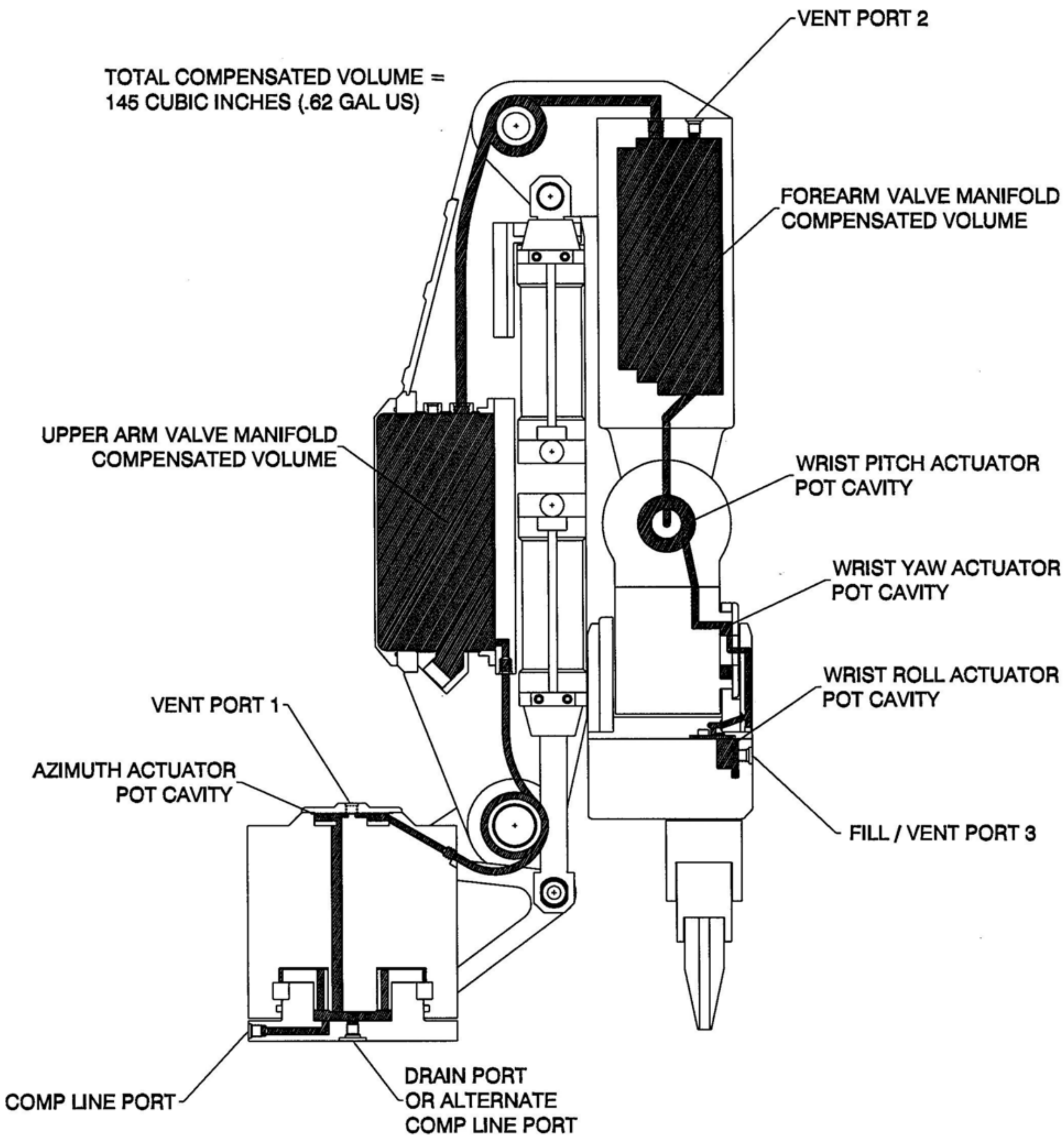


Figure 2-5 *Raptor* Slave Arm Compensation System

2.5.3.2 Filling the Compensation System

Note: The compensating fluid must be of the same type as the manipulators working fluid. The *Raptor* slave arm can be filled in either the stowed position or with the arm in a fully extended vertical position. The system is designed such that the low points contain fill/drain ports and the system high points have ports for the venting of air. All ports in the compensation system are No.4 SAE straight thread O-ring type having a 7/16-20 UNF-2A thread.

Reference Figure 2-5 for port locations.

To fill the manipulator arm in the stowed position:

1. Make certain that all hydraulic connections are tight and that all manipulator cover plates and seals are in place.

2. Remove the hollow hex plugs from vent port 1 on top of the azimuth actuator, vent port 2 at the forearm manifold, and fill/vent port 3 on top of the wrist roll actuator housing.

3. With the arm in the stowed position, first introduce fluid at fill/vent port 3. As the manipulator forearm begins to fill with fluid, air will exhaust at the top of the forearm manifold from vent port 2. Fill to a level just below vent port 2.

4. Fill the remainder of the arm from either of the two comp line ports located at the base of the azimuth actuator. Replace the vent port plugs as fluid appears at the top of the port opening, beginning with vent port 1.

To fill the manipulator arm in the fully extended vertical position:

1. Make certain that all hydraulic connections are tight and that all manipulator cover plates and seals are in place.

2. Position the manipulator upward in a fully extended vertical position.

3. Remove the hollow hex plugs from vent port 1 on top of the azimuth actuator, vent port 2 at the forearm manifold, and fill/vent port 3 on top of the wrist roll actuator housing.

4. With the arm in a vertical position, introduce fluid at either of the two comp line ports located at the base of the azimuth actuator. As the manipulator begins to fill with fluid replace the vent port plugs beginning with vent port 1.

Note: Care should be taken to insure that all air is purged from the compensated volumes within the manipulator arm. Failure to eliminate all air may place excessive demand upon the compensator resulting in insufficient fluid to properly compensate the arm at depth.

2.5.4 Hydraulic Fluid Requirements

All Kraft hydraulic manipulators are tested and operated at the factory using Shell Tellus-32 (SUS/150/100°F) or MIL-H-5606 aircraft hydraulic oil (SUS/70/100°F). Shell Tellus-22 (SUS/105/100°F) or MIL-H-5606 is recommended when the manipulator arm is to be operated in temperatures below 32°F.

Premium antiwear hydraulic oils of similar performance and viscosity may also be used. Viscosity limits of SUS/70/100°F to SUS.170/100°F are recommended.

2.5.5 Filtration Requirements

All hydraulic fluid introduced into the system should be filtered to 25 micron absolute, or finer, particle size. A dedicated high pressure filter located immediately upstream of the manipulator is recommended. Use of filters with a bypass feature is not recommended as unfiltered downstream flow can occur in the bypass mode. Failure to provide proper filtration can cause degradation of performance or component failure.

2.6 OCU INSTALLATION REQUIREMENTS

Systems using the mini-master and portable operator control unit do not require any special mounting provisions other than a stable surface to place the OCU on. The OCU can also be placed in your lap for operation. Clearance requirements for table top operation are shown in Figure 2-6. Cables leaving the operator station should be secured so that they can not be accidentally pulled loose during operation of the system.

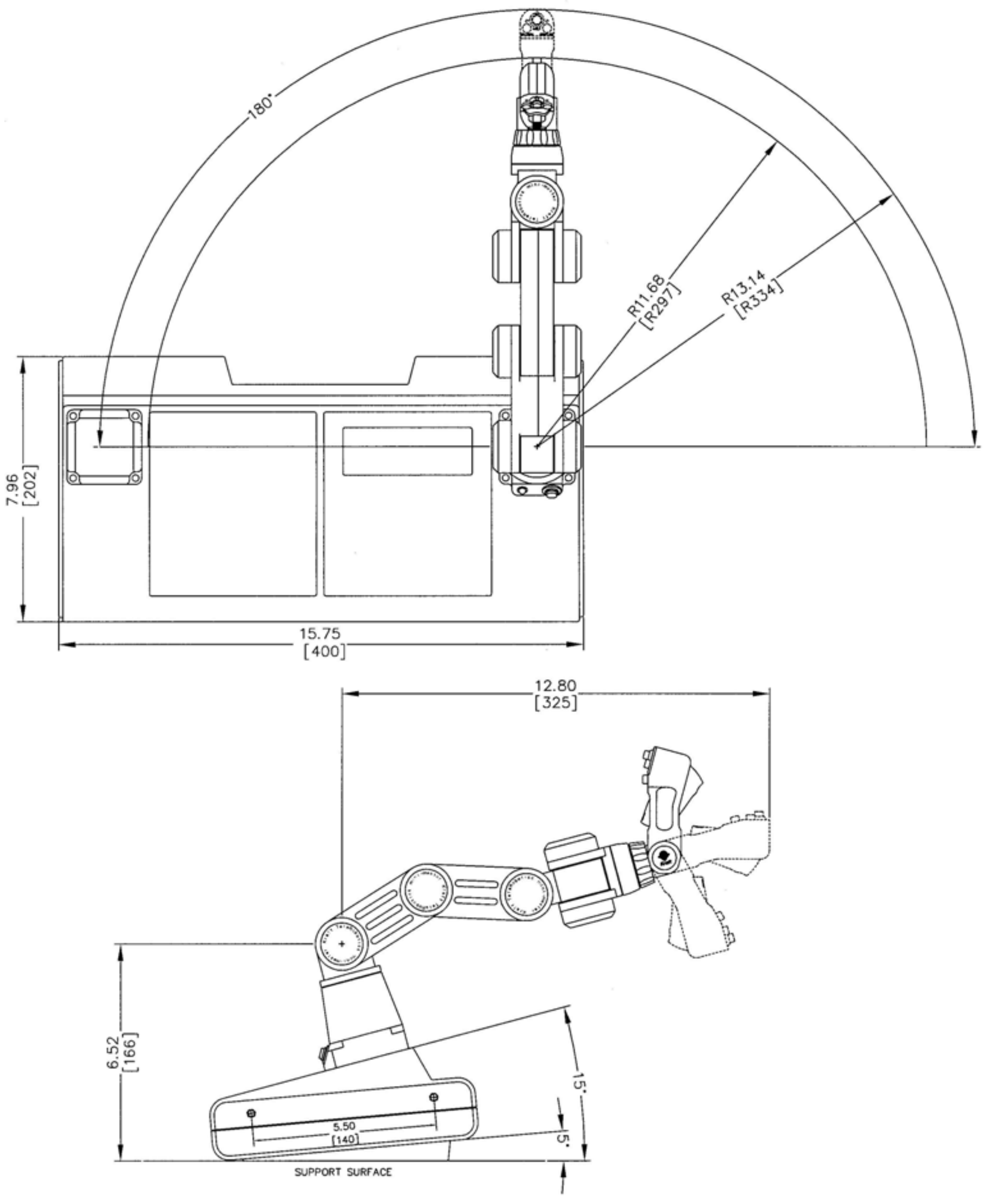


Figure 2-6 Operator Control Unit with mini-master® Controller

2.7 ELECTRONICS INSTALLATION REQUIREMENTS

2.7.1 KMC 9100F Chassis

The KMC 9100F electronics system is packaged in a standard 19" rack mount chassis based on the MIL STD 189 or EIA (Electronic Industries Association) RS-310 standard. The chassis can be mounted in a rack, in a cabinet, or on a bench top. Mounting holes are provided for slide mounting. The KMC 9100F effective front panel height is 5.25" or 3 RETMA increments and is shown in Figure 2-7. The KMC 9100F chassis requires 1" of free space on the sides and 2" of free space at the rear to provide adequate ventilation.

2.7.2 RSD 9100 Remote Servo Driver

Because of its small size the RSD module can be mounted almost anywhere as long as it is protected from the environment. In subsea applications the RSD module must be installed in a 1 atmosphere bottle. The RSD module is secured using (4) 8-32 screws as shown in Figure 2-8. The connector mounting plate is held in place by two of the RSD module mounting screws and provides separate threaded mounting holes for securing the 25 pin Sub-D connector to the module.

The RSD module is connected to a customer furnished power supply as shown in Figure 2-9. Fully regulated switching or linear DC power supplies should be provided. To prevent damage to the RSD module, proper voltage and polarity should be observed when making power connections.

In hard wired systems (twisted pair/coax) with high voltage power conductors in close proximity to the twisted pair or coax, an optional Line Protector (KPN 500-0163-00) can be installed as shown between the twisted pair or coax and the RSD module. This will provide the RSD module with additional protection from the effects of surges or high voltage spikes on the twisted pair or coax.

In addition to powering the RSD module, 24 Vdc must be supplied to one side of the on/off solenoid valve located in the upper arm valve manifold. This 24Vdc is applied to pin 10 of the Brantner connector on the manipulator via the manipulator umbilical as shown in Figure 2-9 (See also wiring diagram, Kraft Dwg. No. 004-3177-00, in the Maintenance Section). The RSD module switches the solenoid valve on and off by grounding the other side of the solenoid coil.

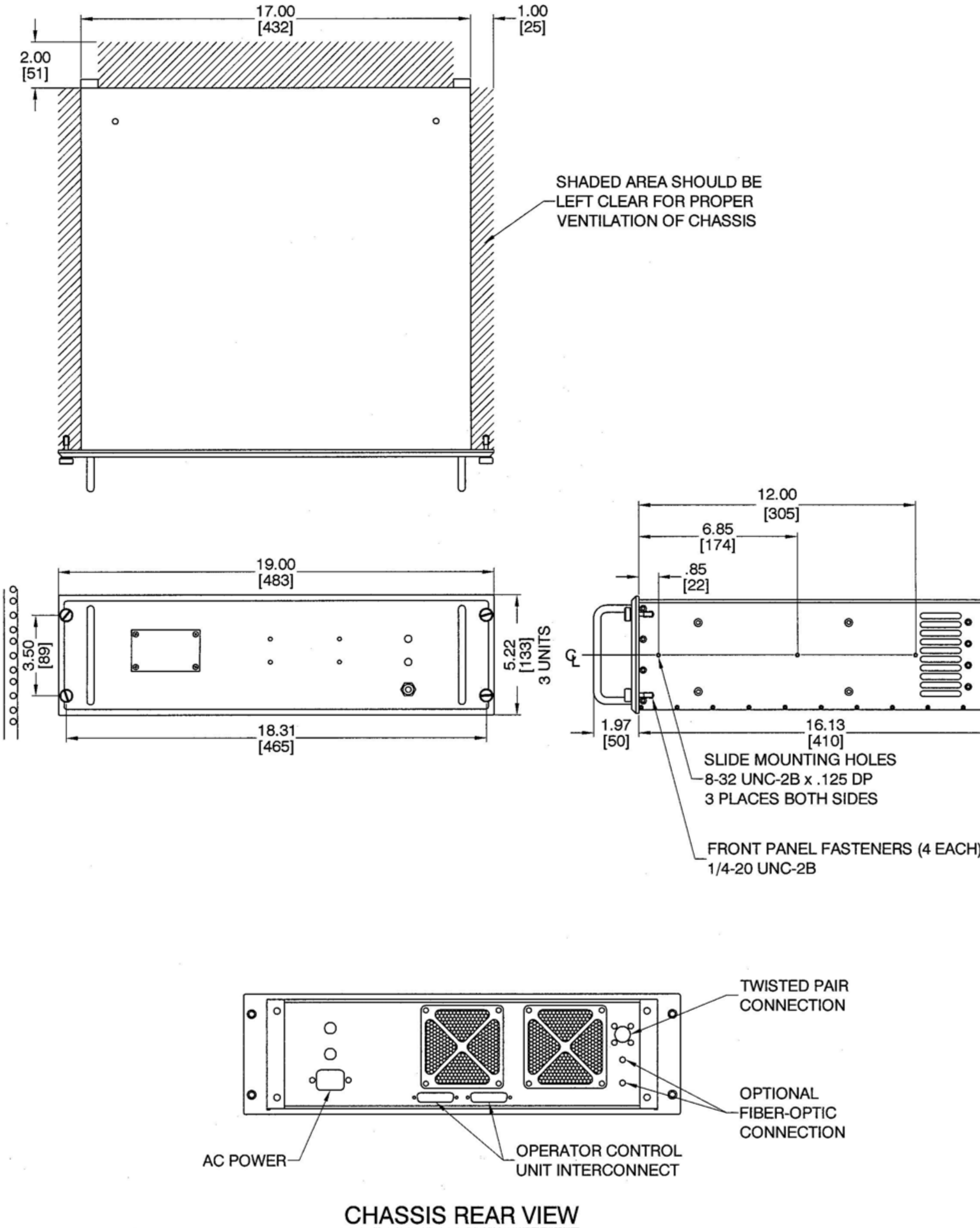


Figure 2-7 KMC 9100F Chassis

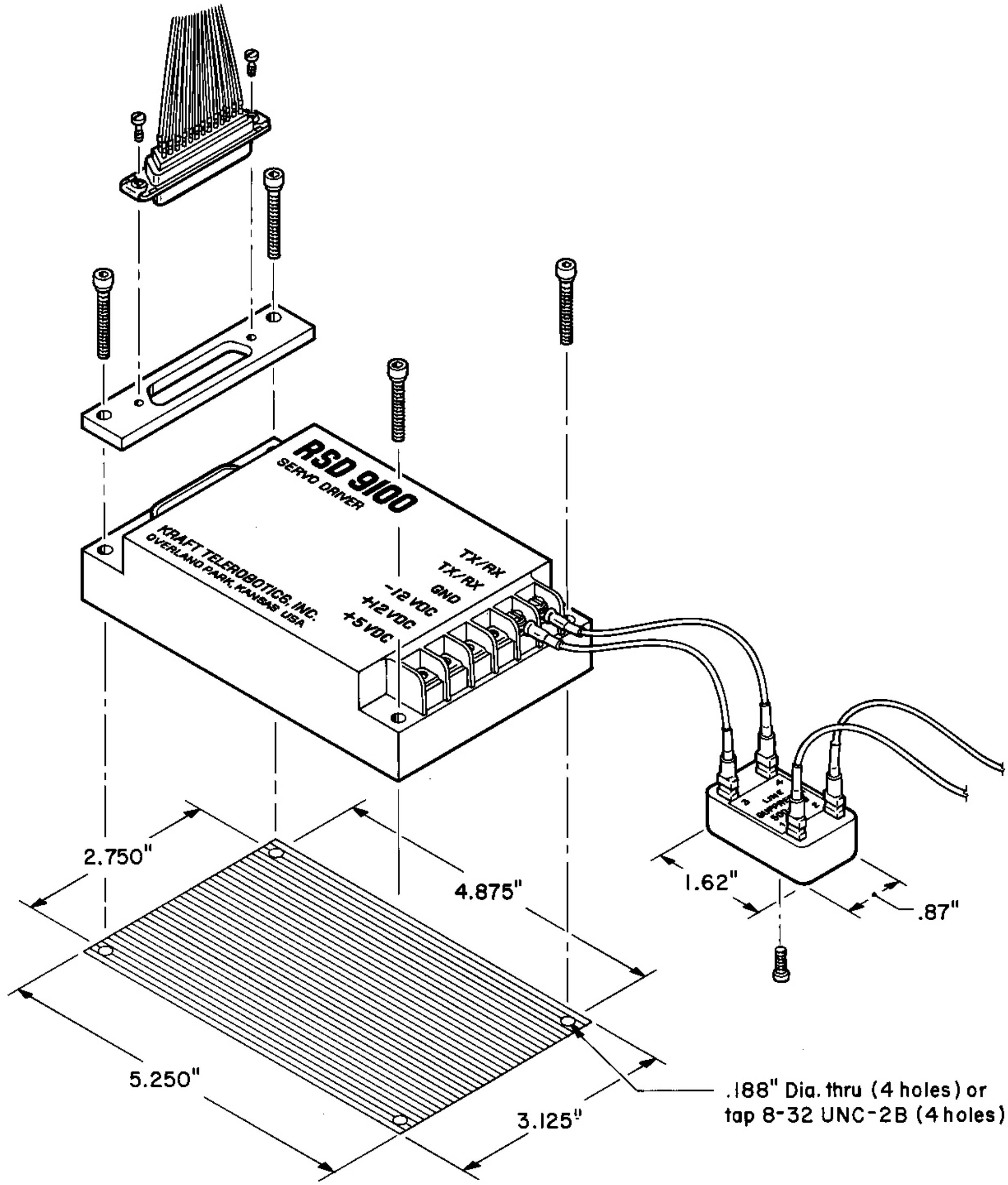


Figure 2-8 RSD Module Mounting

2.8 SETTING UP

The *Raptor* manipulator system is broken down into four major components for ease of set up and system integration. These four major components include, the slave manipulator, operator control unit, KMC 9100 electronics chassis, and remote servo driver (RSD) module. These components are interconnected as illustrated in Figure 2-9.

2.8.1 Customer Furnished Equipment Check List

The following customer furnished items are required to complete installation of the *Raptor* manipulator system:

Slave Arm -

Manipulator Stand, Pedestal, or Vehicle Platform
Hydraulic Power Unit
Hydraulic Hoses (pressure and return line)
Compensator (underwater installations only)
Manipulator Electrical Umbilical
Mounting Hardware (nuts & bolts) and Hydraulic Fittings

Master Arm -

Master Stand or Pedestal (Not required for mini-master console)
Mounting Hardware (nuts & bolts)

KMC 9100 Chassis & RSD Module -

Telemetry Cable (twisted pair, coax, or fiberoptic)
RSD Module Power Supply
24 Vdc power supply (slave arm on/off solenoid)
Mounting Hardware (nuts, bolts and screws)

2.8.2 System Assembly

1. Bolt the manipulator arm to a stand, pedestal, or vehicle platform.

2. Place the operator control unit (OCU) on a stable surface.

3. Connect the (OCU) interface cable to the back of the KMC 9100 electronics chassis using the Y-adapter cable. Connect the opposite end of the OCU interface cable to the appropriate connector on the back of the OCU (Figure 2-10).

4. Connect the hydraulic pressure and return line hoses to the slave manipulator.

   Note: Insure that the pressure line is connected to the fitting marked "P" and the return line to the fitting marked "R".

5. Connect one end of the manipulator arm umbilical cable to the manipulator, then connect the other end to the RSD module (Note: Insure that 24Vdc is applied to pin 10 of the manipulator umbilical for powering the solenoid valve). When using the optional RSD enclosure, connect the cable directly to the proper connector on the enclosure.

6. Connect the coax, twisted pair, or fiber optic telemetry cable between the KMC 9100 electronics chassis and the RSD module.

7. Connect the KMC 9100 electronics chassis to a 120 Vac source.

8. Connect a power source to the RSD module and 24Vdc to pin 10 of the manipulator umbilical. The optional RSD enclosure contains a power supply which provides the 24Vdc for energizing the slave arms solenoid valve. If using the optional RSD enclosure connected the enclosure to a 120 Vac source.

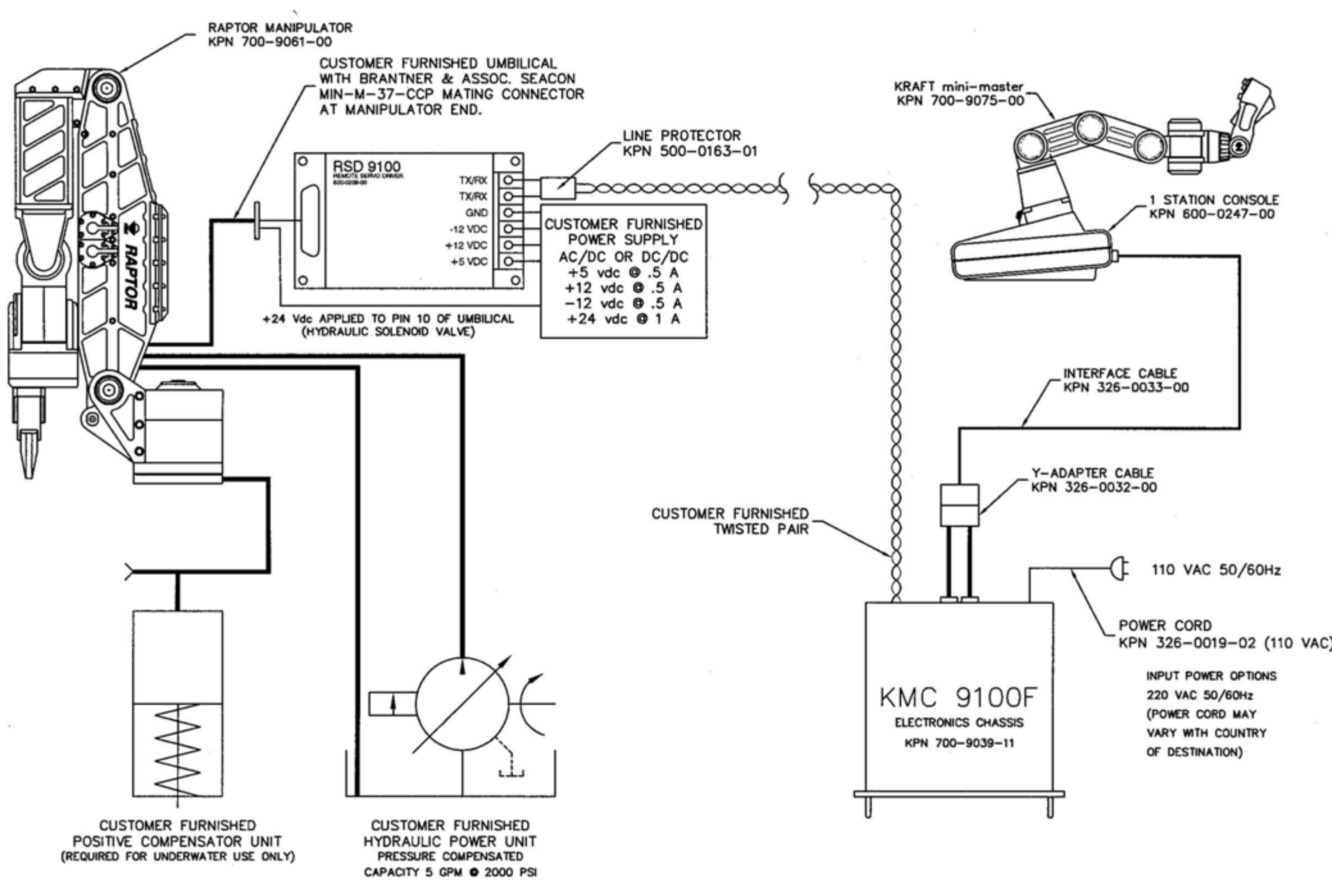
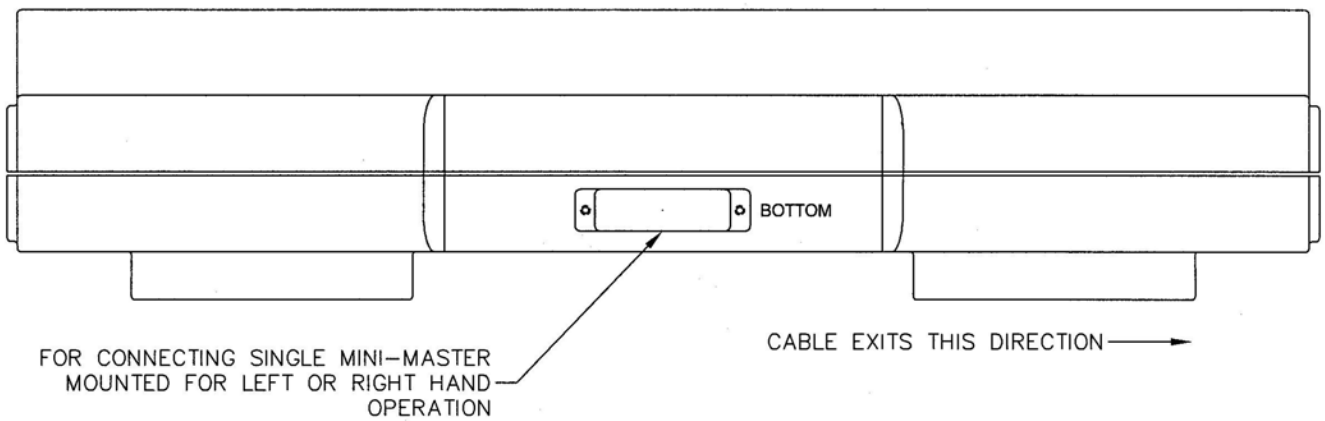
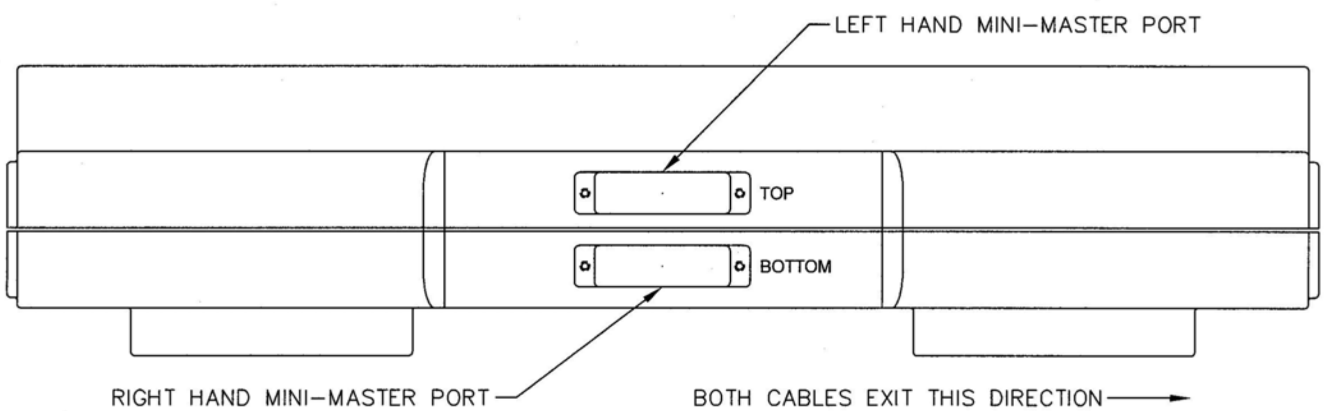


Figure 2-9 *Raptor* Manipulator System - Interconnect Diagram (mini-master)



SINGLE STATION OPERATOR CONTROL UNIT (OCU)



TWO STATION OPERATOR CONTROL UNIT (OCU)

REAR VIEW OPERATOR CONTROL UNIT (OCU)

Figure 2-10

3 Operation

3.1 INTRODUCTION

Operation of the *Raptor* manipulator system is easy to learn. Manipulator arm motion is controlled by simply moving the master controller through the desired range of motion at the desired speed. The manipulator arm will follow the motion of the master control arm in spatial correspondence. The operator views the arm in operation either directly or through a video system. The Kraft mini-master® allows the operator to control complex manipulator motions in a comfortable and intuitive manner.

3.2 OPERATOR CONTROL UNIT

The operator control unit includes the following features and controls (Figure 3-1).

- o Mini-master® control arm
- o Sealed membrane keypad
- o Operator display

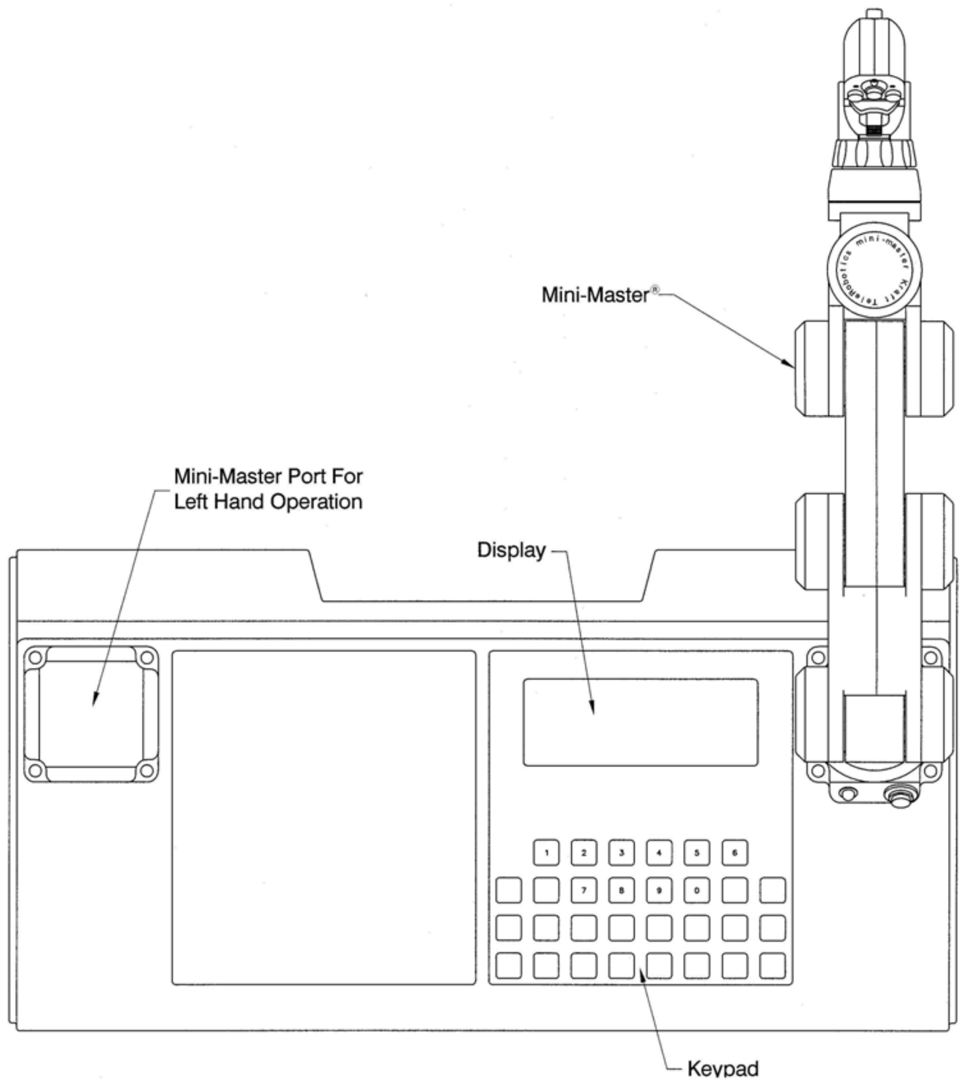


Figure 3-1 Operator Control Unit

3.2.1 Mini-Master® Control Arm

The master control arm (Figure 3-2) is all that is needed for basic control of the manipulator slave arm. When a joint is moved at the master control arm the corresponding joint at the slave arm will move. The manipulator jaw is activated by depressing the trigger switch on the master control arm's hand grip.

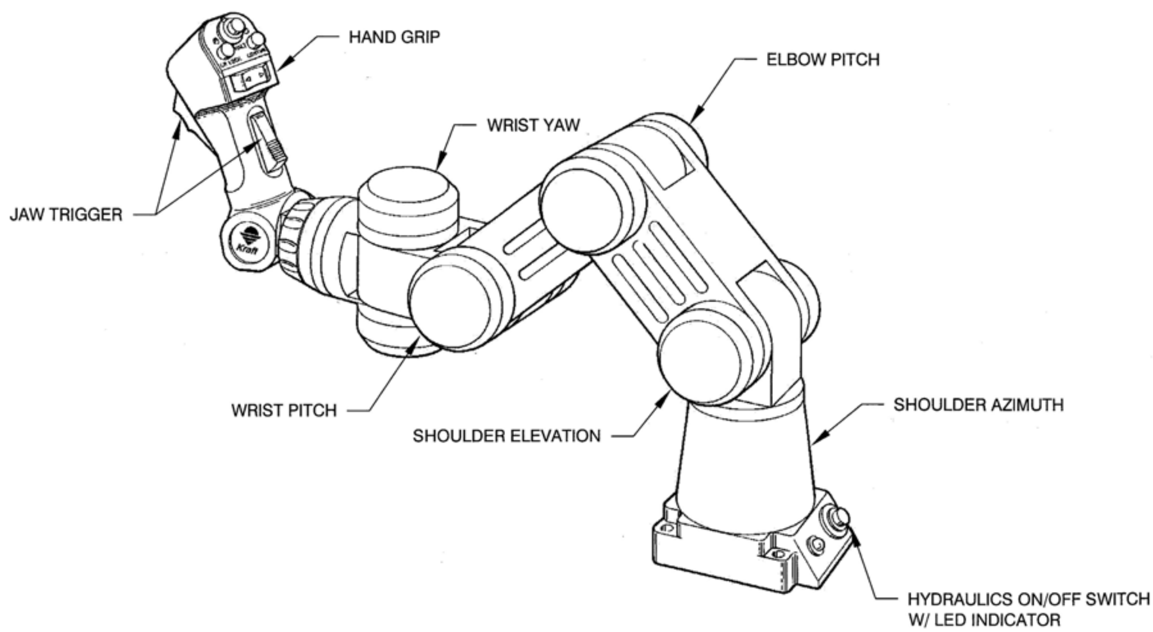


Figure 3-2 Force Feedback Mini-Master®

In addition to providing basic control of the manipulator arm, the master controller has switches located on the hand grip (Figure 3-3) to provide the operator with direct access to the following functions:

Index and Power Alignment

Pressing the Index button commands the manipulator to "freeze" in position. The operator can then move the master to a more comfortable position and re-engage with the manipulator arm by simply pressing the index button again. If you press and hold the index button momentarily, the master will automatically move into alignment with the manipulator under it’s own power.

Wrist Mode

The wrist mode select button will alternately select between the "continuous wrist" and "slaved wrist" operating modes. The continuous wrist LED indicator will illuminate when in the continuous wrist mode.

Continuous Wrist

When the continuous wrist operating mode has been selected the rocker switch is used to control wrist rotation of the manipulator. Depressing the rocker switch will cause a variable speed of continuous wrist rotation in either direction, depending on which side of the rocker switch has been depressed. During this operating mode the slaved wrist function is not available and thus motion introduced at the master in wrist roll will have no effect.

Slaved Wrist

When the slaved wrist operating mode has been selected, the wrist is controlled by wrist roll action at the master. The manipulator will follow the natural motion of the operator's wrist. The orientation of the master wrist to the manipulator wrist may also be indexed.

Grip Lock

Depressing the grip lock button will cause the amount of force currently being exerted at the trigger switch to be "locked in" so that the trigger switch may be released while still retaining the selected closure force. The next depression of this button will relinquish control of the gripper to the trigger switch again. The grip lock LED indicator will illuminate when in the locked mode. It should be noted that if the grip lock mode is entered when no force is being applied, then the gripper will be locked at a no force level and attempts to close the gripper with the trigger switch will be unsuccessful.

CAUTION ! If the grip lock button is pressed while in the grip lock mode, the jaws will open. Objects or tools held by the jaw may be released or dropped. To prevent this from occurring depress the trigger switch on the master before exiting the locked mode.

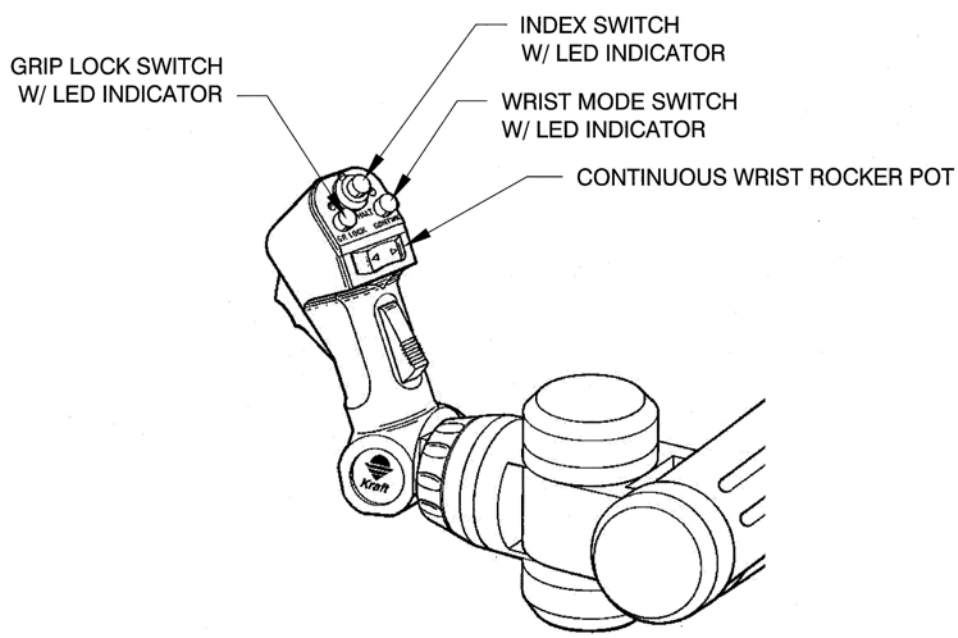


Figure 3-3 Mini-Master® Hand Grip Switches

3.2.2 Keypad

The keypad is used to select various operating options and capabilities not controlled directly by the master control arm. The function of each key is labeled above the key.

3.2.3 Operator Display

The vacuum fluorescent display above the keypad displays system status and other information during operation. The display provides high brightness and a wide viewing angle. Four user-selectable levels of brightness are available. Display intensity can be changed after power up by pressing the [0] key on the keypad and following the displayed instructions.

3.3 START UP

******************** **WARNING** ********************

The manipulator arm is a powerful hydraulic device capable of extremely rapid motion within a large volume of space. The volume of space in which the manipulator operates is referred to as the "performance envelope" and is shown as Figure 1-3 in the General Information section of this manual. The boundaries of the performance envelope are not obvious, and therefore, a safety barrier should be provided to prevent personnel from entering the performance envelope during operation of the manipulator. When the INDEX mode is selected at the master, the manipulator is held in position electronically and personnel should not enter the performance envelope. If it is necessary to enter the performance envelope, turn the hydraulic power unit off and allow any hydraulic pressure in the manipulator supply lines to bleed off before proceeding.

****

The sequence for start up of the manipulator system is as follows:

1. Turn electrical power to the manipulator (RSD) module “ON”.

2. Turn the KMC 9100 power switch to the full up FFB “ON” position.

   The two green power LEDs illuminate.
   The green self test LED comes on for a few seconds then goes out.
   The green valid comm LED will illuminate.
   The “Ready for [HYD]” message will display at the operator control unit.

3. Clear personnel and equipment from the manipulator arm’s performance envelope.

4. Turn the hydraulic power unit “ON”.

5. Enable arm hydraulics by pressing the hydraulics On/Off button at the base of the master arm. When the HYD ON button is pressed the following will occur:

   a) The blue Hydraulics On LED at the base of the master will illuminate

   b) The solenoid isolation valve in the manipulator arm will open and apply hydraulic power to the manipulator.

CAUTION ! If the manipulator arm moves in an erratic or unpredictable manner hydraulics should be disabled immediately!

Note: Slight movement of the slave manipulator arm may occur as any air in the system is initially expelled.

---

   c) A run time clock will display indicating you are in the "Normal Operation" mode.

6. To begin operation simply press the HALT/INDEX button on the master. The manipulator is now engaged and the slave arm will follow the motions of the master controller. To close the jaws, squeeze the trigger of the master grip.

3.4 SHUTDOWN

To shut down the manipulator system:

1. Return the manipulator to its stowed position if desired.

   Note: All arm joints, with the exception of the shoulder elevation joint, will relax when hydraulic power is turned off. The shoulder elevation joint has a check valve to prevent the arm from falling when hydraulic power is removed. The jaw will also relax when hydraulic power is removed. Release any objects or tools from the jaws before shutdown.

2. Disable manipulator hydraulic power by pressing the pushbutton at the base of the master.

3. Turn HPU power “OFF”.

3. Turn electrical power “OFF” at both the KMC 9100 chassis and the RSD module.

3.5 ADDITIONAL OPERATING FEATURES

In addition to basic operation of the manipulator arm, the KMC 9100 provides advanced features and capabilities to enhance both system performance and ease of operation. These additional capabilities are described in the remainder of this section.

3.5.1 NORMAL OPERATION

The term "Normal Operation" refers to a specific operating mode in which manipulator hydraulic power has been enabled and the manipulator arm is ready to be position controlled through the KMC 9100 system. The following commands are valid during normal operation and are selected by using the keypad. Wherever possible, the messages presented to the operator display valid key entries in brackets.

3.5.2 KMC 9100 Command Summary

The following is a list of commands that are functional out of the normal mode of operation as indicated by the run time clock.

Grip Force

Pressing the GRIP FORCE key will prompt the user for a new grip force of 0 - 9 as well as display the current grip force. The number entered will set the range of grip force which may be applied by fully depressing the trigger switch on the master. [0] is the lowest force limit with [9] being the maximum available force. The system will default to the maximum force value of 9 at each power up of the KMC 9100.

Cancel

The CANCEL key functions as a means to "back out" of a command previously selected. For instance, if the TEACH key is depressed and it is decided not to teach a sequence, then the CANCEL key will back out of the teach mode and return the system to normal operation.

Setup

The SETUP key provides a means of altering system setup parameters.

Axis Lock

The axis lock function is used to selectively lock one or more axes of the manipulator so that motion at the master has no effect on the locked axis. Indexing once will unlock any previously locked axes.

Force Feedback Ratio

The FFB RATIO key , when depressed, will prompt the user for a new force ratio of 0 - 9 as well as display the current ratio. The number entered will set the ratio of force reflected at the master compared to forces at the manipulator. [0] is the lowest force ratio with [9] being the maximum available force. The system will default to the maximum force value of 9 at each power up of the KMC 9100.

Display Comm

The DISPLAY COMM key, when depressed, will display communication diagnostics. This includes the current percent of valid communications and the totalized number of communication errors. This may be reset by depressing the [0] key.

Display Pot

The DISPLAY POT key, when depressed, will display the potentiometer diagnostics. This shows the converted 12 bit binary value read by the KMC 9100 system for a selected axis at the master and the manipulator.

Display Xducr

The DISPLAY XDUCR key, when depressed, will display the pressure transducer diagnostics. This shows the converted 8 bit binary value read by the KMC 9100 system for a selected axis.

Directory

The DIRECTORY key provides a means of viewing the task numbers that exist in system memory.

Delete

The DELETE key provides a means of selectively deleting tasks from system memory.

Rate

The RATE key provides a means of altering the rate of playback of any subsequently executed tasks.

3.6 Calibration

Calibration is the process that establishes an angular relationship between the master control potentiometers and the manipulator potentiometers, such that a position established at the master results in the desired position of the manipulator. The KMC 9100 system accomplishes this process in software, relieving the operator from the very tedious process of accomplishing this calibration using potentiometer adjustments. This software calibration, if needed, can be done in minutes, and does not require accessing any circuit boards, or opening of the electronics enclosures. An additional advantage is that the positioning of a potentiometer in either the manipulator or the master is not critical. Thus if a potentiometer should need replacing, a very non-critical positioning of the replacement potentiometer is all that is required.

Calibration is accomplished by obtaining four calibration points; two at the master, and two at the manipulator. The KMC 9100 using these points then establishes a mathematical relationship between the master and the manipulator. The four calibration points additionally become the effective limits of travel for both the master and the manipulator.

3.6.1 All Axes Calibration

When you receive your Raptor manipulator and KMC 9100 system it will have been calibrated at the factory. This calibration provides the manipulator with its full performance envelope with the exception of the shoulder azimuth and shoulder elevation joints. You may wish to modify this calibration in order to tailor the working envelope to a specific installation or application. Commonly, a piece of equipment may be in the working envelope of the manipulator. An "all axes" calibration is not required for this alteration (see single axis calibration). An "all axes" calibration refers to the process by which the manipulator is calibrated when no calibration data exists in the system whatsoever. The first calibration of a new system obviously falls into this category. During the calibration process the KMC 9100 system stores parameters into permanent memory. In this way, calibration data is not lost when the system is powered down. The only way that the "all axes" calibration mode may be entered is by erasing the CAL data stored in the system. Normally this process is not required and thus requires the entry of a special security number. When this number is entered, all previous data contained in the system is irretrievably destroyed, and the system will require an "all axes calibration" before it can be operated. It is possible for calibration data to become altered if a power loss occurs during a time when the KMC 9100 system is accessing this data. In this event, the "memory error" message will be displayed indicating a loss of data. The system will then automatically enter the "all axes" calibration mode. After applying power to an uncalibrated system, it will first prompt the operator with the Ready for [HYD] message. This indicates that depressing the [HYD] button at the base of the master will activate the hydraulics. At this time the master will not control the manipulator and the position of the master is irrelevant. Next the KMC 9100 will display the calibration status display to the operator. The display will appear as shown in Figure 3-4.

Figure 3-4 CAL * * * * *

The display of asterisks represent axes, and are in the order of SA (shoulder azimuth), SE (shoulder elevation), EL (elbow), WP (wrist pitch), and WY (wrist yaw) respectively. The asterisk indicates that the axis has NOT been calibrated. As each axis is calibrated, the asterisk will become a dash indicating a successful calibration of the respective axis. Figure 3-5 shows a system with shoulder azimuth and shoulder elevation calibrated.

Figure 3-5 CAL - - * * *

Generally, the calibration will progress from left to right as indicated by the status display. When prompted with the CAL status display, the operator should select the axis he wishes to calibrate by depressing the appropriate key. If for example, the [SA] key is depressed, the message "SA < [CAL]" will be displayed. This means that shoulder azimuth has been selected and the system is waiting to acquire the first two calibration points. The arrow indicates the left side cal points are to be established. At this time, the operator should position the master on the left side of its travel at a point, at the operators discretion, which will become the effective limit of travel for the master on the left side. Next he should position the manipulator at a point on its left side of travel, which he wishes to correspond with the current position of the master. Since the master presently has no effect on the manipulator, the operators means of controlling the manipulator is through the rocker switch located on the control grip. This rocker switch will allow the operator to very precisely position the axis which has been selected. By depressing either the right or left side of the rocker switch, the operator can drive the manipulator in either direction. Additionally, the speed at which the manipulator moves is dependent upon how far the rocker switch is depressed. When the operator is satisfied with the position of both the master and the manipulator, he should then depress the [CAL] key. The first two calibration points have now been established and the operator will be prompted to do the same procedure for the right side with the display "SA > [CAL]". When the [CAL] key is depressed the second time to obtain the second set of points, the data will be committed to permanent memory. Also, control of the axis calibrated will be relinquished to the master at this time. This procedure is duplicated for all axes until they have all been calibrated. After calibrating the last axis, the system will be in normal operation and the run time clock will display.

The operator should confirm that his calibration is correct by taking all axes through their full excursion, verifying that the manipulator does not reach its mechanical limits of travel. If one is incorrect, it may be corrected using the "single axis" cal mode.

CAUTION ! When calibrating any axis, it is essential that calibration points selected for the manipulator do not allow the hydraulic actuators to reach their mechanical limits of travel. A small amount of travel must be left on each end to provide a fluid cushion for deceleration of load. If this is not done, inertial loads moving at high velocities may damage the actuator.

3.6.2 Single Axis Calibration

During normal operation, as indicated by the run time clock, the [CAL] key is accepted as a valid entry. When this key is depressed, the KMC 9100 will display the cal status as shown in Figure 3-6.

Figure 3-6 CAL - - - - -

This indicates that all axes have been calibrated. Any axis maybe selected for re-calibrating, at this time, by depressing the appropriate key as described in "all axes cal". At the moment a particular axes is selected, control of that axis will be transferred from the master to the rocker switch. Calibration at this point is identical to the procedure described in "all axes calibration". After completing calibration of the selected axis, the system will return to normal operation. The calibration may be aborted at any time prior to the second depression of the [CAL] key by depressing the [CANCEL] key. The master/slave correspondence routine will be invoked for alignment of the master and manipulator. If a calibration is aborted, all calibration data existing prior to the cal attempt will be retained. A summary of the command entries for a single axis calibration is given in Figure 3-7.

Figure 3-7 Command Summary of Single Axis Calibration

Action	Display
Normal Operation	0010:31:14
[CAL] Key Depressed	Cal - - - - -
[SA] Key Depressed	SA < [CAL]
[CAL] Key Depressed	SA > [CAL]
[CAL] Key Depressed	0010:32:16

Note: This table omits the necessary positioning of the master and slave as previously described.

3.6.3 Calibration Out Of Stop Mode

During the stop mode of operation, as indicated by the message "READY FOR [HYD]", the [CAL] key is accepted as a valid key entry. When depressed, the KMC 9100 will display "IS CAL REQUIRED" message for verification of the request. If [YES] is entered followed by activation of hydraulic power to the manipulator the calibration status will be displayed as shown in Figure 3-8.

Figure 3-8 CAL - - - - -

This indicates that all axes have been calibrated. There are two reasons for this entry point into the calibration routine:

1. If a potentiometer is replaced in either the master or the manipulator, there is a chance that the master/slave correspondence routine will not allow the operator to get "on line" with the system. This is because replacing a pot negates the calibration for that axis. By using the "cal out of stop" feature, the operator can avoid the need for an "all axes cal". At this point, the operator selects the axis in which the potentiometer was changed, goes through a calibration for the selected axis, and is then "on line" with the system. This procedure should always be followed when changing out a potentiometer.

2. The manipulator, for whatever reason, may be outside of the operating envelope which has been defined by a previous calibration. In this case, when the KMC 9100 system is turned on, the master/slave alignment routine will not allow the operator to get "on line" with the system because it is in "illegal" territory. Cal out of stop may be used to maneuver a selected axes of the manipulator into the calibrated performance envelope using the rocker switch. Then the operator can "CANCEL" out of cal to retain the previous calibration. This is a circumstance that should seldom exist, yet one that could be very difficult to manage without this ability if it should happen.

The following table gives a command summary of the "cal out of stop" mode.

Figure 3-9 Command Summary for Calibration Out of Stop Mode

Action	Display
Stop Mode	READY FOR [HYD]
[CAL] Key Depressed	IS CAL REQUIRED [YES] OR [CANCEL]
[YES] key depressed	READY FOR [HYD]
[HYD] Depressed	CAL - - - - -
[SA] Key Depressed	SA < [CAL]
[CAL] Key Depressed	SA > [CAL]
[CAL] Key Depressed	- -
Alignment of master	0000:01:24

Note: The preceding table does not show the necessary positioning of the master and manipulator for calibration as described in the preceding section.

3.6.4 Slaved Wrist Calibration

Calibration of slaved wrist is performed in software to establish a positional relationship between the wrist at the master controls and the wrist at the manipulator. This capability is provided as a set up feature but may be used to change the orientation during actual use of the manipulator. It may, at times, be more advantageous to have the manipulator wrist oriented horizontally with the master wrist oriented vertically. At other times, it may be better to have both oriented vertically. The orientation established will remain in the system after power down and is only changed by an actual wrist cal or system initialization.

Sequence for a slaved wrist cal is as follows:

The manipulator wrist should be placed in the position you wish it to be in when the master wrist is vertical. This positioning is accomplished by using the master wrist. The [WR] key should then be depressed. This will lock the manipulator wrist in its present position and display the message "WRIST CAL". The master wrist should now be positioned vertically and the [WR] key depressed again. This will complete the wrist calibration.

One precaution exists in this procedure. The feedback potentiometer in the manipulator wrist has approximately 330 degrees of usable electrical travel. The wrist function, in any orientation, travels 180 degrees. When performing this calibration, the 180 degrees of wrist travel must be located somewhere within the 330 degrees of electrical travel available. If the 180 degrees falls into the dead area of the potentiometer, the wrist will not function properly. Refer to the alignment specification in the maintenance section of this manual for information regarding the open pot end location.

3.6.5 Continuous Wrist Calibration

The rocker switch located on the back of the master control handle is used to control the continuous wrist mode of operation. This control activates a spring centered potentiometer located within the pistol grip that is not accessible for adjustment. In the centered position the potentiometer typically outputs + or -200 mv from zero. This will cause improper operation of the continuous wrist function, as well as improper operation of the rocker switch function during calibration. A software routine is used to correct the span and zero of the potentiometer so that a critical center positioning can be tolerated. This routine is evoked ONLY during the system initialization. If it is suspected that the rocker switch requires calibration this procedure should be followed.

3.7 System Initialization

The KMC 9100 system can be initialized by entering the security number 5423 out of STOP mode. This will cause all calibration data to be lost and system default parameters to be loaded into the system. The user will be prompted to define the system as force feedback or non force feedback as this effects system operation.

3.8 Default Parameter Settings

1. K1 Gain Settings

   These values control the position loop gain of each axis. If it is suspected that an adjustment may be needed at one or more of the manipulator axes refer to the maintenance section of this manual.

Item	Default
Shoulder Azimuth Axis	008
Shoulder Elevation Axis	002
Elbow Pitch Axis	002
Wrist Pitch Axis	008
Wrist Yaw Axis	008

2. Automatic shutdown On

   This setting when ON will cause the hydraulic solenoid valve to automatically shut off in the event of a comm error. This will result in the manipulator relaxing to the gravity dictated position. If this setting is OFF the manipulator will hold position in the event of a comm error as long as hydraulic power is applied and the RSD module is functional.

3.8.1 Modifying System Parameters

The system parameters may be either altered or viewed by depressing the [SETUP] key. The system will then prompt the user for the security number (5423) before granting access to system parameters. Each parameter will be sequentially displayed and the operator may pass by depressing the [CANCEL] key or he may enter a change. Figure 3-10 shows the command summary for viewing and changing parameters.

Figure 3-10 Command summary to view setup parameters

Action	Display
System in normal	0001:42:12
[SETUP] key depressed	EDIT PARAMETERS [YES] OR [CANCEL]
[YES] key depressed	ENTER SECURITY# [CANCEL] TO EXIT
enter [5423]	CHANGE K1 GAIN ? [YES] OR [CANCEL]
[YES] key depressed	SELECT AXIS [CANCEL] TO EXIT
[SA] key depressed	ENTER CHANGE ___ SA K1 GAIN IS 010
enter [015]	ENTER CHANGE 015 SA K1 GAIN IS 010
[CANCEL] key depressed	SELECT AXIS [CANCEL] TO EXIT
[CANCEL] key depressed	[YES] TOGGLE STATE AUTO SHUTDOWN__ON
[YES] key depressed	[YES] TOGGLE STATE AUTO SHUTDOWN__OFF

3.9 Stow/Deploy

Stow/Deploy is a system enhancement supplied with all Raptor manipulators using the KMC 9100 control system. It allows the operator to automatically deploy the manipulator from its stowed location, using a previously taught sequence, to an area away from other equipment and in camera view. When the deploy is complete the operator gains control of the manipulator through the master/slave correspondence routine in a "safe" working area where only a very nominal alignment of the master and manipulator is required. When the operator wishes to stow the manipulator, the same taught routine is called to return the manipulator to its stowed location.

When you receive your Raptor manipulator and KMC 9100 control system, it will not have a stow/deploy sequence in memory. The manipulator is, however, completely operational without using the stow/deploy feature. After installation of the manipulator a stow/deploy sequence may be taught.

3.9.1 Teaching a Stow/Deploy Sequence

To teach a stow/deploy sequence, the [TEACH] key is depressed during normal operation. The KMC 9100 will display the "[STOW][TEACH]" message. To teach a stow, the [STOW] key should be depressed at this time. The KMC 9100 will now display the message:

LOCATE AS STOWED
[YES] BEGIN TEACH

This is a request for the operator to position the manipulator, using the master, to the exact location that will be defined as the stowed position. When satisfied with the position the [YES] key should be depressed. The KMC 9100 is now in the learn mode and all motions are being recorded for future playback. The system will display the "teach meter" as at the hand terminal as shown below. This indicates the remaining amount of teach time.

TCH -----*******
[CANCEL] END TEACH

The asterisks tick off to dashes indicating the use of available teach time. When the last asterisk is gone the system will display the message:

NOW VERIFY STOW
[YES] TO EXECUTE

If the routine is already known to be unacceptable, depress the[CANCEL] key. This will simply return the system to normal operation. If the [YES] key is depressed, the KMC 9100 will stow the manipulator by playing back the taught deploy routine in reverse and will display the "stow meter" as it stows the manipulator as shown below.

STW ----*******
[CANCEL] END TASK

This lets the operator know when the manipulator has completed the stow. The KMC 9100 will now display the message:

SAVE TAUGHT STOW
[YES] OR [CANCEL]

meaning, was the stow acceptable? If the [CANCEL] key is depressed, the system will return to normal operation, retaining any previously taught stow/deploy sequence. If the [YES] key is depressed, the "PROGRAMMING STOW" message will be displayed while the routine is being committed to permanent memory. Figure 3-11 shows the command summary for teaching a stow/deploy sequence.

Figure 3-11 Command summary for a stow/deploy teach sequence

Action	Display
Normal Operation	0004:52:02
[TEACH] Key Depressed	[STOW] OR [TEACH]
[STOW] Key Depressed	LOCATE AS STOWED [YES] BEGIN TEACH
[YES] Key Depressed	TCH -----******* [CANCEL] END TEACH
[CANCEL] key depressed	NOW VERIFY STOW [YES] TO EXECUTE
[YES] Key Depressed	STW --------**** [CANCEL] END TASK

Manipulator Stowing	|	SAVE TAUGHT STOW [YES] OR [CANCEL]
[YES] Key Depressed	|	PROGRAMMING STOW
Wait For One Minute	|	0004:52:02 [DEPLOY] READY

The actual process of teaching a successful stow/deploy will take few practice runs to get a feel for what is needed. The deploy sequence should take the manipulator to a point, usually in front of the vehicle, where it is most removed from all other equipment. This allows the operator to get "on line" with the manipulator with no concern for damage to nearby equipment.

3.9.2 Normal Use of Stow/Deploy

When the KMC 9100 is switched on, the message "[DEPLOY] READY" will be displayed in normal mode if it was previously taught a stow/deploy sequence and if the KMC 9100 evaluates the current position of the manipulator to be within the "stowed window". To go to work with a "stowed manip", the operator should depress the [DEPLOY]. The KMC 9100 will begin the deploy sequence. The deploy meter shown below will be displayed.

DPY -------****
[CANCEL] END TASK

This shows the operator the progress of the auto deploy sequence. After the deploy, the KMC 9100 will relinquish control to the master through the master/slave correspondence routine using a loose alignment. The system is now in normal operation and the operator is ready to go to work. A summary of the key entries necessary to get "on line" with the manipulator is shown in Figure 3-12.

Figure 3-12 Auto deploy from power up

Action	Display
A.C. Power Applied	READY FOR [HYD]
[HYD] Depressed	0000:00:03 [DEPLOY] READY
[DEPLOY] Key Depressed	DPY ----****** [CANCEL] END TASK
Loose alignment	- - -
Normal Operation	0000:00:03 [STOW] READY

When the operator is ready to stow the manipulator, the [STOW] key is depressed. This will initiate the stow sequence and control of the manipulator will be relinquished from the master to the KMC 9100 through the master slave correspondence routine, again, with a loose alignment. The "stow meter" will be displayed showing the progress of the stow sequence. When completed, the message, "[DEPLOY] READY" will be displayed. A command summary is shown in Figure 3-13.

Figure 3-13 Stowing the manipulator

Display	Action
0003:24:16 [STOW] READY	[STOW] Key Depressed
- - -	Loose Alignment
STW -------***** [CANCEL] END TASK	Manip Stowing
0003:24:52 [DEPLOY] READY	[HYD] Depressed
READY FOR [HYD]	A.C. Power off

After depressing the [HYD] switch as shown in Figure 3-13, the A.C. power to the KMC 9100 may be switched off. The [HYD] switch should always be depressed before turning off the A.C. power to the KMC 9100.

3.10 Task Recall

The "Task Recall" capability refers to an optional system enhancement available as a part of the KMC 9100 control system. With this option, the operator has the ability to "teach" the manipulator routines or tasks lasting for a maximum duration of eight minutes. These routines are saved in the systems memory and may be called upon for execution at a later time. The rate at which a Task Recall sequence executes may be varied at anytime during the execution of the sequence. The eight minutes of teach time could actually translate to days of execution time if the slowest "rate" were selected. Additional capabilities include the ability to pause/resume execution of a sequence, and the ability to forward/reverse execution. This allows the operator to reverse the direction of playback. Task Recall is particularly useful for previewing of action the manipulator will take, prior to actually performing the task. This allows the operator to teach a routine until he is satisfied with it, and then with the actual work tool activated, execute the taught sequence. This takes the operator out of the control loop during the execution of any critical maneuvers. Task Recall is also useful in applications where visibility is disrupted by the work tool when activated. In this case, the operator may teach a sequence with the work tool deactivated, and then, execute the sequence with the tool activated. The loss of visibility is tolerable in that the manipulator is pre programmed to execute in a particular way with direct operator viewing being unnecessary.

At all times during the use of Task Recall the "T/R meter" is displayed. This is simply a numeric display which decrements toward zero as the teach time is used. During the execution of a taught task this numeric display, again, decrements toward zero showing the progress of execution. In applications requiring precise positioning of the manipulator, this "T/R meter" has the added use of being directly related to the position of the manipulator. The manipulator may be advanced to a particular number, that is known to correspond to the start position of a task to be performed, and then put in the pause mode. A tool may, for example, be activated at this time and the rate of execution reduced to one tenth that of normal. After execution to another known number, the tool may be deactivated and the rate increased.

3.10.1 Teaching a Task Recall Sequence

The Task Recall mode is entered out of normal operation. When the [TEACH] key is depressed the "[STOW][TEACH]" message is displayed as a request for the operator to select to teach either a T/R sequence or a stow/deploy sequence. Depressing the [TEACH] key will place the system in the T/R mode and will display the teach meter value indicating memory available and the task number assigned by the system. Depressing the [YES] key will begin the teach sequence. The meter value will begin to decrement toward zero indicating the use of teach time. The teach sequence may be terminated at any time by depressing the [CANCEL] key.

The taught task may then be either saved or discarded and control is returned to the operator through the correspondence routine. Figure 3-14 shows the command summary for teaching a task.

Figure 3-14 Command summary for teaching a Task Recall Sequence

Action	Display
Normal Operation	0009:34:31
[TEACH] Key Depressed	[STOW] OR [TEACH]
[TEACH] Key Depressed	> 4080 TASK# 001 [YES] BEGIN TEACH
[YES] Key Depressed	> 4080..4071..4023..etc. [N] TO END TEACH
[N] Key Depressed	SAVE TAUGHT TASK? [YES] OR [CANCEL]

[YES] Key Depressed	WRITING CASSETTE
Normal operation	0009:35:41

3.10.2 Executing a Task Recall Sequence

To execute a previously taught task, the [EXEC] key is depressed out of normal operation. The system will then prompt the operator to enter the task number he wishes to execute. After the three digit entry is complete the KMC 9100 will search system memory and cassette if installed for the task. If it does not exist an error message will be displayed. If the task is located the operator will be prompted by the master/slave correspondence routine for initial alignment. After alignment is achieved task execution will automatically begin. Figure 3-15 shows a command summary for execution of a task.

Figure 3-15 Command summary for execution of a Task Recall Sequence

Action	Display
Normal Operation	0009:50:33
[EXEC] Key Depressed	ENTER TASK# ___ [CANCEL] TO EXIT
Enter Three Digit Task#	ENTER TASK# 012 [CANCEL] TO EXIT
Prompt for Alignment	-
Task Execution Begins	> 4021 TASK# 012 [CANCEL] END TASK
Normal Operation	0009:51:51

3.10.3 The Forward/Reverse Function

The direction of playback may be reversed at any time during the execution of a T/R sequence by depressing the alternate action [FWD/REV] key. The meter will now increment rather than decrement. If during reverse playback a task reaches its start, it will automatically reverse and begin execution in forward.

Figure 3-16 Command summary for forward/reverse

Action	Display
Executing Sequence	> 2093 TASK# 005 [CANCEL] END TASK
[FWD/REV] Key Depressed	< 2094 TASK# 005 [CANCEL] END TASK
Executing In Reverse	< 2098 TASK# 005 [CANCEL] END TASK
[FWD/REV] Key Depressed	> 2097 TASK# 005 [CANCEL] END TASK
Executing In Forward	> 2093 TASK# 005 [CANCEL] END TASK

3.10.4 Changing the rate of execution

The rate at which a Task Recall sequence executes may be varied at any time during the execution of the sequence by depressing the [RATE] key. When depressed, playback is suspended and a message is displayed indicating the current meter value, task number and rate. The operator may now enter a new three digit rate value or depress [CANCEL] to resume task execution. This allows the rate key to be used to temporarily pause and then resume execution of a sequence. This ability should not be confused with the halt function which would not only halt execution of the sequence but Task Recall as well. Figure 3-17 shows a command summary for changing the rate of execution.

Figure 3-17 Command summary for changing rate of playback

Action	Display
Executing Sequence	> 2096 TASK# 012 [CANCEL] END TASK
[RATE] Key Depressed	> 2094 TASK# 012 RATE IS 000 ___

New rate entered (095)	> 2094 TASK# 012 RATE IS 000 095
Executing Sequence	> 2093 TASK# 012 [CANCEL] END TASK
[RATE] Key Depressed	> 2045 TASK# 012 RATE IS 095 ___
[CANCEL] Key Depressed	> 2044 TASK# 012 [CANCEL] END TASK

3.10.5 Teaching Multiple Tasks

The operator can teach up to 255 tasks with the KMC 9100 system provided the eight minutes of teach time is not exceeded. The lowest available task number will automatically be assigned to the task currently being taught. It is the operators responsibility to keep track of the actual function of a particular task. If ten tasks have been taught then the next task taught will automatically be assigned task number eleven. If task number two is then deleted from the system then the next task taught will automatically be assigned task number two. To execute any previously taught task the operator needs only enter the task number assigned to it. If power to the KMC 9100 system is interrupted all tasks will be lost and the next task taught will receive task number one. If the cassette option is in place all task data will be saved during power down.

3.10.6 Task Directory

The task directory function provides the operator with a means of examining the task numbers that exist in the system. By depressing the [DIRECTORY] key the first task number found will be displayed. Subsequent depressions of the [YES] key will step through and

display each task in the system until all tasks have been found or the user depresses the [CANCEL] key to exit. The command summary for the task directory function is shown in Figure 3-18.

Figure 3-18 Command summary for task directory

```
Action                                  Display
----------------------------------------------------------------
Normal Mode                      |      0000:01:43
                                 |
[DIRECTORY] Key Depressed        |      FOUND TASK# 001
                                 |      [YES] TO CONTINUE
                                 |
[YES] Key Depressed              |      FOUND TASK# 002
                                 |      [YES] TO CONTINUE
                                 |
[YES] Key Depressed              |      FOUND TASK# 006
                                 |      [YES] TO CONTINUE
                                 |
[YES] Key Depressed              |      ALL TASKS FOUND
                                 |      [YES] TO CONTINUE
----------------------------------------------------------------
```

3.10.7 Task Deletion

The task delete function provides the operator with the ability to independently delete any previously taught task. As tasks are deleted from the system the available teach time will increase accordingly. To delete a task the operator depresses the [DELETE] key. He is then prompted for the task number to delete. Upon entry of this three digit number the KMC 9100 will delete the task from memory and from the cassette if one is installed. The command summary for deleting a task is shown in Figure 3-19.

Figure 3-19 Command summary to delete a task

```
Action                                  Display
----------------------------------------------------------------
Normal Mode                      |      0000:30:51
                                 |
[DELETE] Key Depressed           |      ENTER TASK# ___
                                 |      [CANCEL]  TO EXIT
                                 |
Task Number Entry (006)          |      ENTER TASK# 006
                                 |      [CANCEL]  TO EXIT
```

Verification	ENTER TASK# 006 SURE ? [YES] [CANCEL]
[YES] Key Depressed	DELETING TASK
Task Deleted	0000:31:12

The cassette option allows the user to permanently retain tasks taught to the system. Through the use of multiple cassettes the user can permanently retain an unlimited number of tasks. The KMC 9100 system allows the user to teach multiple tasks without having the cassette option and with the cassette option it is not required that a cassette be in place. In either of these cases, however, tasks are not retained if power is lost. When the cassette option is installed it is the operators responsibility to insure that a cassette is in place before teaching a task he wishes to permanently retain. The KMC 9100 system monitors the cassette option for status changes, meaning the installing or changing of a cassette during use of the system. If a status change occurs the next access to any task recall function will load the contents of the cassette. Thus if the operator has been using task recall with no cassette and subsequently installs a cassette, all previously taught tasks will be lost as the content of the cassette is loaded into the system.

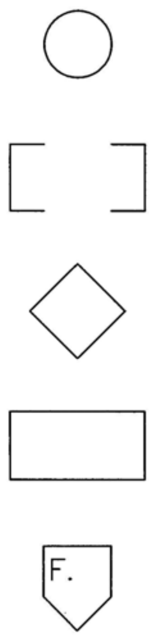
If the operator is using a cassette and then changes cassettes, the new cassette data will be loaded into the system. Thus task number 10 for one cassette will not be the same as task number 10 for another cassette. It is the operators responsibility to catalog cassettes accordingly. The task delete and task directory functions previously described will always pertain to the cassette installed in the system at the time the function is invoked.

3.11 OPERATIONAL FLOW CHART

FLOW CHART REFERENCE TABLE

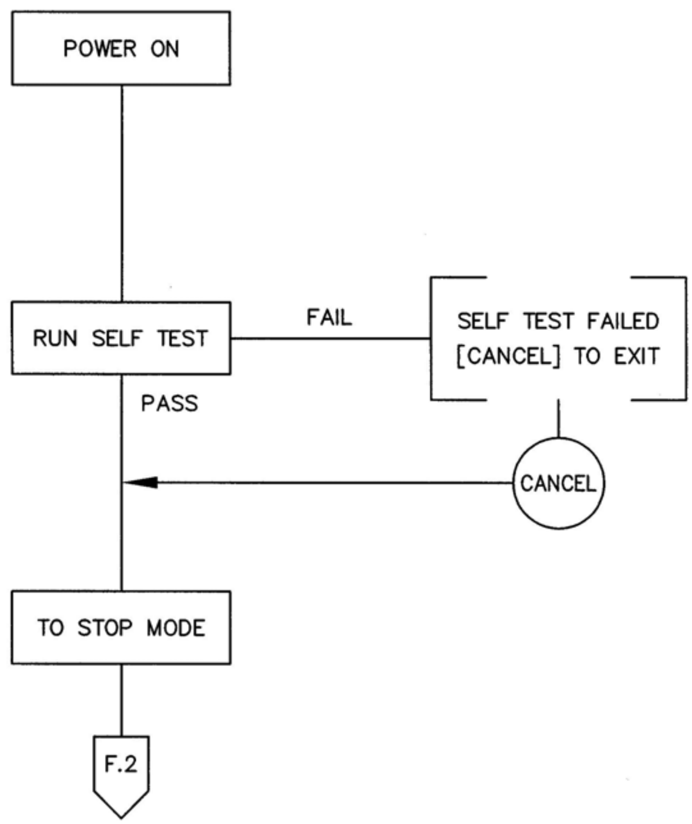
KMC 9100 OPERATION FLOW CHART

LEGEND

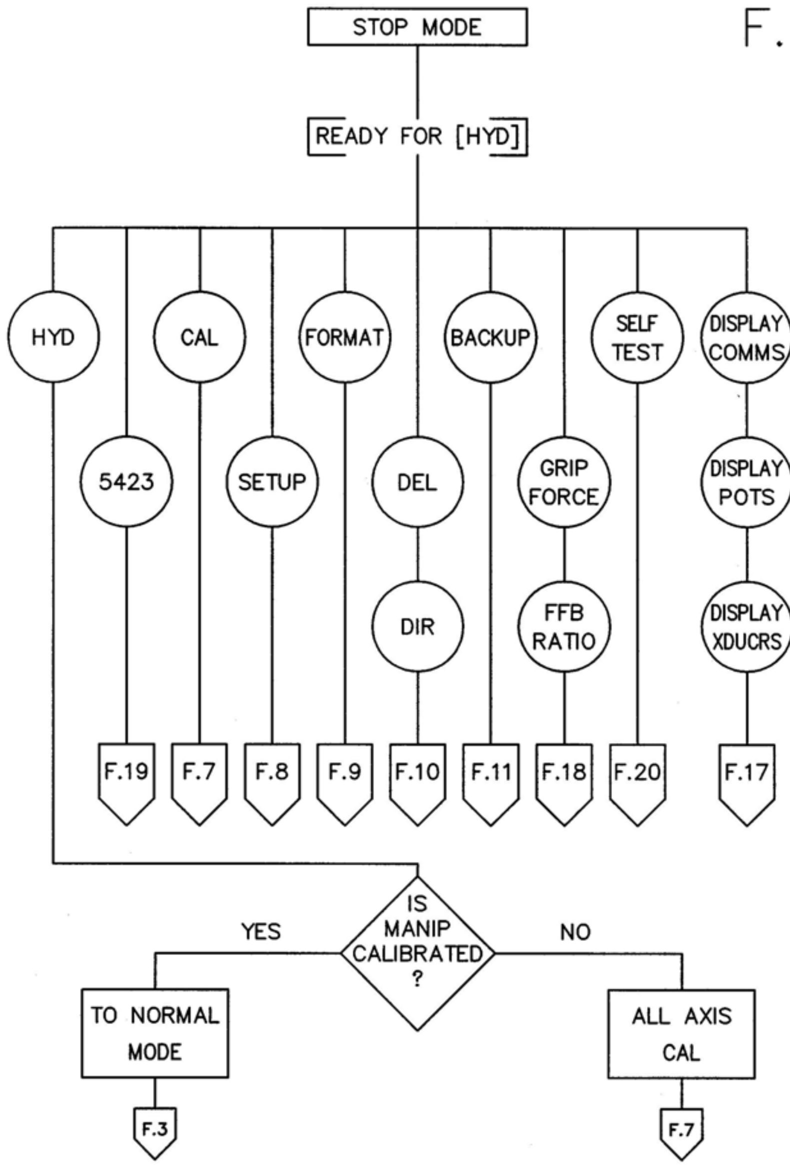


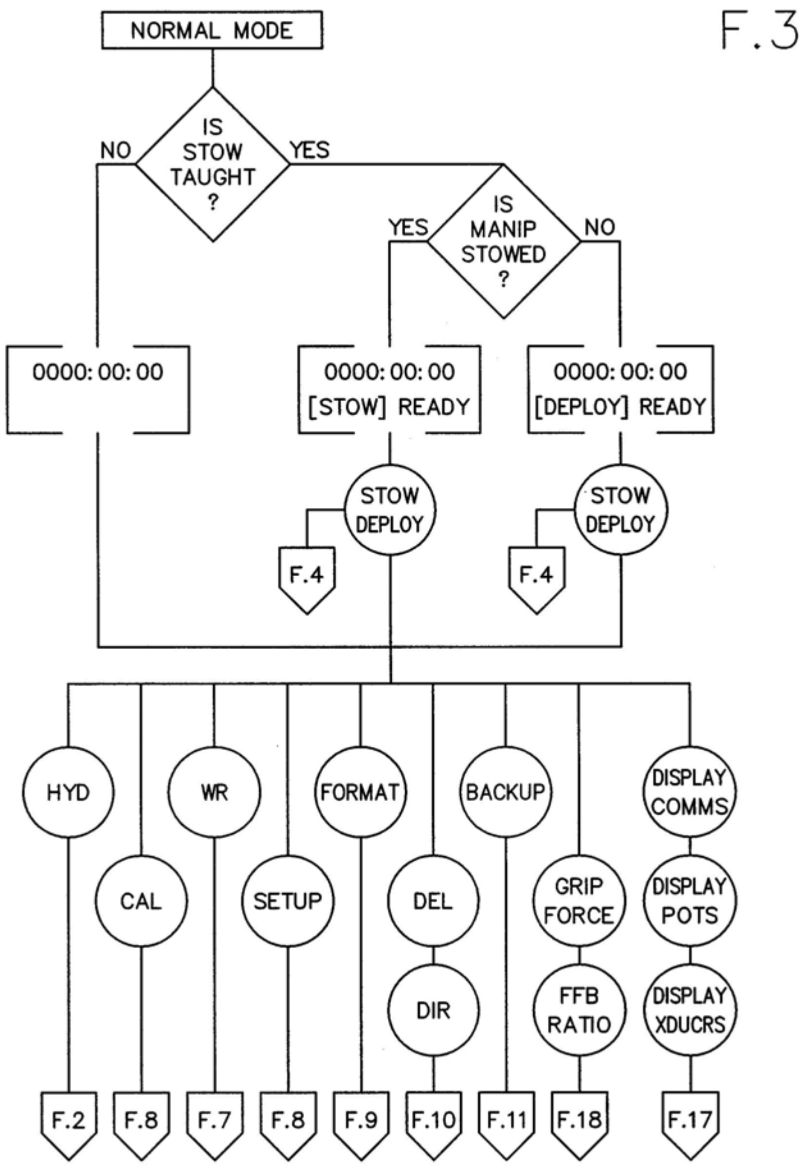
- KEY STROKE
- DISPLAY
- DECISION POINT
- COMPUTER FUNCTION OR DIRECTIONS
- FLOW SHEET REFERENCE

F.1

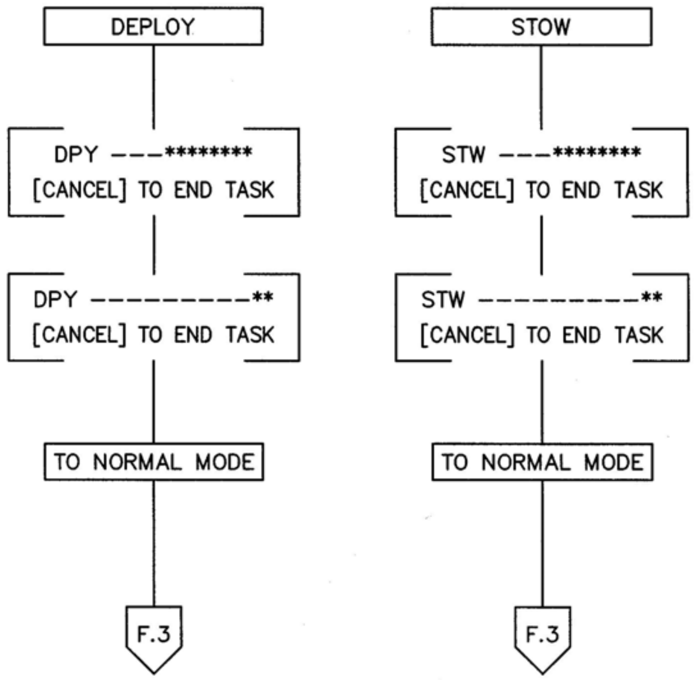

POWER ON
RUN SELF TEST
FAIL
SELF TEST FAILED
[CANCEL] TO EXIT
PASS
CANCEL
TO STOP MODE
F.2

F.2

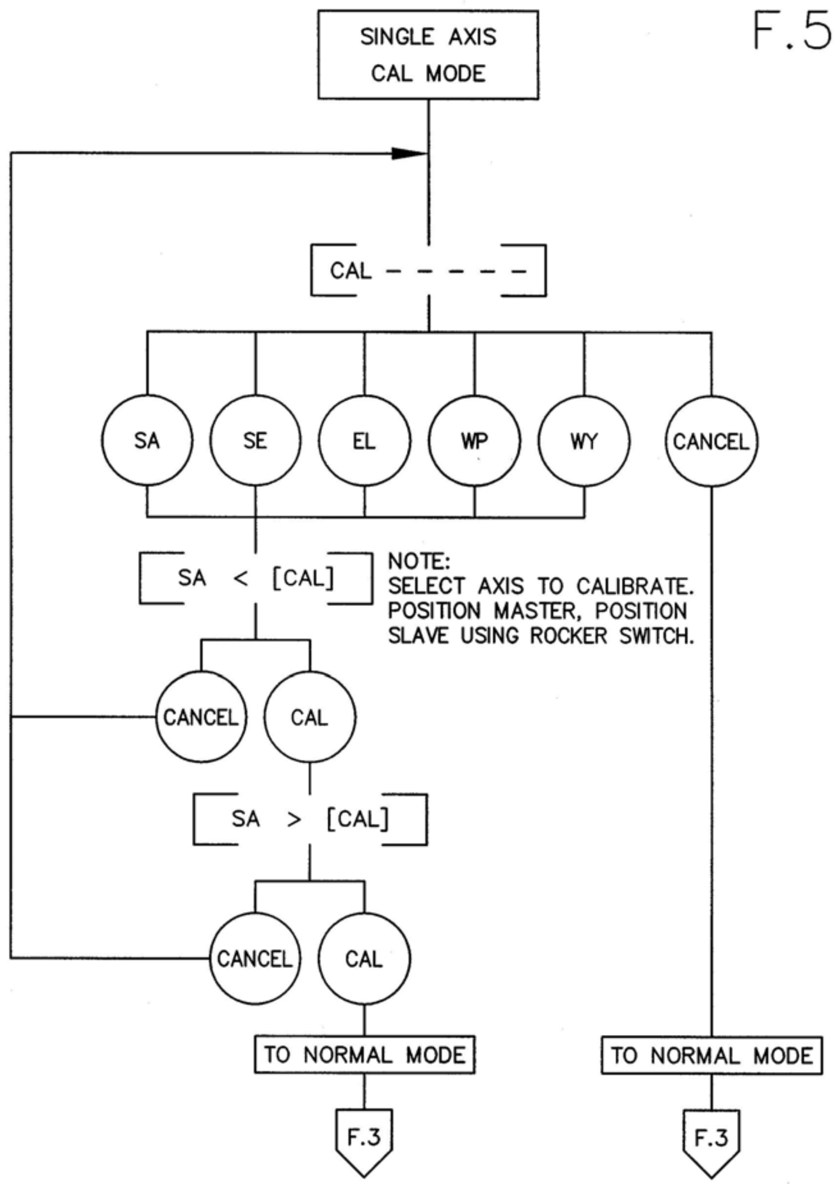

STOP MODE
READY FOR [HYD]
HYD
CAL
FORMAT
BACKUP
SELF TEST
DISPLAY COMMS
5423
SETUP
DEL
GRIP FORCE
DISPLAY POTS
DIR
FFB RATIO
DISPLAY XDUCRS
F.19
F.7
F.8
F.9
F.10
F.11
F.18
F.20
F.17
IS MANIP CALIBRATED ?
YES
NO
TO NORMAL MODE
ALL AXIS CAL
F.3
F.7

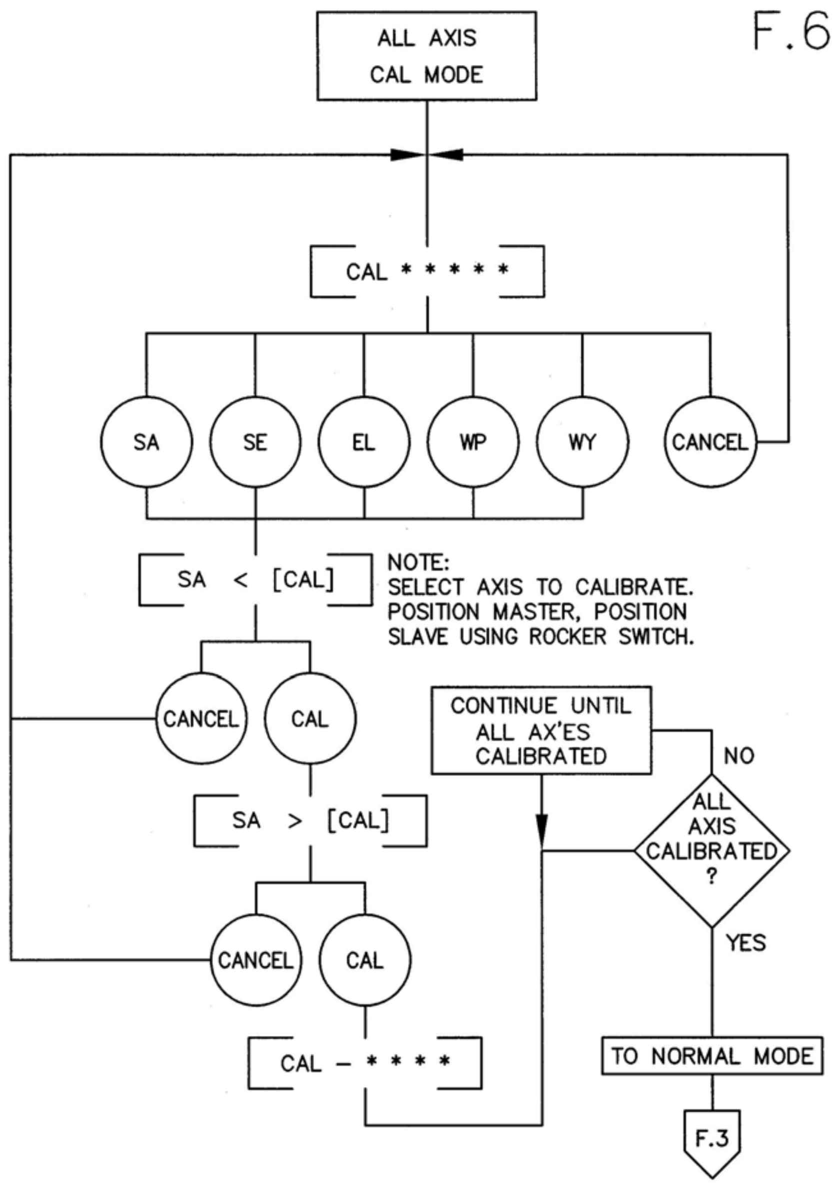

F.3
NORMAL MODE
IS STOW TAUGHT ?
NO
YES
IS MANIP STOWED ?
YES
NO
0000: 00: 00
0000: 00: 00
[STOW] READY
0000: 00: 00
[DEPLOY] READY
STOW DEPLOY
F.4
STOW DEPLOY
F.4
HYD
CAL
WR
SETUP
FORMAT
DEL
DIR
BACKUP
GRIP FORCE
FFB RATIO
DISPLAY COMMS
DISPLAY POTS
DISPLAY XDUCRS
F.2
F.8
F.7
F.8
F.9
F.10
F.11
F.18
F.17

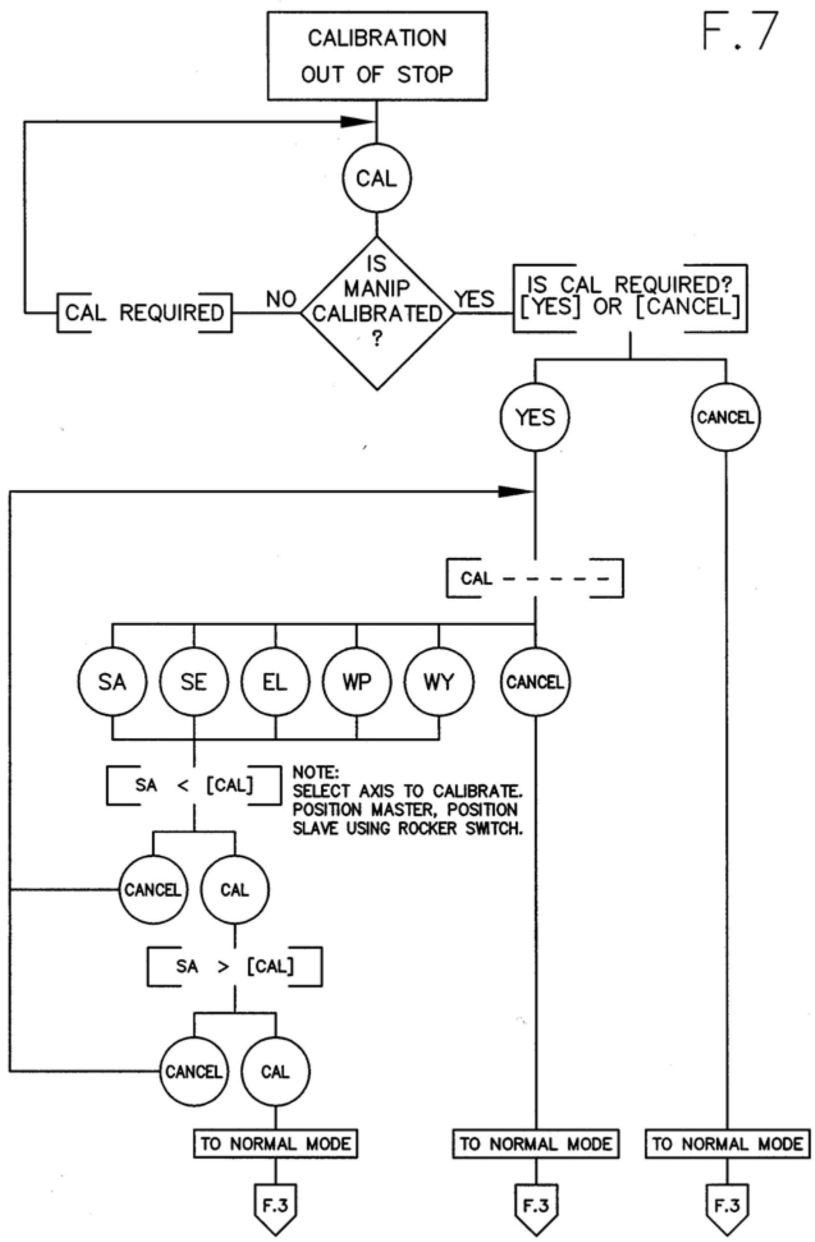
F.4

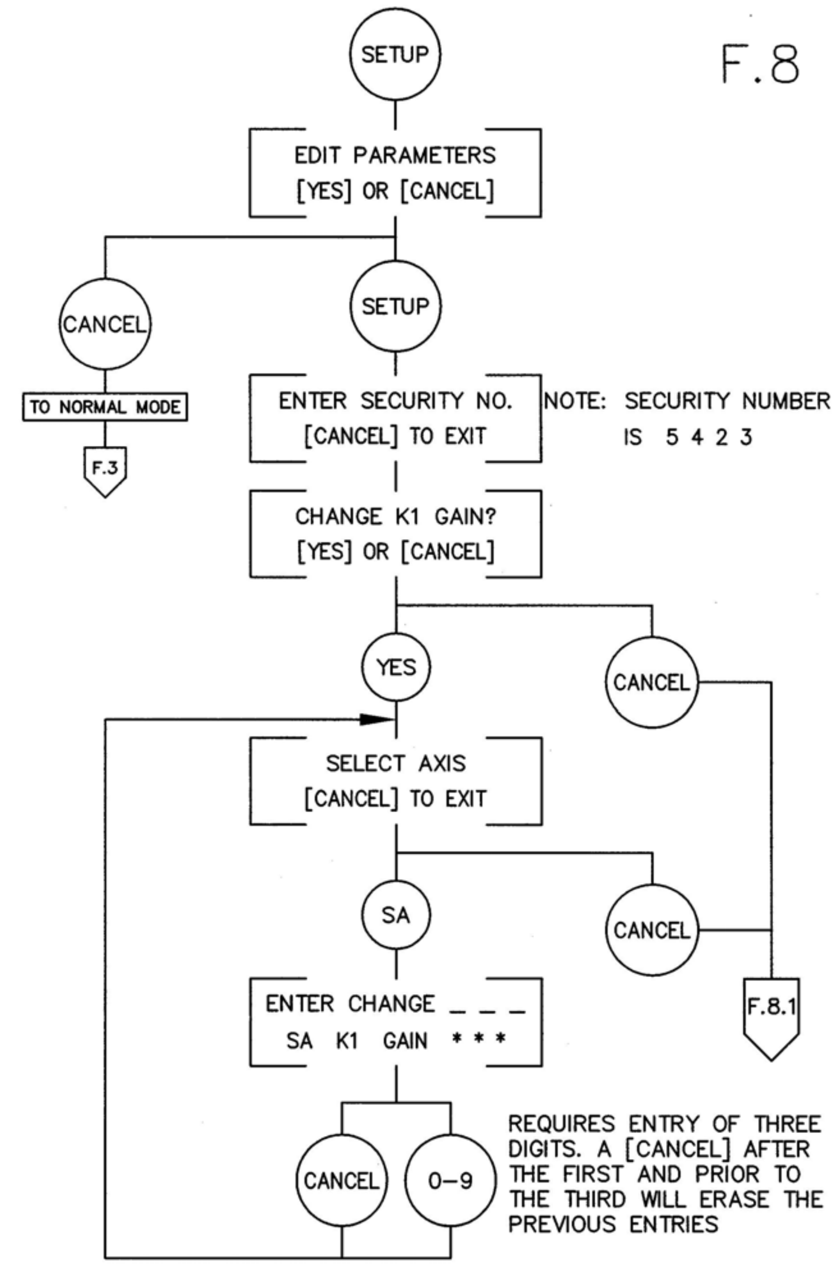

DEPLOY
DPY ---********
[CANCEL] TO END TASK
DPY ----------**
[CANCEL] TO END TASK
TO NORMAL MODE
F.3
STOW
STW ---********
[CANCEL] TO END TASK
STW ----------**
[CANCEL] TO END TASK
TO NORMAL MODE
F.3

F.5

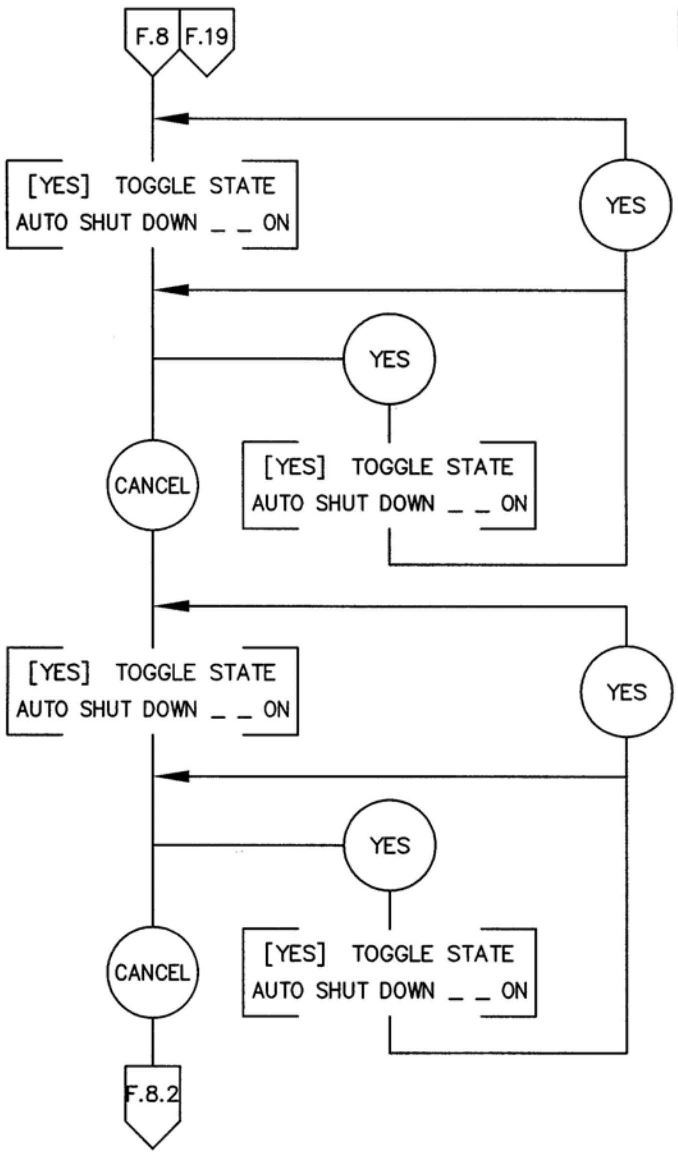

SINGLE AXIS
CAL MODE
CAL - - - - -
SA
SE
EL
WP
WY
CANCEL
SA < [CAL]
NOTE:
SELECT AXIS TO CALIBRATE.
POSITION MASTER, POSITION
SLAVE USING ROCKER SWITCH.
CANCEL
CAL
SA > [CAL]
CANCEL
CAL
TO NORMAL MODE
F.3
TO NORMAL MODE
F.3


F.6
ALL AXIS CAL MODE
CAL * * * * *
SA
SE
EL
WP
WY
CANCEL
SA < [CAL]
NOTE:
SELECT AXIS TO CALIBRATE.
POSITION MASTER, POSITION
SLAVE USING ROCKER SWITCH.
CANCEL
CAL
CONTINUE UNTIL ALL AX'ES CALIBRATED
NO
ALL AXIS CALIBRATED ?
SA > [CAL]
CANCEL
CAL
YES
CAL – * * * *
TO NORMAL MODE
F.3

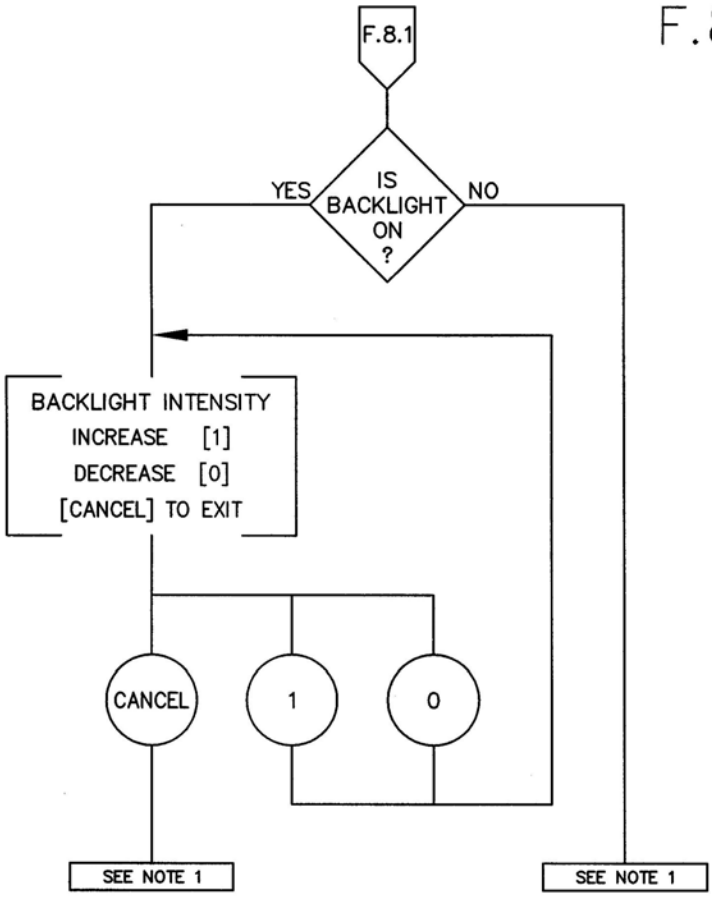

F.7
CALIBRATION
OUT OF STOP
CAL
IS
MANIP
CALIBRATED
?
NO
CAL REQUIRED
YES
IS CAL REQUIRED?
[YES] OR [CANCEL]
YES
CANCEL
CAL - - - - -
SA
SE
EL
WP
WY
CANCEL
SA < [CAL]
NOTE:
SELECT AXIS TO CALIBRATE.
POSITION MASTER, POSITION
SLAVE USING ROCKER SWITCH.
CANCEL
CAL
SA > [CAL]
CANCEL
CAL
TO NORMAL MODE
TO NORMAL MODE
TO NORMAL MODE
F.3
F.3
F.3


F.8
SETUP
EDIT PARAMETERS
[YES] OR [CANCEL]
CANCEL
TO NORMAL MODE
F.3
SETUP
ENTER SECURITY NO.
[CANCEL] TO EXIT
NOTE: SECURITY NUMBER
IS 5 4 2 3
CHANGE K1 GAIN?
[YES] OR [CANCEL]
YES
CANCEL
SELECT AXIS
[CANCEL] TO EXIT
SA
CANCEL
F.8.1
ENTER CHANGE _ _ _
SA K1 GAIN * * *
CANCEL
0–9
REQUIRES ENTRY OF THREE
DIGITS. A [CANCEL] AFTER
THE FIRST AND PRIOR TO
THE THIRD WILL ERASE THE
PREVIOUS ENTRIES

F.8.1

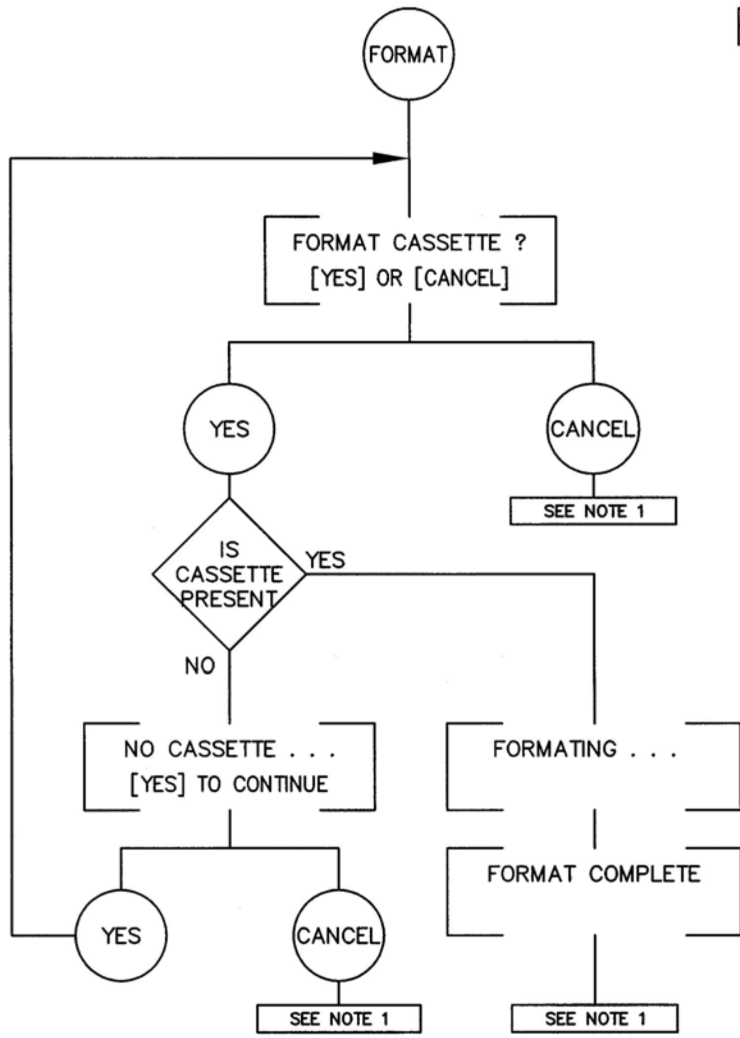

F.8
F.19
[YES] TOGGLE STATE
AUTO SHUT DOWN _ _ ON
YES
YES
[YES] TOGGLE STATE
AUTO SHUT DOWN _ _ ON
CANCEL
[YES] TOGGLE STATE
AUTO SHUT DOWN _ _ ON
YES
YES
[YES] TOGGLE STATE
AUTO SHUT DOWN _ _ ON
CANCEL
F.8.2

F.8.2



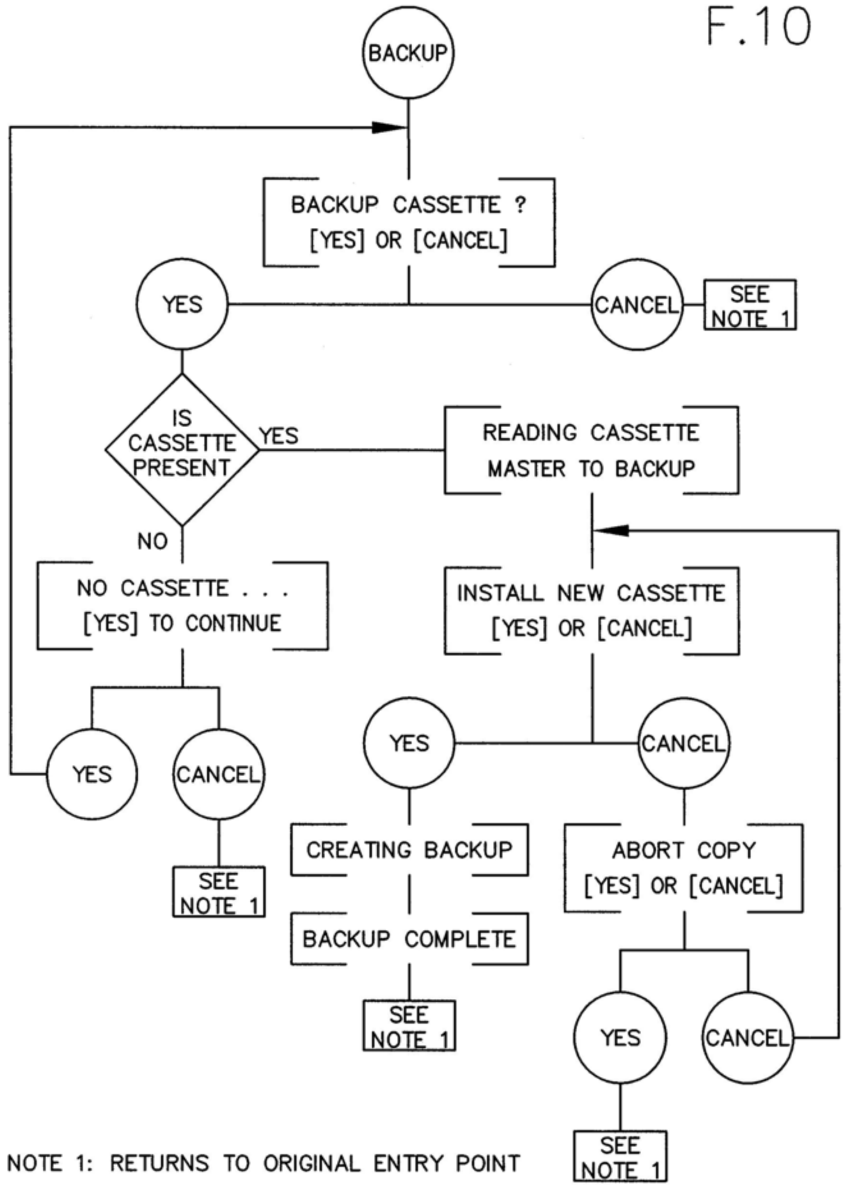
NOTE 1: RETURNS TO ORIGINAL ENTRY POINT

F.9

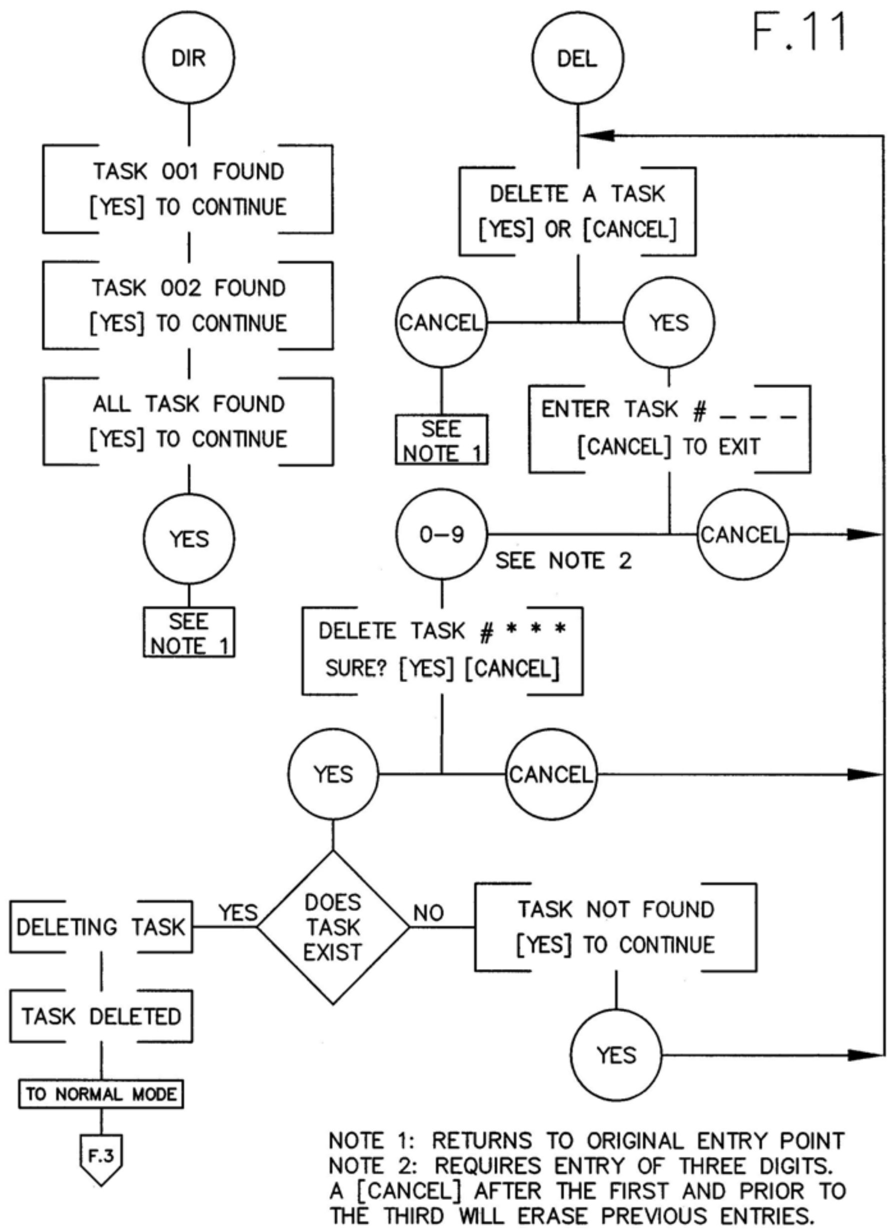


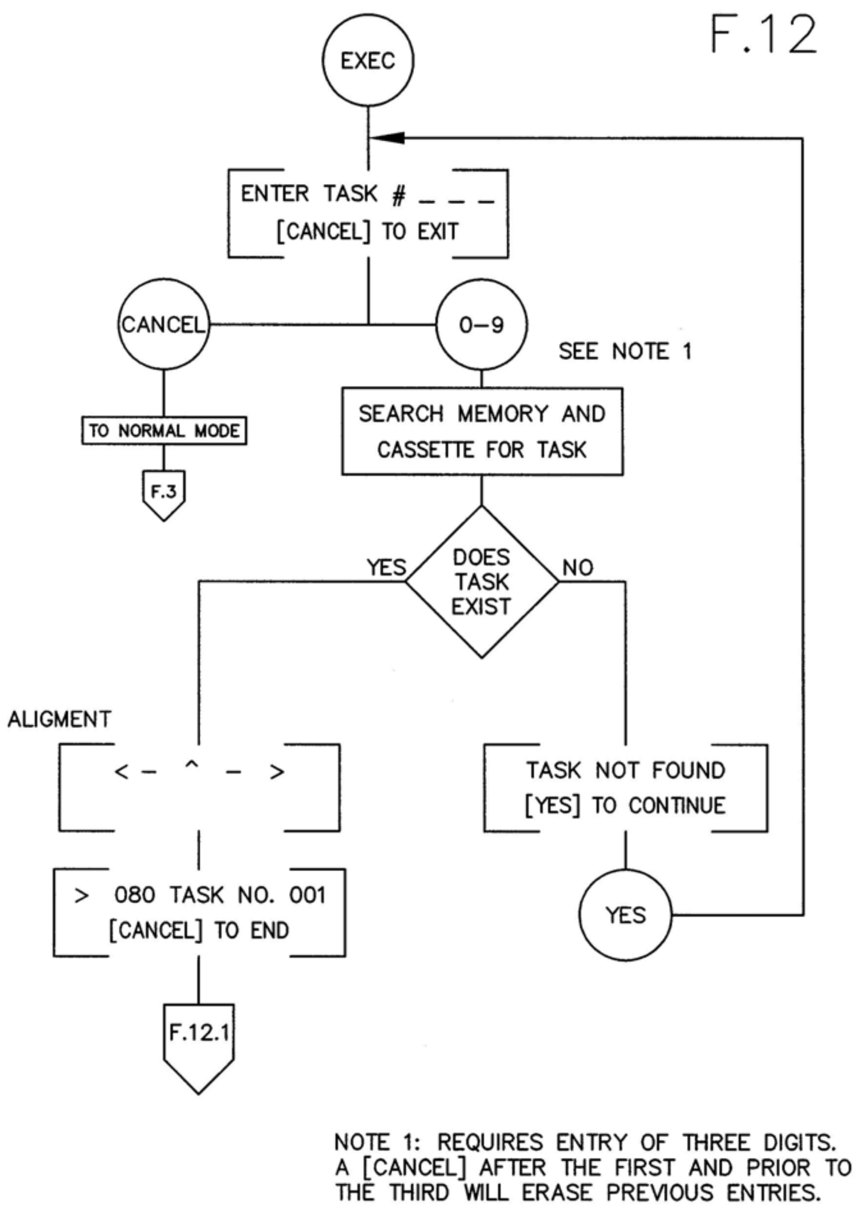
NOTE 1: RETURNS TO ORIGINAL ENTRY POINT

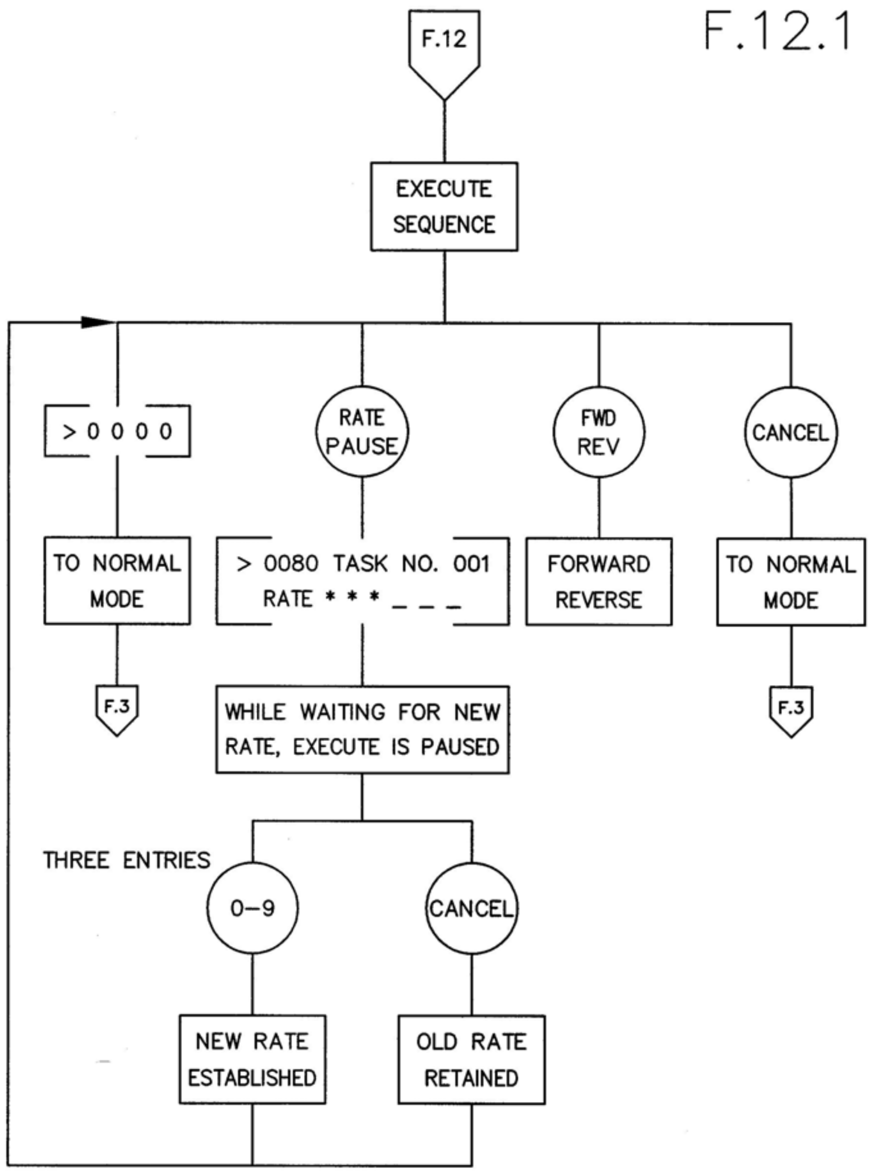
F.10

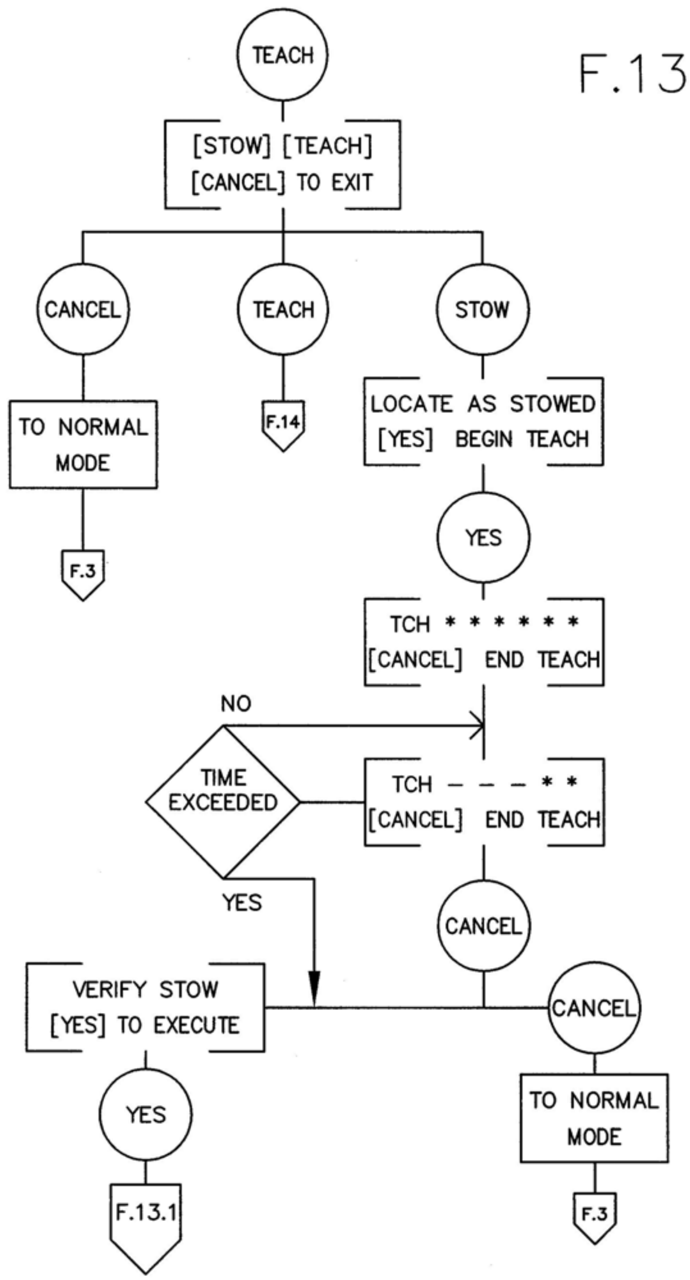


NOTE 1: RETURNS TO ORIGINAL ENTRY POINT

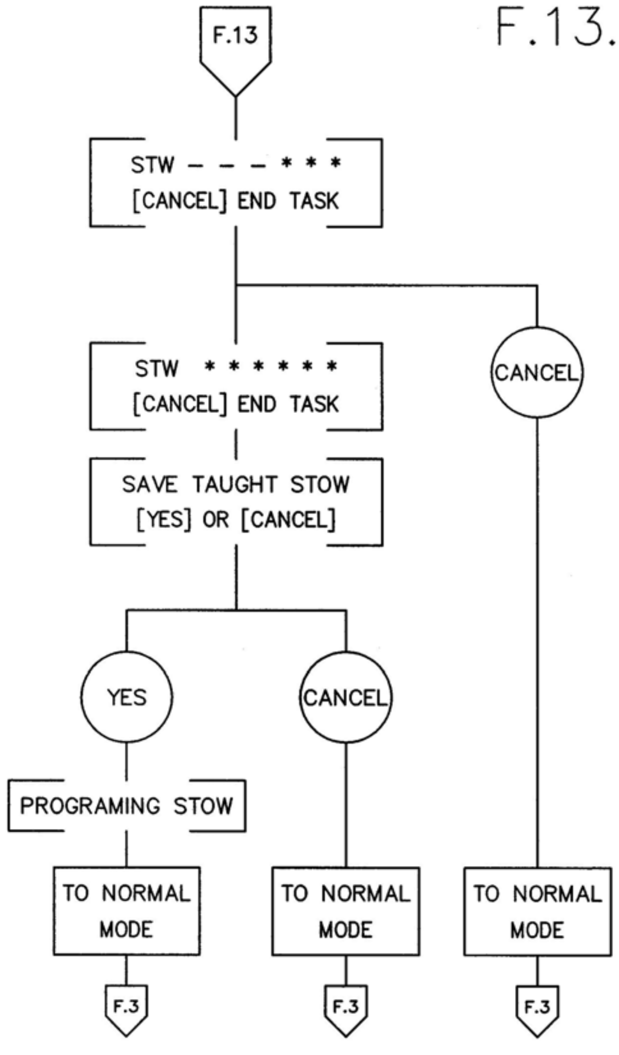

F.11
DIR
TASK 001 FOUND
[YES] TO CONTINUE
TASK 002 FOUND
[YES] TO CONTINUE
ALL TASK FOUND
[YES] TO CONTINUE
YES
SEE NOTE 1
DEL
DELETE A TASK
[YES] OR [CANCEL]
CANCEL
YES
SEE NOTE 1
ENTER TASK # _ _ _
[CANCEL] TO EXIT
0–9
SEE NOTE 2
CANCEL
DELETE TASK # * * *
SURE? [YES] [CANCEL]
YES
CANCEL
DELETING TASK
YES
DOES TASK EXIST
NO
TASK NOT FOUND
[YES] TO CONTINUE
TASK DELETED
TO NORMAL MODE
F.3
YES
NOTE 1: RETURNS TO ORIGINAL ENTRY POINT
NOTE 2: REQUIRES ENTRY OF THREE DIGITS.
A [CANCEL] AFTER THE FIRST AND PRIOR TO
THE THIRD WILL ERASE PREVIOUS ENTRIES.


F.12
EXEC
ENTER TASK # _ _ _
[CANCEL] TO EXIT
CANCEL
0–9
SEE NOTE 1
TO NORMAL MODE
F.3
SEARCH MEMORY AND
CASSETTE FOR TASK
YES
DOES
TASK
EXIST
NO
ALIGMENT
<– ^ – >
TASK NOT FOUND
[YES] TO CONTINUE
> 080 TASK NO. 001
[CANCEL] TO END
YES
F.12.1
NOTE 1: REQUIRES ENTRY OF THREE DIGITS.
A [CANCEL] AFTER THE FIRST AND PRIOR TO
THE THIRD WILL ERASE PREVIOUS ENTRIES.

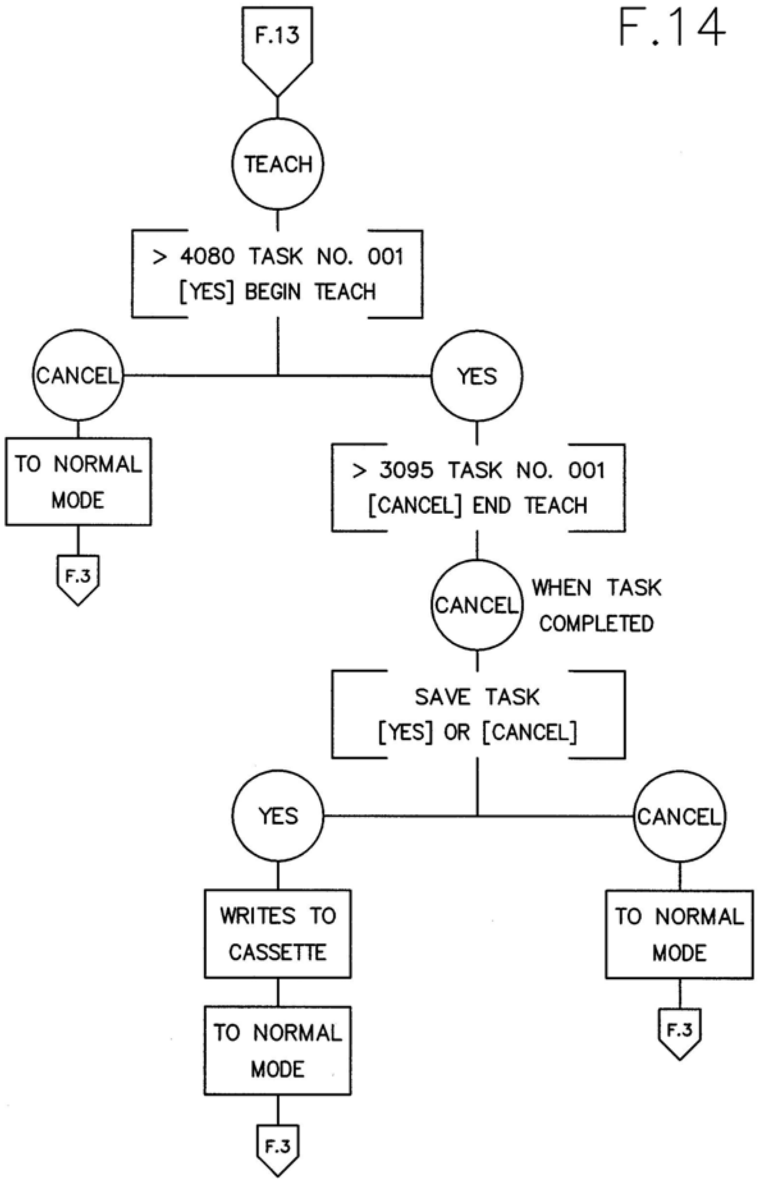

F.12.1
F.12
EXECUTE
SEQUENCE
> 0 0 0 0
TO NORMAL
MODE
F.3
RATE
PAUSE
> 0080 TASK NO. 001
RATE * * * _ _ _
WHILE WAITING FOR NEW
RATE, EXECUTE IS PAUSED
THREE ENTRIES
0–9
NEW RATE
ESTABLISHED
CANCEL
OLD RATE
RETAINED
FWD
REV
FORWARD
REVERSE
CANCEL
TO NORMAL
MODE
F.3


F.13
TEACH
[STOW] [TEACH]
[CANCEL] TO EXIT
CANCEL
TEACH
STOW
TO NORMAL
MODE
F.3
F.14
LOCATE AS STOWED
[YES] BEGIN TEACH
YES
TCH * * * * * *
[CANCEL] END TEACH
NO
TIME
EXCEEDED
TCH — — — * *
[CANCEL] END TEACH
YES
CANCEL
VERIFY STOW
[YES] TO EXECUTE
CANCEL
YES
TO NORMAL
MODE
F.13.1
F.3

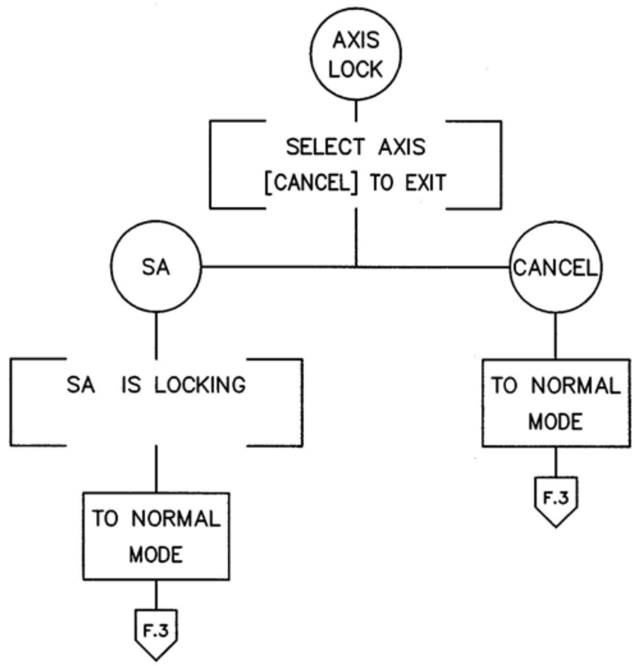
F.13.1


F.13
STW – – – * * *
[CANCEL] END TASK
CANCEL
STW * * * * * *
[CANCEL] END TASK
SAVE TAUGHT STOW
[YES] OR [CANCEL]
YES
CANCEL
PROGRAMING STOW
TO NORMAL MODE
TO NORMAL MODE
TO NORMAL MODE
F.3
F.3
F.3

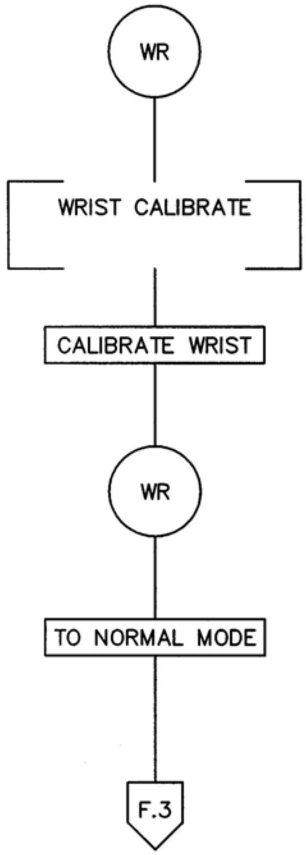
F.14


F.13
TEACH
> 4080 TASK NO. 001
[YES] BEGIN TEACH
CANCEL
YES
TO NORMAL MODE
F.3
> 3095 TASK NO. 001
[CANCEL] END TEACH
CANCEL
WHEN TASK COMPLETED
SAVE TASK
[YES] OR [CANCEL]
YES
CANCEL
WRITES TO CASSETTE
TO NORMAL MODE
F.3
TO NORMAL MODE
F.3

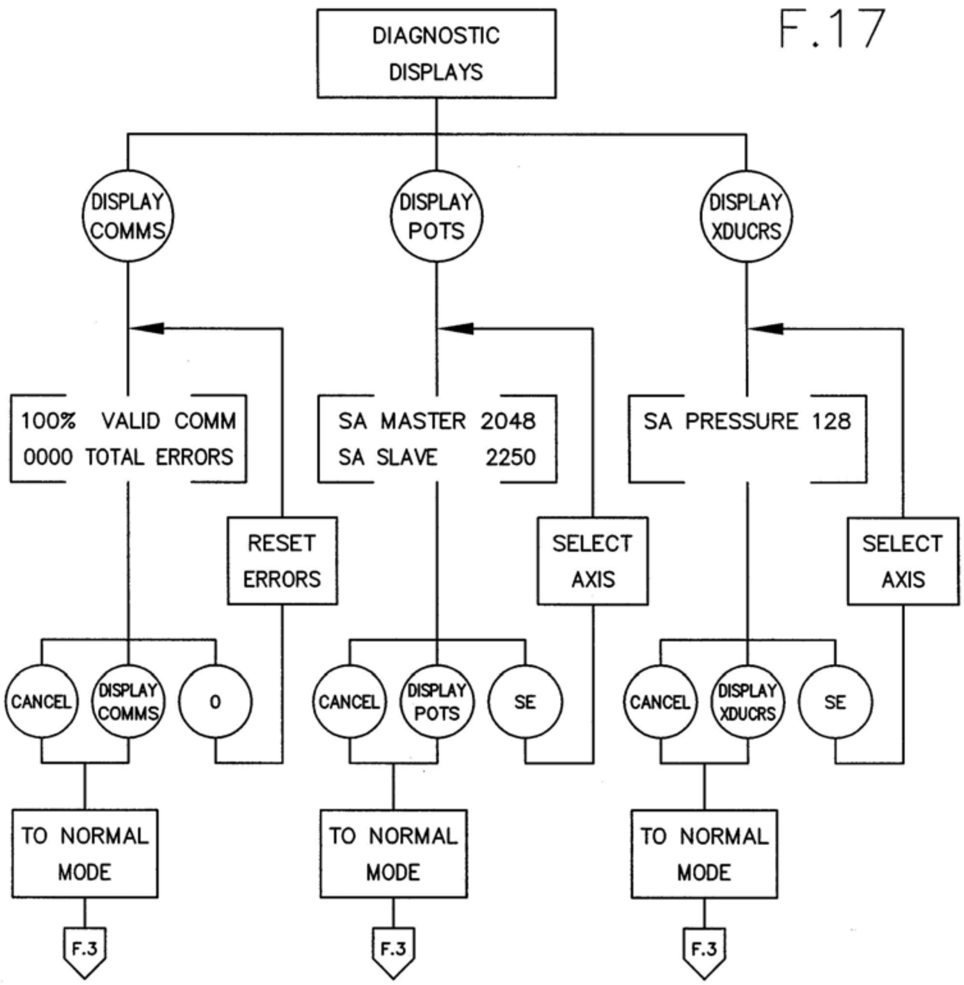
F.15


AXIS LOCK
SELECT AXIS
[CANCEL] TO EXIT
SA
CANCEL
SA IS LOCKING
TO NORMAL MODE
F.3
TO NORMAL MODE
F.3

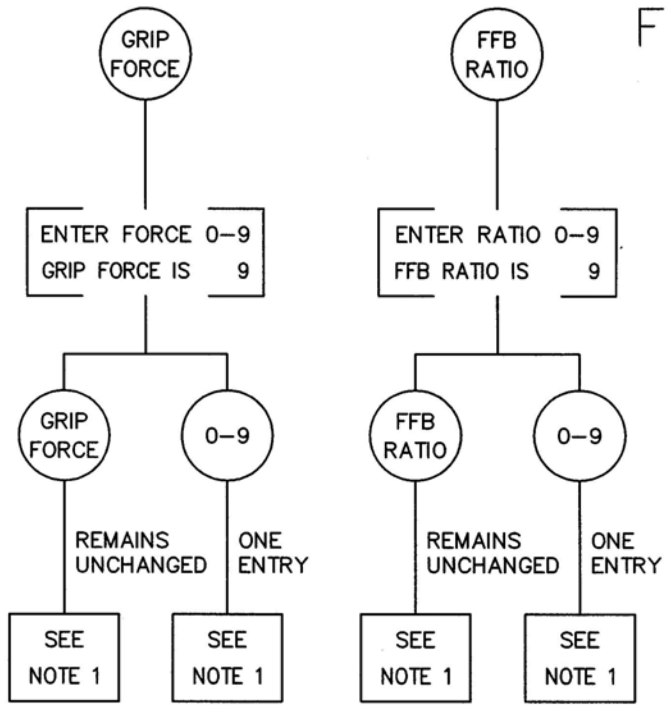
F.16



F.17

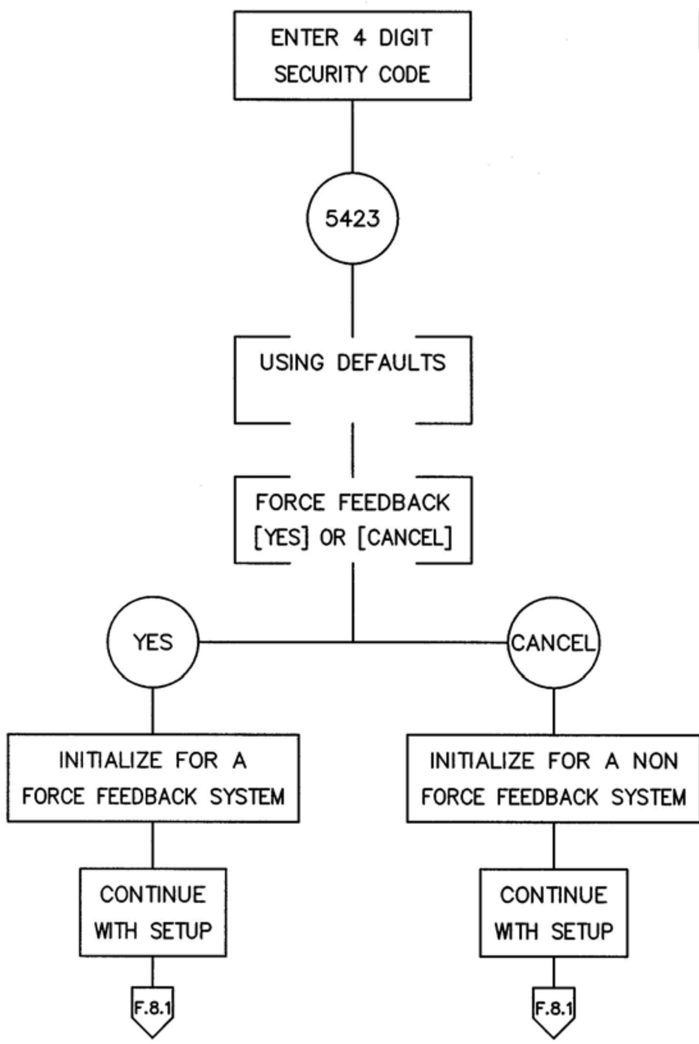

DIAGNOSTIC DISPLAYS
DISPLAY COMMS
DISPLAY POTS
DISPLAY XDUCRS
100% VALID COMM
0000 TOTAL ERRORS
SA MASTER 2048
SA SLAVE 2250
SA PRESSURE 128
RESET ERRORS
SELECT AXIS
SELECT AXIS
CANCEL
DISPLAY COMMS
0
CANCEL
DISPLAY POTS
SE
CANCEL
DISPLAY XDUCRS
SE
TO NORMAL MODE
TO NORMAL MODE
TO NORMAL MODE
F.3
F.3
F.3

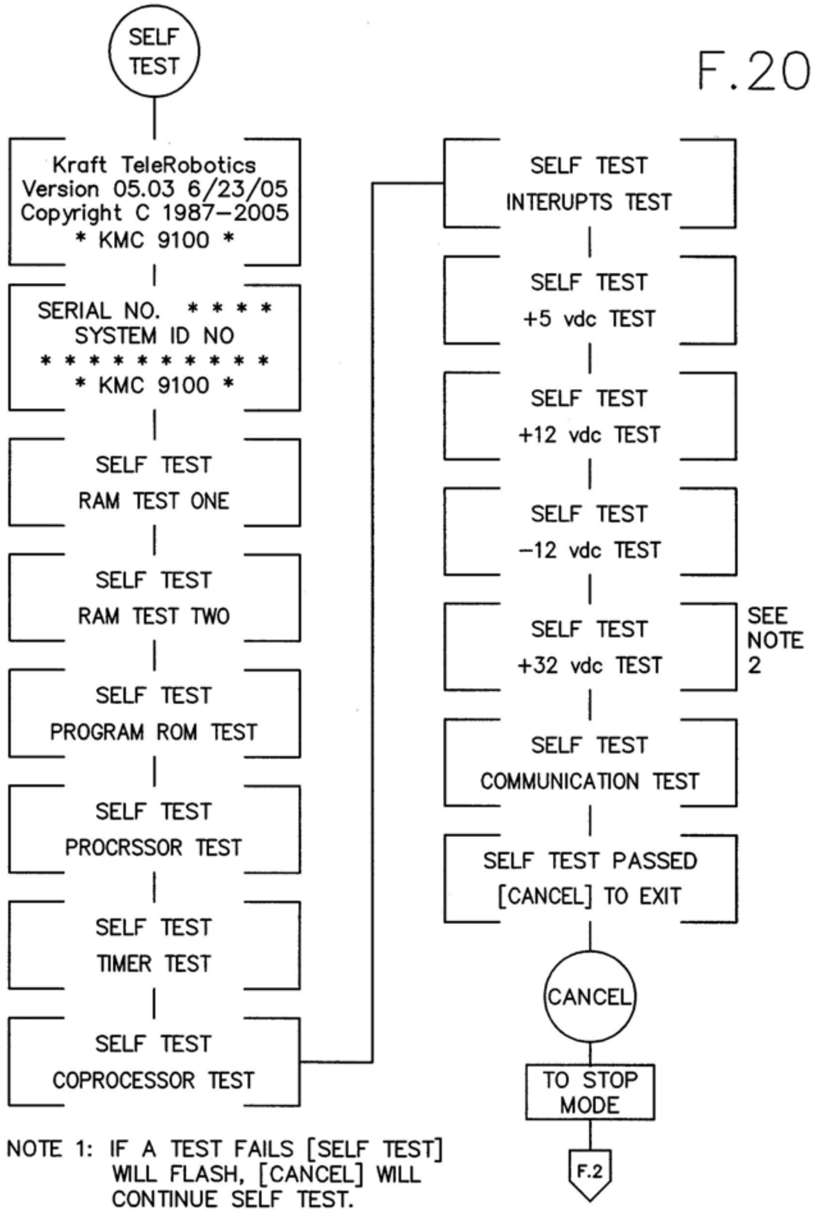
F.18



NOTE 1: RETURNS TO ORIGINAL ENTRY POINT

F.19


ENTER 4 DIGIT SECURITY CODE
5423
USING DEFAULTS
FORCE FEEDBACK [YES] OR [CANCEL]
YES
CANCEL
INITIALIZE FOR A FORCE FEEDBACK SYSTEM
INITIALIZE FOR A NON FORCE FEEDBACK SYSTEM
CONTINUE WITH SETUP
CONTINUE WITH SETUP
F.8.1
F.8.1



NOTE 1: IF A TEST FAILS [SELF TEST] WILL FLASH, [CANCEL] WILL CONTINUE SELF TEST.
NOTE 2: TEST PREFORMED ONLY WHEN FORCE FEEDBACK SELECTED.

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4 Maintenance

4.1 MANIPULATOR

The *RAPTOR* manipulator system does not require any scheduled maintenance other than routine inspection of the system for loose fasteners or fittings and a fresh water rinse for subsea applications.

4.2 KMC 9100 ELECTRONICS SYSTEM

The KMC 9100 electronics system has been designed to require no routine maintenance procedures. All adjustments, with the exception of the force feedback motor drivers, are performed in software with no need for access to the electronics chassis. All major electronic subsystems have been encapsulated to offer maximum environmental protection. If improper operation is experienced cleaning of the electrical connectors within the system may be indicated but is not required on a routine basis. If the connectors on electronics modules should require cleaning, proper precautions against exposure to static electricity should be taken.

4.2.1 System Diagnostic Testing

The KMC 9100 performs a series of system self tests upon power up. During the performance of these tests the TEST lamp on the KMC 9100 chassis will be illuminated. This is strictly a pass or fail test and provides no information as to what failed. Upon a selftest failure the test lamp on the KMC 9100 chassis will begin to blink indicating the failure. Upon demand by depressing the [TEST] key out of stop mode, the system will perform a more comprehensive set of tests and display each test in progress. If a test fails the display will begin to flash while displaying the test which failed. By depressing the [CANCEL] key the system will continue with the remaining tests with the same action applying to any further failed tests. At the end of self test, SELF TEST FAILED will display if any tests performed failed. This, however, will not disallow use of the system. By depressing the [CANCEL] key the system will enter the STOP mode of operation. The obvious precaution to use of the system under these circumstances is that the failed test may effect operation of the system.

The following is a list of items tested during self test and a brief description of the test:

RAM ONE	This test verifies the function of system ram excluding ram used for task recall.
RAM TWO	This test verifies the function of ram used exclusively for task recall.
PROM	This verifies the function and data integrity of all program read only memory.
PROCESSOR	This test verifies the operation of the system microprocessor.
TIMER	This test verifies the operation of several timers which are required for normal operation of the system.
COPROCESSOR	This test verifies the operation of a dedicated math device.
INTERRUPTS	This test verifies the processors ability to service interrupts. Additionally it verifies that system interrupts are occurring at the proper intervals.
+5 VDC	This test confirms that the + 5 volt supply is within tolerance.
+12 VDC	This test confirms that the + 12 volt supply is within tolerance.
-12 VDC	This test confirms that the - 12 volt supply is within tolerance.
+10 VDC REF	This test confirms that the + 10 volt reference supplied to the potentiometers is within tolerance.
-10 VDC REF	This test confirms that the - 10 volt reference supplied to the potentiometers is within tolerance.
+24 VDC	This test is only performed in force feedback configured systems. It confirms that the + 24 volt supply is within tolerance.
COMMUNICATION	This test confirms that the MSC module is able to communicate with the RSD module with at least 90 percent success. The exact percentage of valid communications can be observed by depressing the [DISPLAY COMM] key.

At the operators request the KMC 9100 system will perform a comprehensive self test or diagnostic routine. All diagnostic routines and results are displayed. In addition, error messages may be generated during normal operation. The following is a list of these messages:

COMM ERROR	This error means that communication between the KMC 9100 module and the RSD module has failed consecutively 100 times. Confirm integrity of communication link, including all associated connectors. Check KMC 9100 and RSD power supplies.
SELF TEST FAIL	This error means that one or more of the items tested during self test failed. Refer to the maintenance section of the manual for individual tests and appropriate action.
NULL ERROR	This error means that an attempt was made to activate Hydraulic power when the RSD module was applying voltage greater than +or- .5 Vdc to one or more servo valves. This error will occur if the RSD module is not plugged into the manipulator or if a bad connection exists from the RSD module to the manipulator.
HYD STATUS ERR	This error means that the RSD module detected an illegal voltage value on the output line driving the hydraulics solenoid valve. This test is performed when the STOP mode is entered (tests for > 2.5 Vdc) and when hydraulics are activated (tests for < 2.5 Vdc). Check supply voltages to the solenoid valve and all associated connections.
CAL REQUIRED	This error means that an attempt was made to perform a calibration out of stop when the required existing calibration did not exist.
WRONG ORDER	This error means that an improper relationship existed between the master and the manipulator during an attempt to calibrate an axis. Refer to the calibration section of the manual for detailed instructions regarding calibration.
CAL RATIO ERR	This error means that an illegal angular relationship existed between the master an manipulator during an attempt to calibrate an axis. Refer to the calibration section of the manual for detailed instructions regarding calibration.

USING DEFAULT	This message means that the system is loading in default values and that no calibration data exists. This is caused intentionally by entering a security number out of stop mode or by a power glitch during an access to the KMC 9100 module's non volatile memory. A full calibration will be required before use of the system.
CAL LIMIT	This message means that one or more of the axes of the manipulator are at the calibrated limit of travel.
RESTRICTION	This message preceded by the axis identifier indicates that this axis is not where it is commanded to be, typically meaning some physical restriction of motion at the manipulator. During stow/deploy or task recall execution a restriction will cause task execution to cease until the restriction is corrected.
NO CASSETTE	This message means that an attempt was made to access the cassette system and no cassette was installed.
PARAMETER ERR	This warning means that an attempt was made to enter an illegal numerical value into the KMC 9100 system.
FILE NOT OPEN	This warning means that an attempt was made to write to a task file that had not been previously opened. If error persists format the cassette in use.
NO TASK FOUND	This message means that an attempt was made to locate a task in memory or cassette that did not exist.
BUFFER FULL	This warning means that reserved memory space for task recall has been consumed and a FORMAT is required.
DEVICE ERROR	This error means that the KMC 9100 module is unable to properly read data from the cassette system. FORMAT the cassette and if the error persists initiate a system self test to check for memory defects in the KMC 9100 module. If no memory error is detected and the checksum error persists after formatting the cassette this indicates a failed cassette.

CHECKSUM ERR — This error means that data read from the cassette system was found to have an incorrect checksum indicating data loss. FORMAT the cassette and if the error persists initiate a system self test to check for memory defects in the KMC 9100 module. If no memory error is detected and the checksum error persists after formatting the cassette this indicates a failed cassette.

S.D. REF ERR — This error means that the RSD module +10 Vdc or -10 Vdc reference is out of tolerance. This will typically be caused by a potentiometer failure shorting the reference to ground or by the RSD power supply out of tolerance. Although the reference is current limited, a long duration short circuit could cause a module failure.

S.D. SYSTEM ERR — This error indicates that the perpetual self diagnostics within the RSD module have failed. This failure will cause the solenoid valve to close automatically. (If the RSD module is able to perform this action in its failed mode) Replacement of the module will be required if the error persists after confirming properly functioning power supplies.

A/D TIMER ERR — This error is caused by a component failure internal to the KMC 9100 module or by the KMC 9100 power supply out of tolerance. Replacement of the module will be required if the error persists after confirming power supply.

E2 DEVICE ERR — This error is caused by a component failure internal to the KMC 9100 module or by the KMC 9100 power supply out of tolerance. Replacement of the module will be required if the error persists after confirming power supply.

E2 TIMER ERR — This error is caused by an component failure internal to the KMC 9100 module or by the KMC 9100 power supply out of tolerance. Replacement of the module will be required if the error persists after confirming power supply.

4.3 GENERAL ASSEMBLY PROCEDURES

The following general assembly procedures will build the described assembly from a completely disassembled condition. The procedures are written to assist maintenance personnel in reassembling any portion of the *RAPTOR* system. The assembly procedures are written for use with the corresponding assembly drawing(s) listed at the beginning of each procedure.

All parts should be obtained before beginning any maintenance procedure. Check the tool list and obtain all required tools and materials for disassembly/assembly prior to beginning work. Each part should be visually inspected before installation. Read the entire paragraph of each assembly step before beginning that step, then assemble per the instructions of each sentence.

Hex keys (Allen wrenches) will be used to install most fasteners. Ball driver type hex wrenches can be used for running socket head cap screws but should not be used for tightening as they have a tendency to strip the internal socket.

4.3.1 O-ring Installation

Unless otherwise specified O-ring seals are to be thoroughly and thinly coated with silicone grease or petroleum jelly prior to installation. "**Cleanliness**" is important for proper seal action and long O-ring life. Every precaution must be taken to insure that all parts are clean at assembly. Foreign particles - dirt, chips, etc. - in the gland may cause leakage and can damage the O-ring thus reducing its life. Assembly must be made with care so that the O-ring is properly placed in the groove and it is not damaged as the gland is closed. The O-ring should not be twisted. Twist during installation will readily occur with O-rings having a large ratio of ID to cross section diameter. O-rings should never be forced over sharp corners, threads, slots or other sharp edges.

4.3.2 Loctite Application

The specific Loctite product to be used will be noted in each procedure. Apply Loctite to the threads of the fastener. After installation, all excess Loctite should be removed to prevent contaminating bearings, seals, etc..

AZIMUTH ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0224-01

Tools and materials list:

Silicone grease
Lubriplate 1200-2 Grease
Loctite 222 (pink in color)
Loctite 242 (blue in color)
Loctite 609 (green in color)
3/32" hex key
3/16" hex key
3/8" hex key
1/2" end wrench
9/16" end wrench
Torque wrench with 3/16" and 5/16" hex key socket driver
Small Phillips screw driver
Soldering iron
Wire stripers
===

1. Install both hollow hex plugs (3) in mounting plate (2).

2. Place mounting plate (2) on a clean flat surface. Inspect seal area for nicks and scratches.

3. Inspect groove of seal ring (6) for cleanliness.

4. Install seal (4) into the groove of seal ring (6). The seal must be seated correctly without twisting or spiraling.

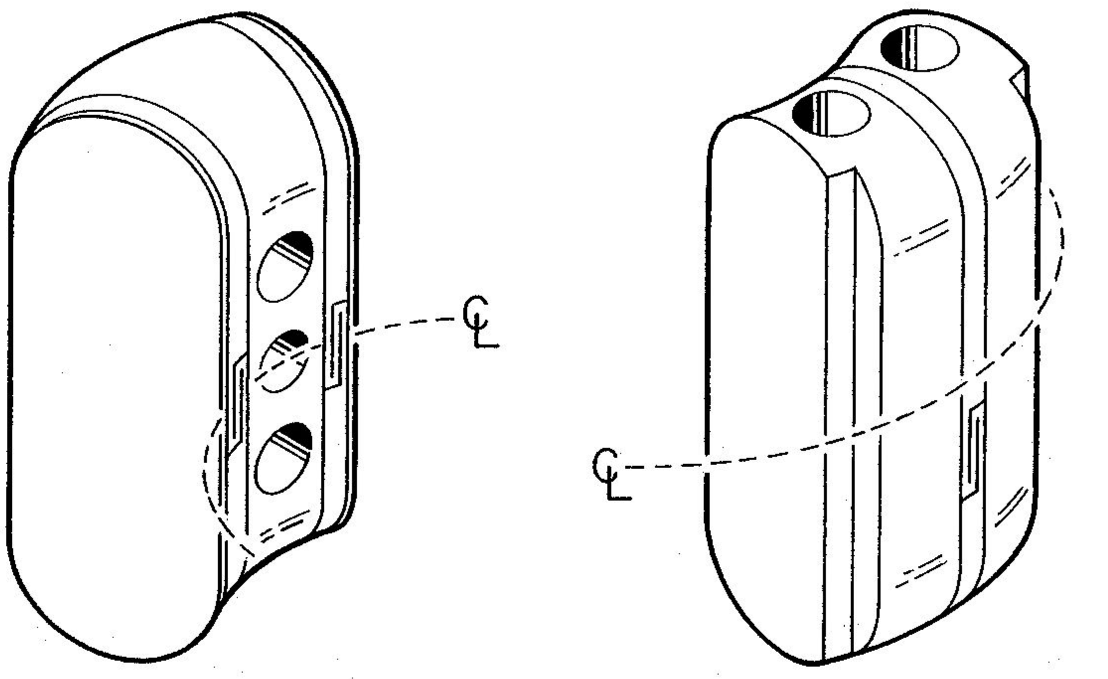
5. Apply a light coating of Lubriplate grease to the chamfer of mounting plate (2).

6. Firmly and slowly push seal ring (6) over hub of mounting plate (2) with a twisting motion. The screw hole counterbores in seal ring (6) must be down. Rotate the seal ring to align any two screw holes in the seal ring with the screw access holes in the mounting plate.

7. Bearing (7) is a precision bearing and should be handled with care. Inject Lubriplate grease through the injection holes in the outer race of the bearing using an 18 gauge grease injector needle. Carefully (line to line fit) slip bearing (7) over hub of mounting plate (2).

8. Set coupling (8) in place with two drilled holes aligned to the front and rear of the mounting plate. Secure coupling using fasteners (10). Tighten all screws in an alternating pattern to 75 inch lbs.

9. Install O-rings (16) into grooves of both rotor vane (19) and stator vane (24). Install vane seals (15) in the seal grooves of both vane (19) and vane (24) with the expanding cut in the seal located as shown in Figure 4-1. Attach vane (19) to shaft (14) using dowel pins (39), and fastener (17). Mark the spline tooth directly opposite the vane with a black ink marker.



Rotor vane (19) Stator vane (24)

Figure 4-1 Location of expanding cut in seal

10. Install seal (11) in both case halves (12),(21).

11. Lightly grease bore and cavity in both halves of the actuator body with Lubriplate grease.

12. Install seals (13),(38) in the seal groove of both actuator bodies (12),(21).

13. Grease shaft/vane assembly with Lubriplate grease, and insert shaft/vane assembly into one half of the actuator with a twisting motion. Be careful not to cut the Teflon glide ring on the edge of the cavity when inserting.

14. Install stationary vane (24) in cavity using dowel pins (18),(23). When slipping vane into actuator body be careful not to cut the Teflon glide ring on the sharp shoulder of the shaft or cavity.

15. Install O-ring (20) in seal groove of actuator body (12).

16. With a twisting motion slide the other half of actuator body over end of shaft aligning dowel pin holes of stationary vane. Make sure seals are all still in place and that they are not cut and do not bunch up when assembling the case halves.

17 Rotate the actuator shaft to the exact mid travel (mechanical the center) position.

18. Orient the splined tooth marked in step 11 so that it is centered toward the rear of the base. Engage spline of actuator shaft with spline in coupling and slide the actuator assembly onto previously assembled base.

19. Bolt case halves together using fasteners (1). Torque bolts in an alternating pattern to 236 inch lbs. Make certain face of actuator is flat across two case halves.

20. Check for free rotation after tightening all screws. Wipe any excess grease from actuator.

21. Install tube fitting (28) in the upper half of the actuator body using Loctite 609. Install tube fittings (22) in lower half of the actuator body with the elbows pointing up. Do not tighten jam nuts at this time.

22. Wire azimuth potentiometer element (31) as shown in Figure 4-2.

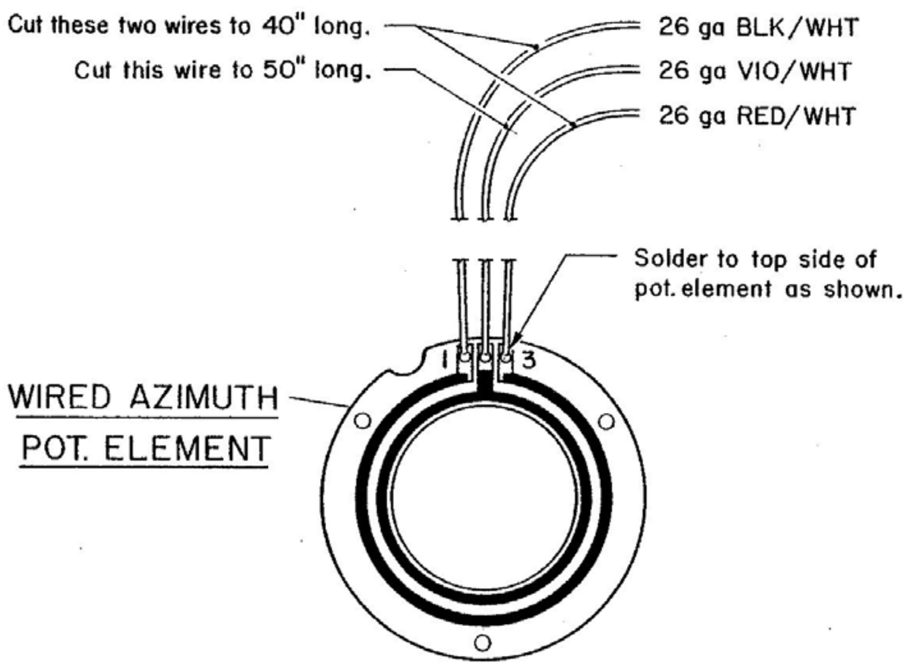


Figure 4-2 Wired azimuth actuator potentiometer element

23. Attach the potentiometer element to plate (29) using screws (32) and Loctite 222.

24. Feed the three potentiometer wires through the drilled passage in the azimuth actuator pot cavity and out through fitting (28). Secure the plate using screws (30). Installed element should appear as shown in Figure 4-3.

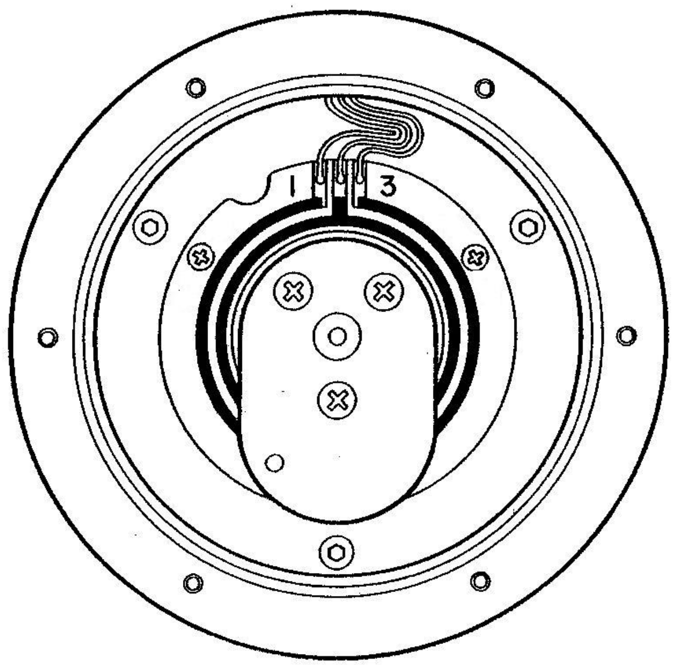


Figure 4-3 View of azimuth actuator potentiometer cavity

25. Attach potentiometer wiper ass'y (33) to the end of the shaft using screws (34) and loctite 222.

26. Install O-ring (35) in the seal groove at the top of the potentiometer cavity and attach cover plate (36) using screws (37). Install hollow hex plug (3) in vent port of cover plate (36).

ELBOW & ELEVATION CYLINDER ASSEMBLY

Reference assembly drawing No. 600-0242-00

Tools and materials List:

Silicone grease	3/32" hex key	Torque wrench with 5/32" hex driver
Lubriplate 1200-2 grease	Internal snap ring pliers	
Loctite 242 (blue in color)	Soldering iron	
5/32" hex key	3/4" of 3/64" Heat shrink	

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1. Press bearing (1) into rod end (2).

2. Install two piece piston seal (16),(17) into seal groove of piston/rod (14). Place bearing (15) in groove of piston.

3. Lightly grease and install three piece rod seal (5) into groove of cylinder head (7). Make certain seal is oriented as shown in assembly drawing.

4. Lightly grease and install two piece wiper (3),(4) in groove of cylinder head. Make certain seal is oriented as shown in assembly drawing.

5. Install O-ring (9) and backup ring (8) in groove of cylinder head. Make certain that backup ring is on the correct side of the O-ring and oriented with the cup towards the O-ring.

6. Lightly grease rod bore of cylinder head with Lubriplate 1200-2 grease. Carefully push cylinder head with twisting motion over the piston rod (14) being careful not to damage seals.

7. Apply Loctite 242 to threads of rod end (2) and screw into piston rod (14). Hand tighten holding piston rod. Remove excess Loctite.

8. Lightly grease chamfer and about 1" of bore on one end of cylinder barrel (13). Lightly grease piston and carefully insert piston rod/head assembly into the cylinder barrel. Secure with fasteners (6) and Loctite 242. Torque to 23 inch lbs. Remove excess Loctite. Check that cylinder extends/retracts smoothly.

9. Place wave spring washer (21) in plate (23). Feed wires of potentiometer element (21) through washer and plate. Slide retaining ring (19) over potentiometer element and install in groove of plate.

10. Apply silicone grease to O-ring (27) and install onto electrical connector (28).

11. Feed the potentiometer element wires through the hole in the side of cavity and out the large O-ring port of the cylinder cap (25). Cut heat shrink in to three 1/4" lengths place on wires. Solder wires to connector per Figure 4-4 and secure heat shrink over solder cups.

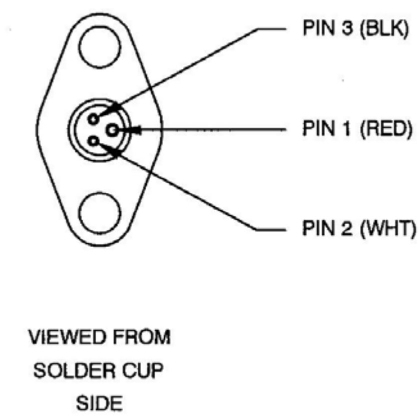


Figure 4-4 Wiring of cylinder electrical connector

12. Install electrical connector into port and secure with fasteners (11) and Loctite 242.

13. Coil excess wire in bottom of cavity and secure potentiometer assembly to cap using fasteners (22) and Loctite 242. <u>Be careful not to pinch wires under pot ass'y.</u>

14. Place O-ring (9) and backup ring (8) in groove of cap. Make certain backup is on correct side of O-ring and oriented with the cup towards the O-ring.

15. Install potentiometer wiper (18) in piston. Make certain that wiper is installed with contacts pointing forward toward the rod end of the cylinder.

16. Lightly grease chamfer on open end of cylinder barrel. Carefully assemble cylinder assembly and rear cap element assembly by inserting potentiometer element through wiper in piston and up into hollow piston rod. Orient the O-ring port in cap to the O-ring port on the head as shown in Figure 4-5 and secure using fasteners (26) and Loctite 242. Torque to 23 inch lbs. Remove excess Loctite. Check that cylinder extends/retracts smoothly.

17. Apply silicone grease to O-rings (10),(24). Install O-ring (24) in counterbore of cap and install O-ring (10) in counterbore of tube ass'y (12). Install tube ass'y on cylinder ass'y and secure with fasteners (12) at head end and fasteners (26) at cap end with Loctite 242. Remove excess Loctite.

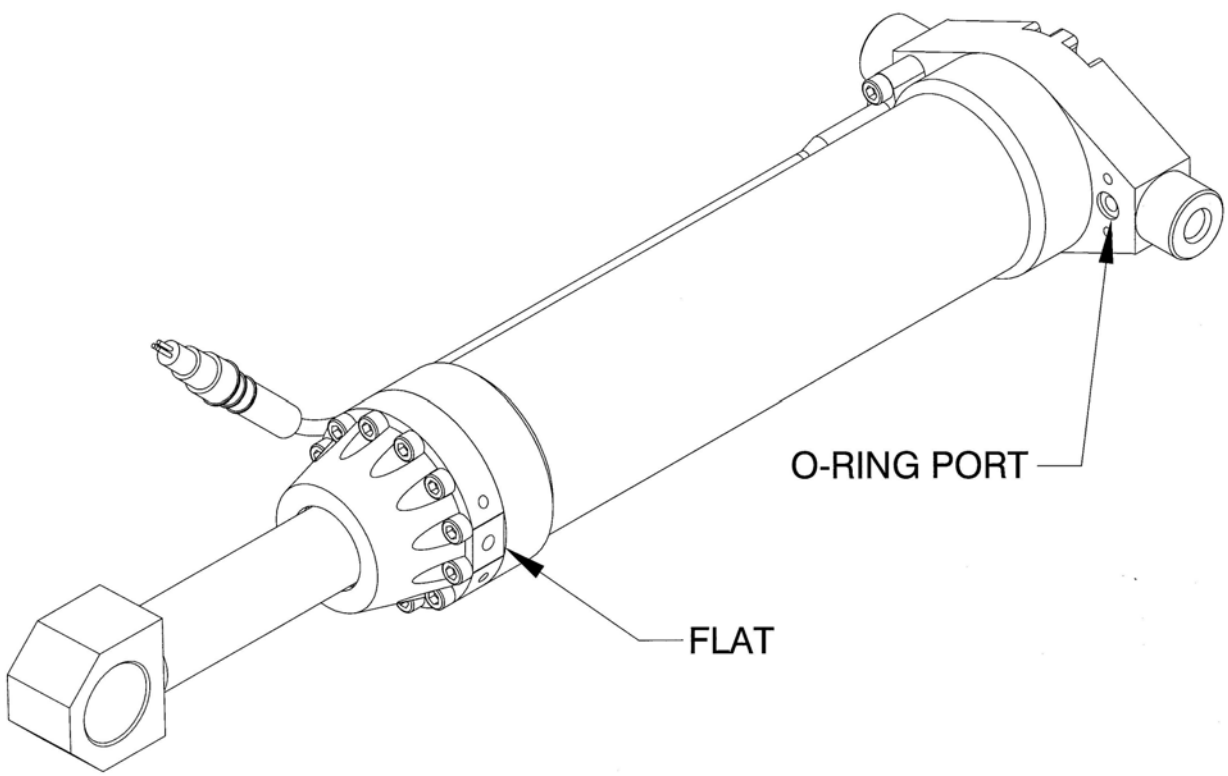


Figure 4-5 Cylinder head/cap orientation

WRIST PITCH ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0227-00

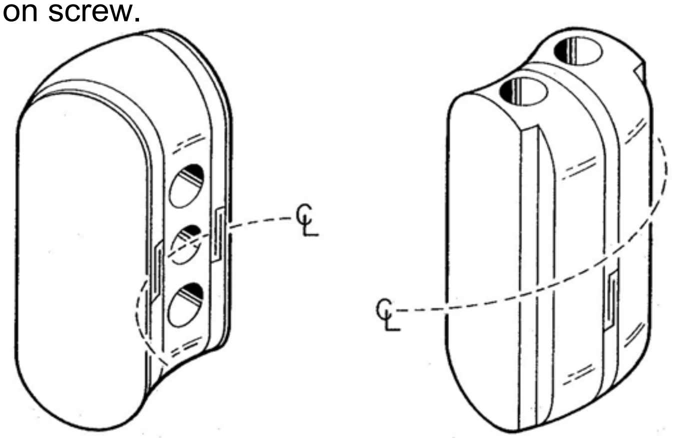
Tools and materials list:

Silicone grease	1/4" flat blade screwdriver
Lubriplate 1200-2 grease	Small Phillips screw driver
Loctite 222 (pink in color)	Wire strippers, soldering iron & solder
Loctite 242 (blue in color)	Heat shrink tubing
5/64" hex key	Torque wrench with 1/4" hex key socket driver
5/32" hex key	

==

1. Install the 2 rotary shaft seals (10),(11) in outer grooves of both case halves (9),(24) *1 two-piece seal in each case half*. Install the 6 rotary shaft seals (12),(13) in the remaining seal grooves of both case halves *3 two-piece seals in each case half*. Place O-ring in the seal groove first, then fold seal ring inward on itself to form a "kidney" shape so it can be inserted through the bore and into the grooves. Release the seal ring allowing it to expand and fill the groove on top of the O-ring. Work seal into the groove and use fingers to remove any creases caused by bending. Make certain that both parts of the seal are installed in a seal groove and <u>not</u> a fluid passage. It is hard to see the 0-ring once installed in the groove so be systematic about installing the seals.

2. Place O-rings (20) in grooves of vanes (16),(22). Install seals (19) into groove of vanes. Expanding cut in the seals must be positioned as shown in Figure 4-6 and Figure 4-7. Attach vane (16) to shaft (21) using dowel pins (17) and screw (18). Use Loctite 242 on screw.



Rotor vane (16) Stator vane (22)

Figure 4-6 Location of expanding cut in seal

3. Lightly grease bore in both halves of the actuator body with Lubriplate 1200-2 grease.

4. Install Quad-ring (14) and seal (26) in both halves of actuator body.

5. Install O-ring (15) in actuator body (9).

6. Insert shaft/vane assembly into actuator case half (9) with a twisting motion. Use care to prevent cutting the vane seals on the sharp cavity edge.

7. Install stationary vane in actuator case half (9) using dowel pins (23). When slipping the vane into the actuator body use care to prevent cutting the vane seals on the sharp cavity edge and the sharp shoulder of the shaft.

8. With a twisting motion slide actuator case half (24) over end of shaft aligning with the dowel pin holes that capture the stationary vane. Make sure all seals are still in place. Use care to insure that the vane seals are not cut and that the vane seals do not bunch up when assembling the case halves.

9. Bolt case halves together using screws (25) and Loctite 242. <u>Make certain face of actuator is flat across two case halves.</u> Torque fasteners to 132 inch lbs.

10. Check for free rotation after tightening all screws.

11. Wipe any excess grease and Loctite from the actuator.

12. Prepare the resistive potentiometer element (7) as shown in Figure 4-8.

13. Place the potentiometer element in the pot cavity of pitch actuator feeding the 2 wires that extend from the back of the element and additionally the BRN/WHT (WR pot return) and GRY/WHT (WY pot return) through the hole to the connector cavity. Secure the element with screws (6). Install standoff (5) and the wire strain relief clamp (4) with screw (3). Feed RED/WHT, BLK/WHT, YEL/WHT wires <u>only</u> through clamp and tighten screw.

14. Attach the potentiometer wiper ass'y (2) to shaft (21) using screws (1). The screws can be tightened with a hex key by rotating the shaft to align the screws with the access hole provided in the hub of the actuator body. After attaching the wiper assembly to the shaft, install O-ring sealing screw (8) to plug the access hole. Install using Loctite 242. Test for correct functioning of the potentiometer with a multi meter.

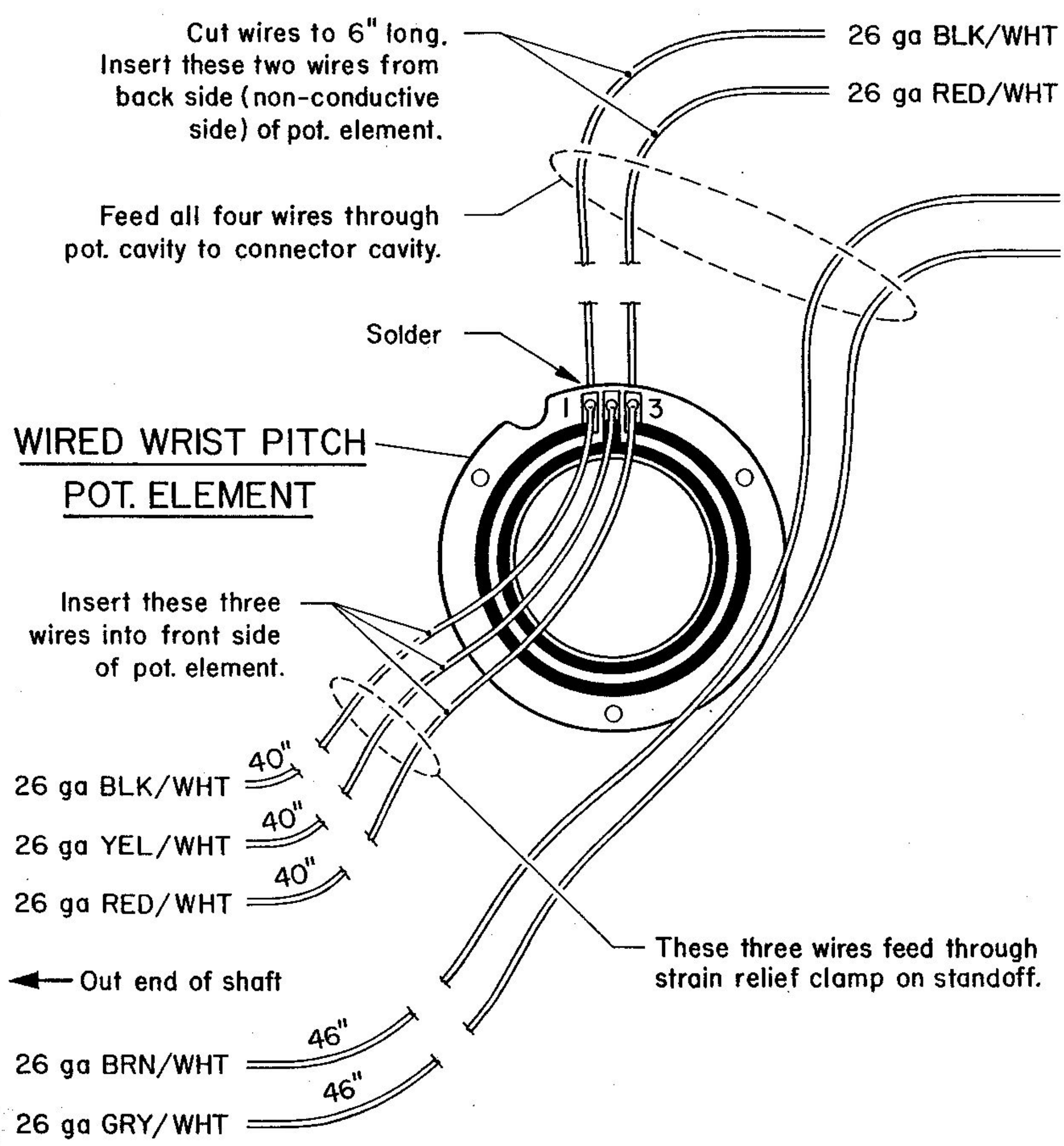


Figure 4-8 Wiring of wrist pitch actuator potentiometer element

15. With the actuator shaft rotated fully counter clockwise, wrap two loose full turns of wire clockwise around the shaft as measured from the standoff. After making 2 full loops of wire around shaft, feed the wires through the side hole and out the end of the shaft. There should be approximately 17-18" of wire extending out the end of the shaft.

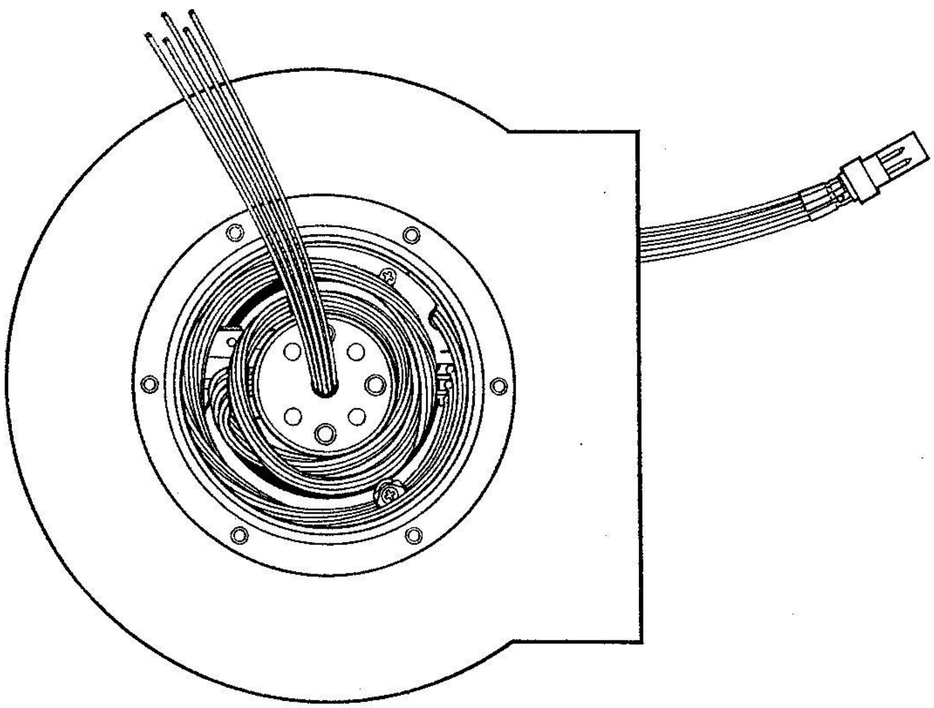


Figure 4-9 View of wrist pitch actuator potentiometer cavity (actuator at mid travel)

WRIST YAW ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0228-00

Tools and materials list:

Silicone grease	Torque wrench with 1/4" hex key socket driver
Lubriplate 1200-2 grease	1/4" flat blade screwdriver
Loctite 222 (pink in color)	#1 Phillips screw driver
Loctite 242 (blue in color)	Wire stripers
5/64" Hex key	Soldering iron
5/32" Hex key	

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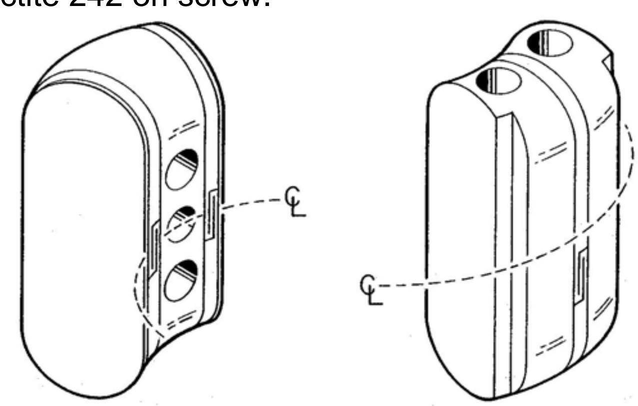
1. Install the 2 shaft seals (10),(11) in the outer grooves of both case halves (9),(25) *1 two-piece seals in each case half*. Install the 4 rotary shaft seals (12)(13) in the remaining grooves of both case halves *2 two-piece seals in each case half*. Place O-ring (13) in the seal groove first, then fold seal ring (12) inward on itself to form a "kidney" shape so it can be inserted through the bore and into the grooves. Release the seal ring allowing it to expand and fill the groove on top of the O-ring. Work seal into the groove and use fingers to remove any creases caused by bending. Make certain that both parts of the seal are installed in a seal groove and <u>not</u> a fluid passage. It is hard to see the O-ring once installed in the groove so be systematic about installing the seals.

2. Place O-rings (20) in grooves of vanes (16)(22). Install seals (19) into groove of vanes. Expanding cut in the seals must be positioned as shown in Figure 4-10 and Figure 4-11. Attach vane (16) to shaft (21) using dowel pins (17) and screw (18). Use Loctite 242 on screw.



Rotor vane (16) Stator vane (22)

Figure 4-10 Location of expanding cut in seal

3. Lightly grease bore in both halves of the actuator body with Lubriplate 1200-2 grease.

4. Install Quad-ring (27) and seal (14) in both halves of actuator body.

5. Install O-ring (15) in actuator body (9).

6. Insert shaft/vane assembly into actuator case half (9) with a twisting motion. Use care to prevent cutting the vane seals on the sharp cavity edge.

7. Install stationary vane in actuator case half (9) using dowel pins (23). When slipping the vane into the actuator body use care to prevent cutting the vane seals on the sharp cavity edge and the sharp shoulder of the shaft.

8. With a twisting motion slide actuator case half (24) over end of shaft aligning with the dowel pin holes that capture the stationary vane. Make sure all seals are still in place. Use care to insure that the vane seals are not cut and that the vane seals do not bunch up when assembling the case halves.

9. Bolt the case halves together using fasteners (25),(26). <u>Make certain that the face of the actuator is flat across the two case halves.</u> Torque fasteners to 132 inch lbs.

10. Check for free shaft rotation after tightening all screws.

11. Wipe any excess grease and Loctite from the actuator.

12. Prepare the resistive potentiometer element (7) as shown in Figure 4-12.

13. Place the potentiometer element in the pot cavity of the yaw actuator feeding the 3 wires that extend from the back of the element and additionally the BRN/WHT Wrist Roll pot return wire through the hole to the connector cavity. Secure the element with screws (6). Install standoff (5) and the wire strain relief clamp (4) with screw (3). Feed RED/WHT, BLK/WHT wires <u>only</u> through clamp, and tighten screw.

14. Attach the potentiometer wiper ass'y (2) to shaft (21) using screws (1). The screws can be tightened with a hex key by rotating the shaft to align the screws with the access hole provided in the hub of the actuator body. After attaching the wiper assembly to the shaft, install O-ring sealing screw (8) to plug the access hole. Install using Loctite 242. Test for correct functioning of the potentiometer with a multi meter.

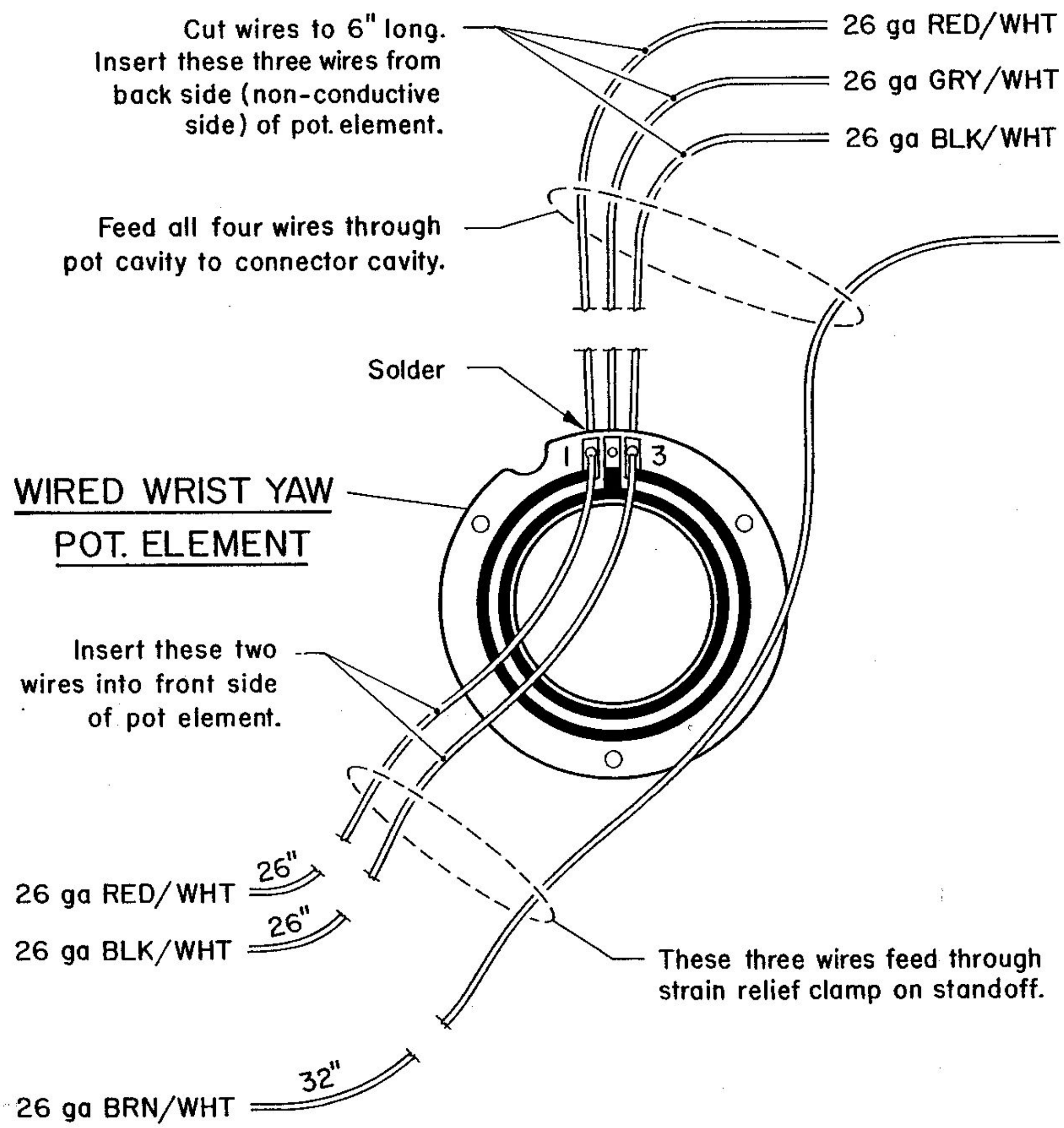


Figure 4-12 Wiring of wrist yaw actuator potentiometer element

15. With the actuator shaft rotated fully <u>counter</u> clockwise wrap two loose turns of wire clockwise around the shaft as measured from the standoff. After making 2 full loops of wire around the shaft, feed the wires through the side hole and out the end of the shaft. There should be approximately 10" of wire extending out the end of the shaft.

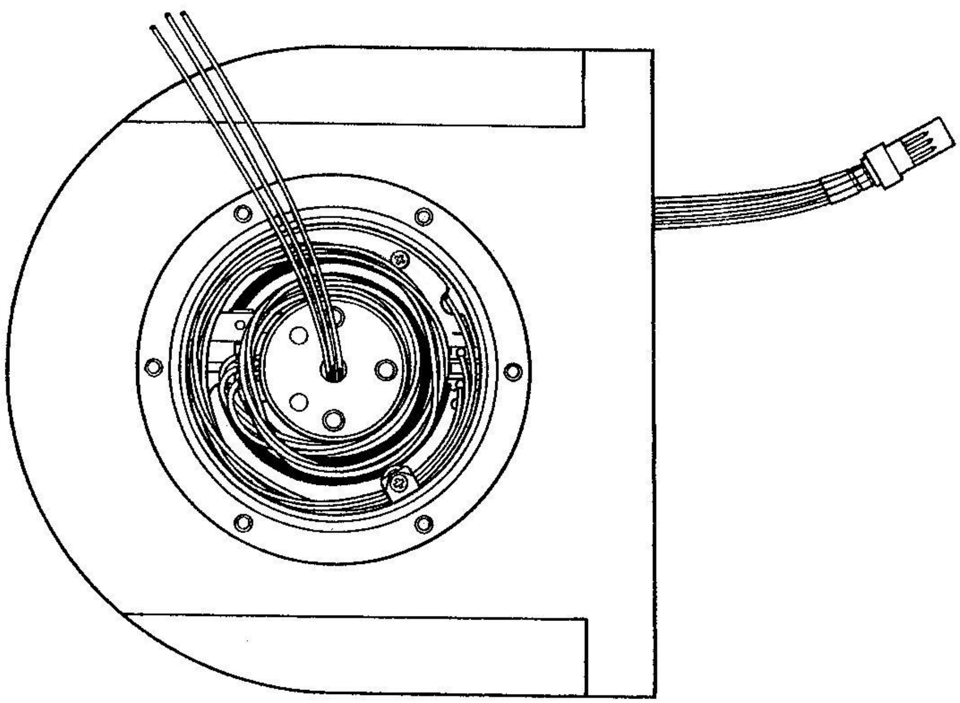


Figure 4-13 View of wrist yaw actuator potentiometer cavity (actuator at mid travel)

WRIST ROLL ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0229-00

Tools and materials list:

Silicone grease
Lubriplate 1200-2 grease
Light oil
Loctite 222 (pink in color)
Loctite 242 (blue in color)
Loctite 609 (green in color)
No.1 Phillips screwdriver
1/8" flat blade screwdriver
3/16" hex key
5/32" hex key
1/8" hex key
9/64" hex key
.035" hex key
==

1. Install bronze bushing (9) in nose of cylinder head (11) (press fit).

2. Install 3 piece rod seal (10) in nose of cylinder head (11).

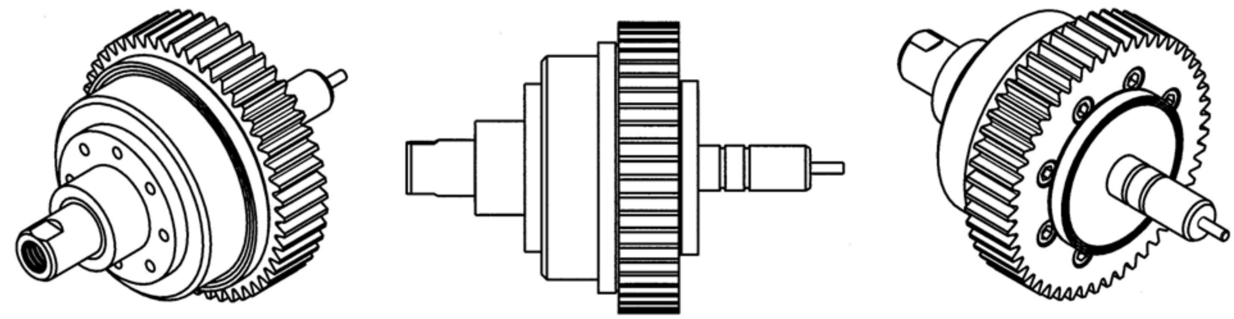
3. Install O-ring (13) in groove of cylinder head (11).

4. Install 3 piece piston seal (15) in groove of piston (14).

5. Lightly grease bore of gripper cylinder (16). Insert piston/rod (14) into cylinder barrel

6. Lightly grease piston rod (14) at chamfer near the thread relief, outside chamfer of cylinder barrel (16) and I.D. of bearing (9) with Lubriplate grease. Insert the piston/rod and gripper cylinder barrel assembly with a twisting motion into the cylinder head (11) seating the cylinder barrel in the cylinder head. Slip bearing (12) over the back end of the cylinder head (11). Install dowel pins (54) into gear (18). Slide the gear over the cylinder barrel (16) and secure using fasteners (20). Torque to 30 inch lbs. Push bearing onto hub of gear seating it against the face of the gear.

7. Slip shim (55) onto end of gripper cylinder. Apply Loctite 609 to I.D. of bearing (19) and slip onto the end of cylinder barrel (16). The gripper cylinder assembly should appear as shown in Figure 4-14.



Front Side Rear

Figure 4-14 Finished gripper cylinder assembly

8. Install the cross port check valves by dropping balls (4) into the holes of the motor cavity. Start ball seat (45) and apply a small drop of 601 to thread. Make sure Loctite does not get into interior of the cavity or on the balls. Screw ball seats into cavity until just below the surface. Remove excess Loctite. Check to insure that both balls are free and rattle when you shake the body.

9. Grease seals (21)(22) with silicone Grease. Install 3 in gripper cylinder fluid slip ring bore and 1 in motor shaft bore in actuator body (25).

10. Install ball bearing (46) in motor cavity and lightly oil. Secure with bearing retainer plate (47) using fasteners (48).

11. Grease motor pinion bore and motor pinion (49) with Lubriplate grease. Install pinion by twisting through seal and seating in supporting ball bearing. Check for free rotation.

12. Place ball (4) in actuator front plate (3). Press in place if necessary but be careful not to dimple front surface of the plate if press is necessary.

13. Press needle bearing (5) into bore of cover plate (3) and grease with Lubriplate grease.

14. Grease seal (7)(8) with silicone grease, install seal in front plate (3).

15. Install O-rings (53) in counter bores of front plate (3). Install motor pintle (51) with fasteners (52). Slip one of the reaction ring ball bearings of assembly (51) over the outside hub of the motor pintle. Make certain it is firmly seated.

16. Grease ball bearing (12) and ball bearing (19) with Lubriplate grease.

17. Lightly grease the drive gear teeth and tail of the cylinder assembly with Lubriplate grease.

18. Grease the bore in the actuator body (25) with Lubriplate grease and insert the tail of the gripper cylinder assembly into the bore through all seals so that bearing (19) seats properly in the actuator body.

19. Install the motor reaction ring and ball bearing by slipping over the hub of the bearing retainer ring (47).

20. Set spider coupling (50) inside the reaction ring mating it with the tangs of pinion (49).

21. Install O-rings (23),(24), and (44) in the front face of the actuator body.

22. Set the motor rotor inside the reaction ring so that the tangs of the rotor engage and mate with the slots in the spider coupling (50). Place the rotor thrust washer over the rotor pintle.

23. Place dowel pins (6) into the actuator body (25).

24. Align all assembled parts, (motor rotor with the pintle, output shaft with bore in front cover plate, and dowel pins) and assemble front plate to case. Secure cover plate using fasteners (2) around the motor cavity and fasteners (1) around the perimeter of the case.

25. This completes assembly of the front half of the gear case. Check for free rotation of the output shaft (friction level will be high but shaft should rotate). Remove all excess grease and Loctite from the assembly. Note: Care should be used in handling as the potentiometer shaft and motor pinion protrude from the back of the actuator body. Do not set the actuator on the back surface.

26. Heat rear plate (38) and install ball bearings (41),(42).

27. Attach potentiometer (29) to mounting plate (31) using cleats (30). Wire the potentiometer and connector as shown in Figure 4-15.

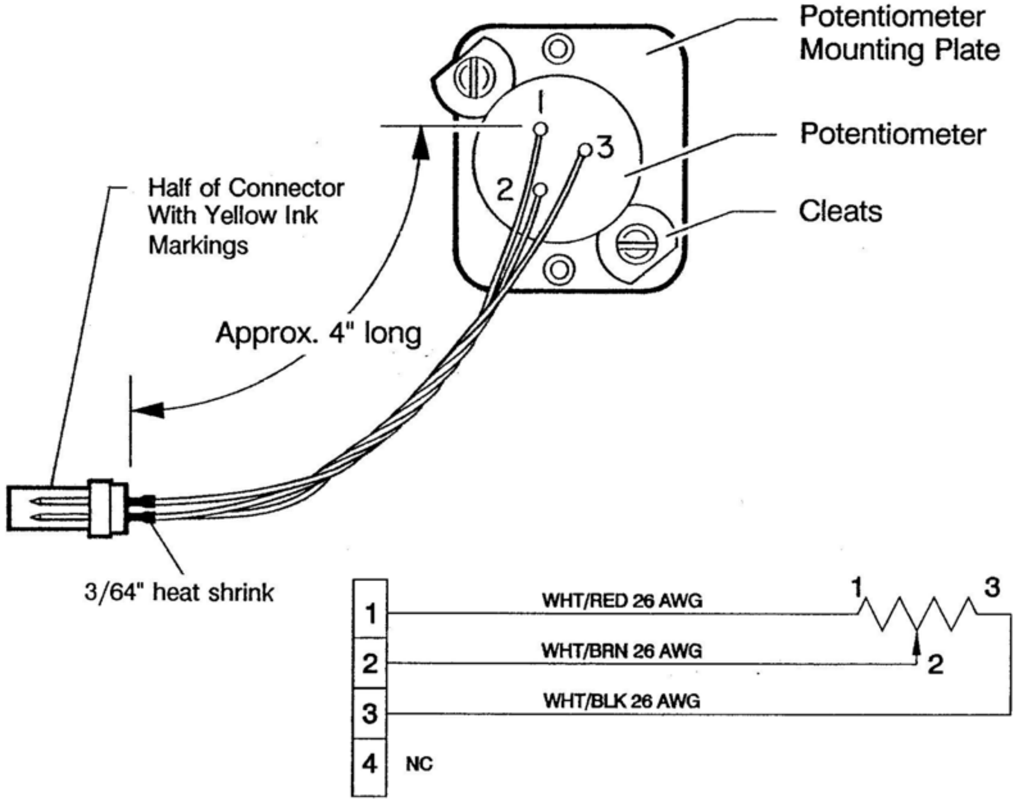


Figure 4-15 Wired wrist roll potentiometer attached to mounting plate

28. Install pot assembly into the left pot cavity of the actuator body and secure using screws (32).

29. Grease all teeth of intermediary gear (43) with Lubriplate. Place gear in actuator body (25).

30. Slip one of gears (33) hub out onto pin of the gripper cylinder tail until approximately flush with the end of the pin. Apply Loctite 222 and tighten gear set screw. Slip second gear (33) hub first onto potentiometer shaft but do not tighten set screw. Figure 4-16 shows a rear view of the wrist roll actuator with the potentiometer and gears installed.

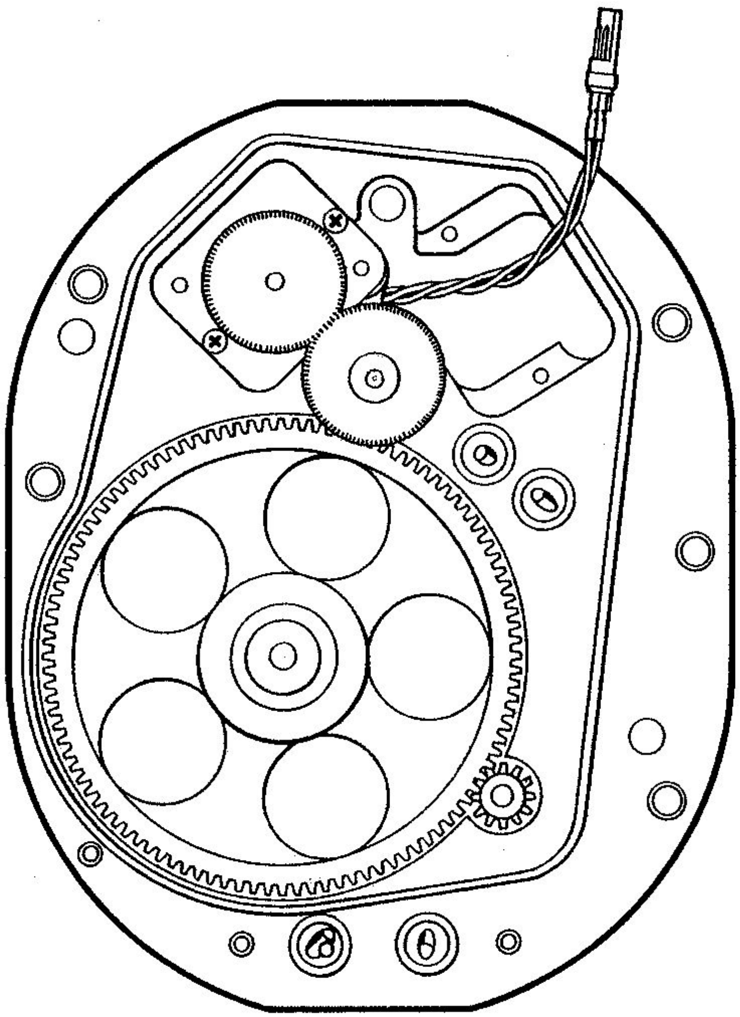


Figure 4-16 Rear view of wrist roll actuator with potentiometer and gears installed

31. Position the actuators output shaft so that any two screw holes align along the vertical center line as shown in Figure 4-17. Turn the gear/potentiometer shaft until 1/2 of the potentiometers total resistance (approximately 2.5K ohms) is measured across pins 1 and 2 of the connector. Apply Loctite 222 to set screw and tighten. Figure 4-18 shows the relationship between the mechanical travel of the actuator and the electrical travel of the feedback potentiometer.

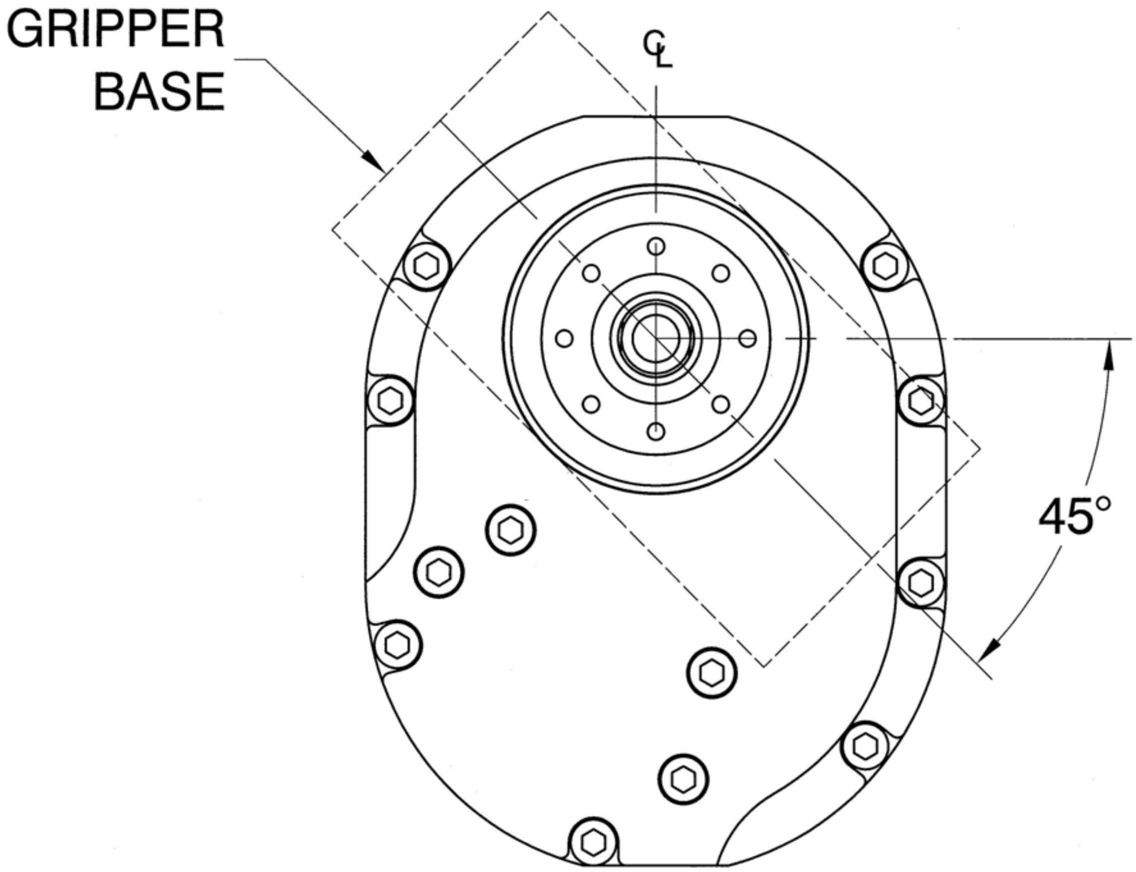


Figure 4-17 Position of wrist roll actuator shaft when centering potentiometer electrical travel

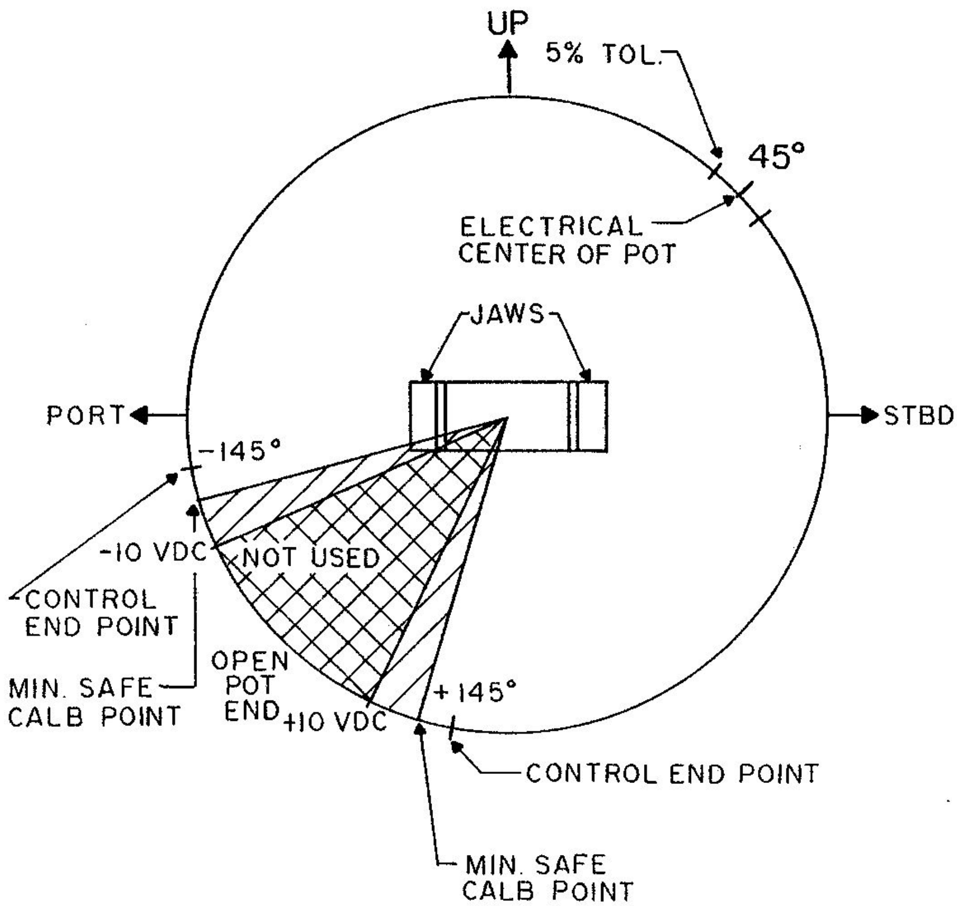


Figure 4-18 Relationship between the mechanical travel of the actuator and the electrical travel of the feedback potentiometer

32. Place dowel pins (54) in rear of actuator body (25).

33. Install O-rings (34),(35) in the rear face of the actuator body.

34. Rear plate (38) is assembled to the actuator body by aligning both dowel pins and gear shafts. Loosely secure using fasteners (1),(39),(40). Note: This plate must be removed for wiring purposes when attaching the yaw actuator assembly.

UPPER ARM VALVE MANIFOLD ASSEMBLY

Reference assembly drawing No. 600-0243-00/01

Tools and materials list:

Silicone grease (for O-rings)
Loctite 242 (blue in color)
9/64" hex key
5/32" hex key
11/32" end wrench
9/16" end wrench
11/16" end wrench
3/4" end wrench
7/8" end wrench
Small flat blade screw driver
==

1. Install hydraulic fittings (14),(15),(16) and hollow hex plug (13) in manifold (12).

2. Install pressure reducing valve (5) and solenoid valve (22) in sub-manifold block (20).

3. Install O-rings (9),(18),(19) in counter bores of sub-manifold block above and attach to manifold plate so that the end of the pressure reducing valve inserts into the receiving hole in the manifold. Secure using screws (21) and Loctite 242.

4. Attach servo valves (8) and check valve (10) with O-rings (9) to manifold plate as shown using screws (6),(7). Position the servo valves so that the valve wiring terminals align with the arrows engraved on the manifold. If the manipulator is force feedback, transducer (27) is installed as shown per drawing and BOM 600-0230-01.

5. Wire connectors (3) per Figure 4-19 slip O-ring (2) on connectors and install in valve can (1). Install hydraulic fittings (4),(16) in valve can.

6. Place O-ring (11) in groove of manifold plate and O-rings (17) into counterbores of manifold plate. Attach valve can to manifold using screws (23) and Loctite 242.

7. Complete wiring of manifold assembly and install connector (25) in valve can using screws (26). Feed wires that run to forearm manifold through fitting.

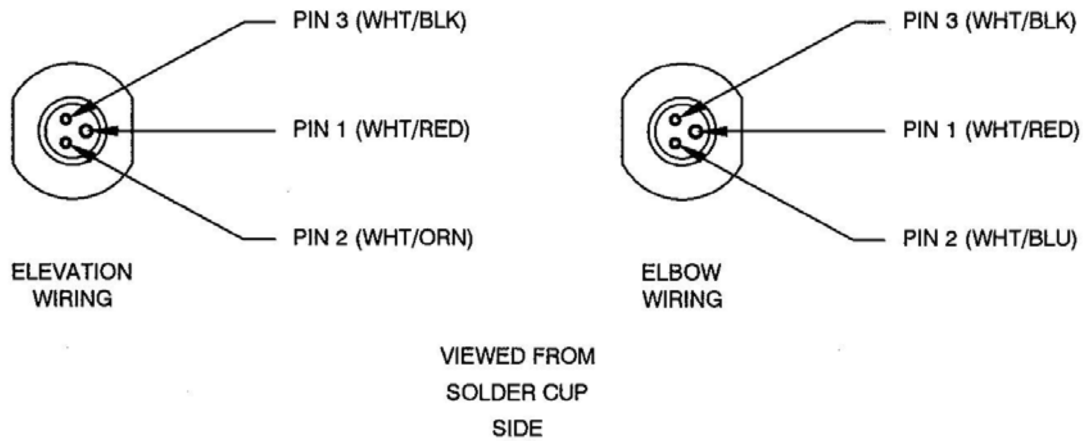


Figure 4-19 Elevation and elbow connector wiring

UPPER ARM ASSEMBLY

Reference assembly drawing No. 600-0244-00/01

Tools and materials list:

Loctite 242 (blue in color)
5/32" hex key
3/16" hex key
1/4" hex key
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1. Attach hoses (7),(10),(19),(20) to manifold ass'y. Orient as shown on ass'y drawing.

2. Press bearings (17) into elevation pivot spool (18). Install spool into left upper arm side plate (12). Orient groove in spool parallel with front edge of side plate and secure with fasteners (4) and Loctite 242.

3. Insert dowel pins (8) in upper arm support bracket (9). Install bracket onto upper arm side plate and secure with fasteners (13) and Loctite 242.

4. Apply silicone grease to O-rings (11) and install in counterbores in manifold plate (6). Install manifold ass'y on to left side plate and secure with fasteners (13),(16) washers (21) and Loctite 242.

6. Route hoses around spool as shown on ass'y drawing.

7. Install right upper arm side plate on to spool, manifold and bracket. Secure with fasteners (4),(13),(16) washers (21) using Loctite 242.

8. Apply silicone grease to O-ring (3) and install in groove in top of valve can. Install valve cover (2) and secure with fasteners (1) and Loctite 242.

9. Attach cover plates (15) to upper arm plates and secure with fasteners (14) and Loctite 242.

UPPER ARM / AZIMUTH ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0245-00/01

Tools and materials list:

Loctite 242 (blue in color)	3/16" hex key
Lubriplate 1200-2 grease	3/8" hex key
Silicone grease	

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1. Insert dowel pins (4) in the right side of azimuth actuator (5).

2. Attach right support bracket (3) using screws (2) and Loctite 242.

3. Insert shoulder elevation pivot pin (1) through bore of support bracket (3).

4. Slide right bearing (20) and upper arm assembly (17) onto shoulder pivot pin supporting the upper arm assembly.

5. Make certain that all hydraulic hoses are routed as illustrated. Attach all hoses to azimuth actuator (5) and insure that all hydraulic hose fittings are tight at both the manifold and actuator.

6. Insert dowel pins (4) in the left side of azimuth actuator. Slide left bearing (20) and left support bracket (6) onto pivot pin and secure using screws (2) and Loctite 242.

7. Install retaining ring (7) in groove of elevation pivot pin.

8. Press bearings (13) into trunnion port caps (12),(18). Grease O-rings (15) and install in O-ring grooves of trunnion port pins (16). Insert pins into trunnion ports. Grease O-rings (14) and install in counterbore on port caps.

9. Install cylinder (19) into lower bores of upper arm ass'y (17) oriented as shown in ass'y drawing. Grease I.D. of trunnion port cap bearings with Lubriplate. Insert trunnion port caps into left and right side plates of upper arm ass'y to capture cylinder trunnions. Secure caps with fasteners (11) and Loctite 242. Route cylinder electrical cable first between the cylinder trunnion and manifold plate and then through the opening between the manifold and arm bracket. Apply silicone grease to connector halves and mate with elevation cable on valve can.

10. Insert pin (8) through the bore of the right support bracket (3), spacers (9) and rod end of cylinder. Install retaining ring (10) in groove of pin.

11. Raise and lower the upper arm to insure that there is no interference.

FOREARM VALVE MANIFOLD ASSEMBLY

Reference assembly drawing No. 600-0246-00/01

Tools and materials list:

Silicone grease
Loctite 242 (blue in color)
5/32" hex key
9/64" hex key
3/16" hex key
11/16" end wrench
Small flat blade screw driver
==

1. Attach servo valves (4)(5) to manifold plate (2) using screws (11),(14). Position the valves so that the valve wiring terminals align with the arrows engraved on the manifold. Note that the valve used in the wrist roll (WR) location is different than the valves used in the wrist yaw (WY), wrist pitch (WP) and gripper (GR) locations. If the manipulator is force feedback transducer (15) is installed per drawing and BOM 600-0234-01.

2. Place O-ring (6) over servo valves and onto shoulder of manifold plate. Attach valve wires per wiring diagram No. 004-3175-00.

3. Place O-rings (3) and (12) in counterbores of manifold plate (2). Place forearm (7) onto manifold assembly and attach first with screws (10) from inside the forearm and then screws (1) using Loctite 242.

4. Install hydraulic fittings (8) and hollow hex plug (9) in the end of forearm (7).

5. Valve wires should be run through hydraulic comp fitting (8).

6. Place O-ring (6) in groove of cover plate (13). Cover plate (13) is installed using screw (1) after completing the forearm/wrist pitch actuator assembly (600-0236-00) and all wiring which occurs in the forearm.

FOREARM / ELBOW ASSEMBLY

Reference assembly drawing no. 600-0247-00/01

Tools and materials list:

Loctite 242 (blue in color)
1/4" hex key
==

1. Press bearing (4) into elbow brackets (3),(5).

2. Insert dowel pins (6) into holes in forearm ass'y (7).

3. Locate right and left brackets (3),(5) onto dowel pins in forearm. Secure plates to forearm using fasteners (1),(2) and Loctite 242.

FOREARM / WRIST PITCH ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0248-00/01

Tools and materials list:

Silicone grease	7/64" hex key	3/16" hex key
Lubriplate 1200-2 grease	9/64" hex key	1/4" hex key
Loctite 242 (blue in color)	3/32" hex key	

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1. Insert bearing (7) into bore of bracket (9) as shown. Slip flat bearing washer (17) over hub of actuator (16). Grease surfaces with Lubriplate grease and slide bracket onto hub of actuator. Check for free rotation.

2. Install shaft seal (18) in potentiometer cover plate (6). Place O-ring (19) in groove of pitch actuator body (16). Grease bore and bearing area of potentiometer cover plate (6) with Lubriplate grease. Feed wires through pot plate and push plate onto end of actuator shaft. Be extremely careful not to pinch wires between the cap and body. Secure plate to actuator body using screws (5) and Loctite 242. Remove excess grease. Check for free rotation.

3. Install O-rings (4)(15) in port plate (3). Feed the 5 wires coming out of the actuator shaft through the center drilled passage of the port plate and then through the center hole of support bracket (9) and finally through the center hole in the side of the forearm (1).

4. Place O-rings (4) and dowel pins (10) in the side of the forearm assembly (1). Attach the pitch support bracket (9) to the forearm assembly (1) using screws (8) and Loctite 242.

5. Carefully and slowly pull wires through forearm (1) and port plate (3) until port plate is seated against the end of the shaft. Attach the port plate using screws (2)(14) and 242 Loctite. Do not fully tighten screws until bracket (11) on opposite side has been installed.

6. Place O-rings (4) and dowel pins (10) in the left side of the forearm (1). Slip bracket (11) onto the actuator shaft and dowel pins. The slot in bracket (11) must center on the middle spline of the shaft. Secure using screws (8) and 242 Loctite.

7. Place O-rings (4) (15) in left port plate (13). Attach port plate (13) to support bracket (11) using screws (2)(14) and 242 Loctite.

8. Insert screw (12) in bracket (11) and tighten to clamp. Use 242 Loctite.

UPPER ARM / FOREARM ASSEMBLY

Reference assembly drawing No. 600-0249-00/01

Tools and materials list:

Lubriplate 1200-2 grease
Silicone grease
Loctite 242 (blue in color)
5/32" hex key
3/16" hex key
==

1. Lightly grease bore of elbow pivot bearings in forearm assembly (14) with Lubriplate grease.

2. Place forearm assembly and bearings (10) between the plates of the arm assembly (1) at elbow. Support both upper arm assembly and forearm assembly. Insert elbow pivot pin (12) through upper arm assembly, bearings, and forearm assembly. Remove any excess grease. Install retaining ring (13) in groove of elbow pivot pin.

3. Press bearings (4) into trunnion port caps (3),(18). Grease O-rings (6) and install in O-ring grooves of trunnion port pins (7). Insert pins into trunnion ports. Grease O-rings (5) and install in counterbore on port caps.

4. Install cylinder (20) into upper bores of arm ass'y (1) oriented as shown in ass'y drawing. Grease I.D. of trunnion port cap bearings with Lubriplate. Insert trunnion port caps into left and right side plates of upper arm ass'y to capture cylinder trunnions. Secure caps with fasteners (2) and Loctite 242. Route cylinder electrical cable through the opening between the manifold and arm bracket. Apply silicone grease to connector halves and mate with elbow cable on valve can. Secure elevation and elbow cables with clamps (8) fasteners (9) and Loctite 242.

5. Insert pin (15) through the bore of the right elbow bracket of forearm ass'y (14), spacers (19) and rod end of cylinder (20). Install retaining ring (17) in groove of pin.

6. Make certain that all hydraulic hoses are routed as illustrated. Attach all hoses to forearm ass'y (14) and insure that all hydraulic hose fittings are tight.

7. Install upper arm cover plate (10) secure with fasteners (11) washers (26) and Loctite 242.

8. Press threaded inserts 24 into right and left guards (21),(22). Install guards and secure with fasteners (23) and Loctite 242.

9. Raise and lower the forearm to insure that there is no interference.

WRIST YAW / WRIST ROLL ACTUATOR ASSEMBLY

Reference assembly drawing No. 600-0238-00 & 600-0229-00

Tools and materials list:

Silicone grease
Lubriplate 1200-2 grease
Loctite 242 (blue in color)
3/32" hex key
3/16" hex key
3/8" hex key
1/2" end wrench
9/16" end wrench
Soldering iron
Wire stripers
==

1. Insert bearing (7) into bore of pot side support bracket (8) "flange up". Slip flat bearing washer (9) over hub of actuator. Grease surfaces with Lubriplate grease and place bracket (8) onto hub of actuator. Check for free rotation.

2. Install shaft seal (16),(17) in pot. cover plate (5). Place O-ring (6) in groove of yaw actuator body. Grease bore and bearing area of pot. cover plate with Lubriplate grease. Feed wires through pot. cover plate (5) and push plate onto end of shaft. Be extremely careful not to pinch wires between the cap and body. Secure to actuator body (10) using screws (4). Check for free rotation and remove excess grease.

3. Install O-rings (3),(13) in the port plate (2). Feed the 3 wires coming out the shaft end through the center drilled passage of the port plate then through support bracket (8) and finally through the rear plate of the wrist roll actuator (Reference item (38) on assembly drawing no. 600-0229-00).

4. Place O-rings (3) and dowel pins (20) in rear plate of roll actuator (21). Do not use Loctite 601 when installing the dowel pins. Loosely attach the support bracket to the rear plate using fasteners (18). (Do not tighten fasteners (18) until bracket (11) is installed).

5. Carefully and slowly pull wires until port plate (2) is seated against the end of the shaft. Attach the port plate using fasteners (1),(15).

6. Terminate wires with connector half shown on the wrist roll assembly drawing no. 600-0229-00 as item (28) and re-attach wire retaining plate (37) on drawing 600-0229-00.

7. Mate connector halves and use heat shrink to prevent connector from pulling apart.

8. Coil wire service loop in the potentiometer cavity of the wrist roll actuator body making certain it will not get into the potentiometer drive gears and re-attach rear plate of wrist roll actuator.

9. Place dowel pins (20) and O-rings (3) in the rear plate of the wrist roll actuator (21). Do not use Loctite 601 when installing dowel pins.

10. Couple the wrist roll and wrist yaw actuator by slipping splined support bracket (11) onto splined shaft of the yaw actuator (10). The slot in the support bracket must align with the screw hole in the end of the yaw shaft that is on center on a spline tooth. Attach the bracket using fasteners (19).

11. Place O-rings (3),(13) in counter bores of port plate (14) and attach to support bracket (11) using fasteners (15). After plate is attached bolt to end of actuator shaft using fasteners (1). After plate is pulled up to and sealing on the end of the splined shaft install and tighten screw (12) to tighten slotted splined plate on shaft.

ARM / WRIST ASSEMBLY

Reference assembly drawing No. 600-0250-00/01

Tools and materials list:

Silicone grease
5/16" Hex key
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1. Place dowel pins (2) in wrist assembly (5).

2. Place O-rings (3)(4) in counter bores of yaw actuator body.

3. Mate the electrical connector.

4. Align dowels pins with holes and couple the arm and wrist sections. Secure using screws (6) and 242 Loctite. Caution: Use care to prevent pinching wires between the actuator faces.

RAPTOR FINAL ASSEMBLY

Reference assembly drawing No. 700-9061-00

Tools and materials list:

Loctite 242 (blue in color)
1/8" hex key
5/32" hex key
1/2" end wrench
5/8" socket & torque wrench
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1. Remove side plate and lever link of gripper assembly (2) as shown. Extend the gripper piston rod.

2. Place gripper assembly onto output shaft of wrist roll actuator. Secure gripper to wrist roll actuator output shaft using screws (5) and Loctite 242.

3. Set swivel (3) in slot of bottom lever link. Attach swivel to the piston rod with screw (4) and Loctite 242. Hold rod with 1/2" end wrench (being careful not to damage rod) and tighten screw with 5/8" socket.

4. Reinstall lever link and side plate. Loctite all screws.