Chapter 1

INTRODUCTION

1.1 4400-Series System Overview

The 4400-Series Production Sputtering Systems are manufactured in three (3) specific configurations, as follows:

MODEL 4400 A manually-loaded system capable of limited automatic operation, but requiring manual selection of target and sputtering mode. The Model 4400 sputtering head is equipped with four (4) 8" round cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. (Mo shields, vane shutter, and full circle shutter.)

MODEL 4450 A manually-loaded system capable of fully automatic operation. The Model 4450 sputtering head is equipped with three (3) Delta™ cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. Using optional adaptors, the cathode apertures can also accept 8" round targets. (Mo flame sprayed shields and shutters standard; W-C flame sprayed shields and shutters optional.)

MODEL 4480 A cassette-to-cassette automatic wafer loading system capable of fully automatic operation. Capacity per pallet (in automatic wafer handling mode):

SIZE WAFERS	QTY. PER PALLET
3" (75mm)	16
4" (100mm)	12
5" (125mm)	8
6" (150mm)	7

The Model 4480 sputtering head is equipped with three (3) Delta™ cathode positions, one (1) of which may be fitted with an in-process heater fixture in place of a target. Using optional adaptors, the cathode apertures can also accept 8" round targets. (Mo flame sprayed shields and shutters standard; W-C flame sprayed shields and shutters optional.)

The Perkin-Elmer 4400-Series Production Sputtering Systems deposit a wide

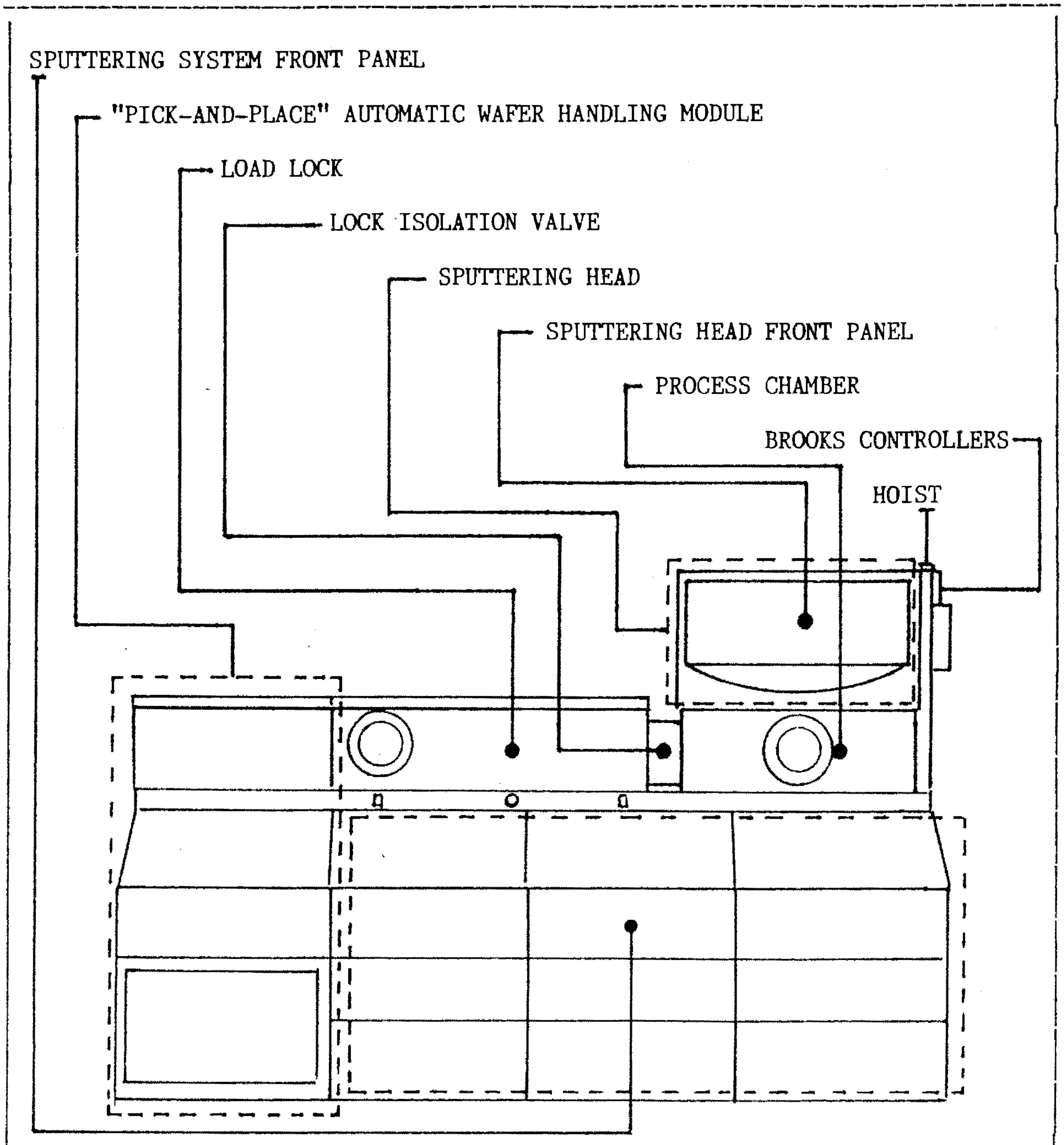


FIGURE 1-1

THE MODEL 4480 SPUTTERING SYSTEM (FRONT VIEW) variety of materials onto substrates such as ceramics, metals, plastics, glass and semiconductors. The systems also can be used for RF sputter-etching, a process in which material is removed from, rather than being deposited on, the substrates prior to sputter deposition.

These sputtering systems sequentially deposit thin films of up to three different materials onto a single substrate, thus attaining sandwich-structured films such as multi-layer optical interference filters or semiconductor devices. Resulting thin films range in thickness from a few Angstroms up to several microns.

For improved throughput and added convenience, the high-capacity load lock permits substrate wafer loading without breaking vacuum in the process chamber. A microprocessor-based Main System Controller (MSC) provides complete automation of sputtering operations on Models 4450 and 4480 (target and mode selection are NOT automated on the Model 4400).

Table 1-1 compares the features of different 4400-Series systems.

TABLE 1-1
COMPARISON OF FEATURES

FEATURES	4400	4450	4480
4400-SYSTEM BASIC CONSOLE	STD.	STD.	STD.
MAIN SYSTEM CONTROLLER (MSC)	STD.	STD.	STD.
DGC-III ION TUBE CONTROLLER	STD.	STD.	STD.
DELTA™ CO-SPUT HEAD WITH FLAME SPRAYED SHIELDING	N/A	STD.	STD.
DELTA™ TARGETS	N/A	STD.	STD.
8" ROUND TARGETS	STD.	OPTION	OPTION
RF OR DC WITH RF BIAS	STD.	STD.	STD.
RF POWER SPLITTING	STD.	N/A	N/A
AUTOMATIC WAFER HANDLING	N/A	N/A	STD.
PE-6100 DATA TERMINAL	STD.	STD.	STD.
LOAD LOCK HI-VAC PUMP	OPTION	OPTION	STD.
PROCESS CHAMBER TURBO PUMP	OPTION	OPTION	OPTION
LOAD LOCK RADIANT HEAT	OPTION	OPTION	STD.
IN-PROCESS RADIANT HEAT	OPTION	OPTION	OPTION
BROOKS AUTOMATIC GAS CONTROL FOR 1, 2, OR 3 GASES	OPTION	OPTION	OPTION

STD = STANDARD OPTION = OPTIONAL N/A = NOT AVAILABLE

1.1.1 Description of Features

- High-rate DC magnetron sputtering (4450 and 4480 only). Aluminum and aluminum alloys can be sputter deposited at rates of up to 200 Angstroms per kilowatt-minute.
- Optimum use of processing equipment for maximum wafer efficiency and production rate.
- Maximum versatility to process a variety of products, applying the proper sputtering operation for each application.
- High vacuum to ensure contamination-free conditions for critical deposition processes (e.g., aluminum alloys, platinum).
- Specialized pallets for ease of substrate loading/unloading.
- "Drop-in" targets for quick target changes -- no screws to bother with.
- "Snap-out" deposition shields for quick, easy maintenance.
- Fail-safe system protection (e.g., water-flow switches to shut down system automatically in the event of cooling system failure, etc.)
- Additional safety features for operator and system protection (e.g., two-button initiation of pump-down and load sequences, interlocked equipment covers, etc.).

1.2 The Sputtering Process

Sputtering is a momentum transfer process in which atoms from a cathode/target are driven off (or "sputtered") by bombarding ions. In this process the momentum of the bombarding particles is more important than the energy. For example, a hydrogen or helium ion accelerated to 3,000 eV will cause very little sputtering compared to an ion of argon (which is chemically inert) with the same 3,000 eV energy, simply because the much lighter hydrogen or helium ion has much less momentum.

Sputtered atoms travel until they strike a substrate, where they are deposited to form the desired thin film. As individual atoms, they can be chemically active and form compounds with the ions and atoms of the bombarding gas. For this reason, inert argon typically is used as the bombarding gas. In some applications, however, a reactive gas is intentionally added to the argon to alter the chemical composition of the deposited film (e.g., nitrogen gas in combination with tantalum sputtering to form tantalum nitride, TaN).

When argon atoms strike the target, their electrical charge is neutralized and they return to the process as atoms. If the target is an insulator, the neutralization process results in a positive charge on the target surface. This charge may grow so large that the bombarding ions are repelled and the sputtering process stopped. To allow the process to continue, polarity of the target must be reversed, attracting enough electrons from the discharge to eliminate the surface charge. This periodic reversal of polarity is accomplished automatically by applying RF voltage to the target assembly (hence the term "RF sputtering").

Of interest here is the diode rectifier-like behavior of the target and discharge system. This results from the vast difference in mobilities of ions and electrons. Electrons, being so much faster, are attracted in greater numbers to the target during the positive half-period of the RF voltage than are ions during the negative half-period. Thus, the target develops a negative DC bias.

4400-Series Production Sputtering Systems perform a number of sputtering processes (described below), each of which is ideal for a different application.

1.2.1 RF Diode Sputter Deposition

When the vacuum set point is reached, sputtering gas (typically argon) is introduced into the process chamber at a pre-selected rate (typically 40 sccm). A plasma, or self-sustaining glow discharge, initiated by an automatic plasma igniter, appears when RF power is applied between the target and electrical ground, ionizing the argon gas.

A negative (-) potential applied to the target, as a result of the applied RF power, attracts the ionized argon at a momentum determined by a) the magnitude of the applied potential and b) the mass of the ion. The momentum of the incoming argon ion is transferred to the target material, causing surface atoms or molecules of target material to be ejected (sputtered). These sputtered atoms travel across the gap separating the target (cathode) and substrate table (anode), and are deposited on the substrates (wafers) which are arranged on the substrate pallet.

1.2.2 RF Magnetron Sputter Deposition

RF magnetron and RF diode sputtering are very similar, except that during RF magnetron sputtering a magnetic field deflects the secondary electrons (which are produced during normal sputtering operation) away from the substrates. The sputtering process, which is cooler than RF diode sputtering, permits materials to be sputter deposited on substrates at lower temperatures and greatly reduces the chance of radiation damage to delicate substrates.

Because the impedence of a magnetron is lower, higher power densities are possible at lower potentials, effecting higher sputter rates.

1.2.3 DC Magnetron Sputter Deposition

DC magnetron targets enhance the plasma density and increase the sputtering rate, by trapping electrons in an electromagnetic "envelope." This "envelope" is formed when lines of the magnetic field enter and exit the target face and when the loci of maximum transverse magnetic fields form a closed figure. Because the currents involved are very large, a separate, positively-biased anode (a dark space shield) is used to collect the electrons. A similar dark space shield is used in RF diode and RF magnetron deposition. This dark space shield prevents the sides of the target and target backing plate from sputtering.

1.2.4 RF Sputter-Etching

Essentially the reverse process of RF diode sputter deposition, in which the substrate table becomes the cathode (negative pole) and the target assembly becomes the anode (positive pole). Under these circumstances, surface material from the substrates is ejected. Surface impurities are ejected along with substrate material, making this process useful for pre-cleaning substrates prior to sputter deposition. In order to prevent ejected material from contaminating the target, a shutter is positioned between target and substrate.

1.2.5 Bias Sputter Deposition

Bias sputtering combines the DC or RF sputtering and the RF etching operations. While DC or RF power is applied to the target, a small amount of RF is also applied to the substrate table. As a result, the substrate and target are both bombarded by ions (the substrate to a lesser extent than the target). In many applications this process yields superior quality films than can be attained using DC or RF sputtering with grounded substrates. Bias sputtering influences the crystal structure, and tends to re-sputter trapped argon from the growing film during deposition and rearrange individual atoms of the sputtered material; this improves stoichiometry and step coverage. Bias sputtering can be used to adjust film resistivity and film stress to desired levels.

1.2.6 Reactive Sputtering

Some metals, such as nitrides and oxides, are best deposited by this method: the target is the parent metal and a small amount of nitrogen or oxygen is introduced into the process chamber along with the argon sputtering gas. Because ionized gases are typically highly reactive, a film deposited in a mixture of argon and a reactive gas will often form a compound with the reactive gas (e.g., a nitride or an oxide).

WARNING

IF OXYGEN IS TO FORM 7% OR MORE OF THE SPUTTERING GAS MIXTURE, SPECIAL PRECAUTIONS MUST BE TAKEN (E.G., USING SPECIAL MECHANICAL PUMP OILS [SUCH AS FOMBLIN] AND USING OXYGEN SERVICE PUMPS). CONSULT YOUR PERKIN-ELMER FIELD SERVICE REPRESENTATIVE.

1.2.7 Co-Deposition

Sometimes called co-sputtering or dual deposition, co-deposition is identical in principle and practice to other types of sputter deposition, except that two targets (typically of different materials) are simultaneously activated. Substrates passing sequentially and repeatedly beneath the targets are coated with alternating, very thin films of the two materials. Under certain circumstances, the resultant film can be equivalent to or better than one formed using a composite target. During co-deposition, both targets may be RF, both DC, or one RF and one DC.

1.2.8 Target Pre-Cleaning

RF or DC power is applied to the target to remove oxidation and accumulated foreign material. Oxidation occurs each time the system is vented to atmosphere, and is also present on newly installed targets. Pre-cleaning is also recommended prior to processing each batch of substrates when certain alloys are used. In order to prevent ejected material from contaminating the substrate table, a shutter is normally positioned between it and the target.

CAUTION

IN THE CASE OF DC MAGNETRON PRE-CLEANING, TEMPERATURES REACHED DURING TARGET PRE-CLEANING MAY BE SUFFICIENT TO WARP SHIELDS. FOLLOW PRE-CLEANING PROCEDURES GIVEN BELOW.

1.2.8.1 Pre-Cleaning a New Target

When pre-cleaning ("burning-in") a new target, especially aluminum, the target must slowly be brought up in power from about 2 kW to the full power of the power supply being used (5 kW or 10 kW). Pre-cleaning must continue until all evidence of arcing disappears, and target power and voltage are stabilized. THIS AMOUNT OF SPUTTERING WILL WARP A CLOSED SHUTTER. It is therefore recommended that pre-cleaning of a new target be done with the an empty pallet in the chamber, in the normal sputter mode (i.e., shutters

OPEN).

1.2.8.2 Pre-Cleaning a Contaminated Target

A target is considered to be contaminated if it has been exposed to atmosphere. Pre-cleaning a contaminated target consists of removing 500 - 1000 Angstroms of material from the target (the removed material is usually deposited onto closed shutters). IF MORE THAN 1000 ANGSTROMS OF MATERIAL IS TO BE REMOVED AT ONE TIME, THE PROCEDURE FOR PRE-CLEANING A NEW TARGET MUST BE FOLLOWED, TO PREVENT WARPING OF SHIELDS.

Use Table 1-2 as an approximate guideline for removing the desired thickness of material from your target.

TABLE 1-2

MAT'L	8" ROUND RF DIODE	8" ROUND DC MAGNETRON	DELTA RF DIODE	DELTA RF MAGNETRON	DELTA DC MAGNETRON
Ag	140	290			480
Al	40	120			200
Al_2O_3[3]	12			40	
Au	100	310			400
C		5			
Cr	35	110			180
CrNx	25	115			160
$CrSi_2$	18	90			125
Cu	75	280	80		320
Mo	30	130			220
$MoSi_2$	20	140			150
Ni[2]	40	150			
Nichrome	35	165			125
Pd	80	280			390
Perm-alloy[2]	30	150			
Pt	60	170			280
Quartz[3]	20		25	50	
Si[3]	20			90	
Si_3N_4[3]	10			30	
Ta	20	110			150
TaNx	20	100			140
Ti	30	110			140
TiNx	15	25			125
Ti/W(10%)	30	110			150
W	20	125			150
WNx		90			125
Zr	40				

Rates shown above are given in Angstroms/min/kW, and are typical only. Actual rates for any given system will depend upon process and system parameters. Rates are approximately linear with applied power except where otherwise indicated. The maximum power levels for 8-inch round targets are 5 kW DC/2 kW RF; for Delta™ targets 10 kW DC/3 kW RF. Some materials, due to their nature, are limited to power levels substantially less than the maximum power rating of each cathode type.

NOTES:

[1] Insufficient data available for most materials with RF Delta™ operation -- DC magnetron recommended for metals.

[2] Ferromagnetic materials -- magnetron mode is possible with thin targets only, but not recommended.

[3] Dielectric materials -- require the use of RF power. Rates are non-linear.

Chapter 2

MODEL 4400

2.1 OVERVIEW: Model 4400

FEATURES OF THE MODEL 4400

- MICROPROCESSOR MAIN SYSTEM CONTROLLER (MSC)
- SPUTTER HEAD ASSEMBLIES FOR UP TO FOUR (4) 8" ROUND CATHODES
- RF/RF POWER SPLITTING (OPTIONAL - DIODES ONLY)
- DGC-III ION GAUGE CONTROLLER
- BROOKS AUTOMATIC GAS CONTROL SYSTEM FOR 1, 2, OR 3 GASES (OPTIONAL)
- PERKIN-ELMER PE-6100 DATA TERMINAL
- LOAD LOCK HI-VAC PUMPING (OPTIONAL)
- LOAD LOCK 200 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- RF BIAS
- IN-PROCESS 350 DEGREE CENTIGRADE RADIANT HEATER (OPTIONAL)
- SUBSTRATE TABLE INDEXING
- ULTRA-HIGH VACUUM COMPONENTS
- HYDROGEN GETTER PUMP (OPTIONAL)
- FULL FLOOD MEISSNER TRAP
- THREE (3) OPERATING MODES (WITH OR WITHOUT RF SUBSTRATE BIAS):
    * DC MAGNETRON
    * RF MAGNETRON
    * RF DIODE

The Model 4400, in a typical configuration, is controlled via the following: the Main System Controller (MSC), the Servo Match™ Controller, The DGC-III Digital Ion Gauge Controller, the Load Lock Turbomolecular Pump Frequency

Controller, the DC Magnetron Controller, the RF Power Supply and Power/Voltage Stabilizer, and the Precision Table Rotation Speed Control.

2.1.1 Main System Controller (MSC)

The MSC is the communication link between opeator and system. It controls, directly or indirectly, all process and substrate loading instruction sequences programmed by the operator.

The MSC may be used in the manual mode, by manipulating toggle switches, to control the operation of the pumps, valves, and mechanical assemblies. WHEN USED IN THE MANUAL MODE, THE MSC SAFETY INTERLOCK SYSTEM IS INACTIVE. THE MANUAL MODE IS FOR THE USE OF SERVICE PERSONNEL AND SYSTEM ENGINEERS ONLY.

For all routine production operations, the system is designed to be controlled from the MSC in the AUTOMATIC mode. In the automatic mode, the MSC can control any pre-programmed sequence of the following operations:

- Process Time (Deposition or Etch)
- DC and RF Power/Voltage ON/OFF
- DC and RF Power/Voltage Levels
- Process Gas ON/OFF
- Process Gas Flow Levels (Requires Brooks Automatic Gas Controller Option; otherwise, the throttle valve is pre-set at 40 sccm at 10 milliTorr)
- Process Gas Pressure (Requires Automatic Pressure Control Option, Included with the Brooks Gas Controller Option; otherwise, set via manually operated toggle-ON/OFF and micrometer flow regulating needle valves)
- Process Heat ON/OFF (Requires Process Heat Option)
- Automatic cryo pump regeneration
- Automatic Meissner trap fill cycles and regeneration
- Automatic pump down from atmosphere
- Load Lock Heat ON/OFF (Requires Load Lock Heat Option)
- Transfer of Substrate Pallet from Load Lock to Process Chamber and Back
- Substrate Table Height (in Process Chamber)

The following functions CANNOT be controlled from the system controller (i.e., they must be selected manually by the operator, using switches on the control panel of the sputter head assembly);

- Sputtering Mode SELECTION (i.e., RF Deposit, Bias Deposit, Etch, DC Deposit)

- Shutter Position

- Target Selection (TARGET NUMBER 1, 2, 3 OR 4)

During the process cycle, the computer monitors the process gas pressure and flow control system option (if installed). If any of the parameters associated with these subsystems varies unacceptably from programmed levels, the computer will halt the process and sound an alarm.

2.1.2 DGC-III Ion Gauge Controller

The Perkin-Elmer DGC-III controller monitors base pressure in both the process chamber and the load lock. Pressure set point values are programmed into the DGC-III front panel by the operator.

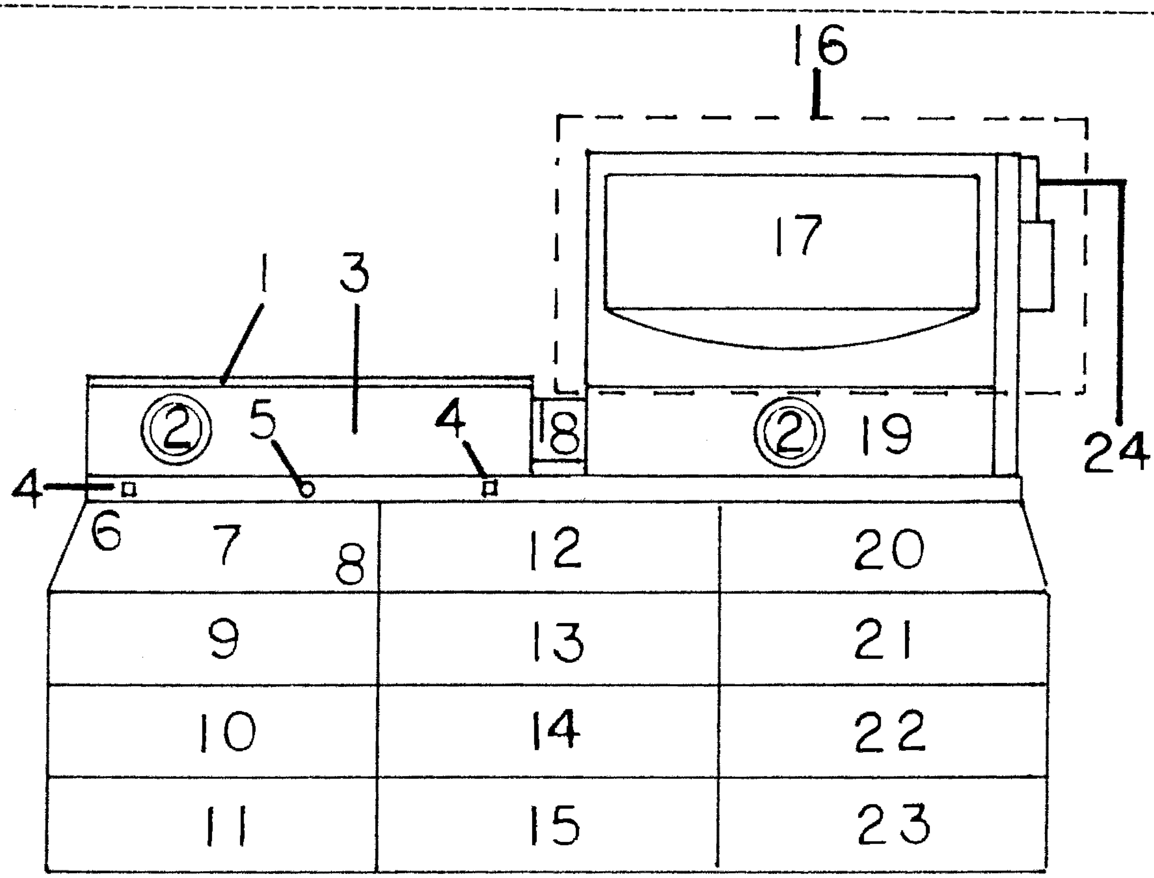


FIGURE 2-1

MODEL 4400 SYSTEM LAYOUT

1. LOAD LOCK LID
2. VIEW PORTS
3. LOAD LOCK
4. LID UP/DOWN SWITCHES
5. EMERGENCY STOP PUSHBUTTON
6. TARGET ELAPSED TIME INDICATOR
7. PRECISION TABLE ROTATION CONTROL
8. DGC-III ION GAUGE CONTROLLER
9. ION SWITCH PANEL
10. LOAD LOCK HEATER POWER SUPPLY
11. NOT USED AT THIS TIME
12. MSC (MAIN SYSTEM CONTROLLER)
13. PROCESS PRESSURE REGULATOR
14. L/L TURBO FREQUENCY CONTROLLER
15. WATER FLOW SWITCHES
16. 4400 SPUTTER HEAD ASSEMBLY
17. SPUTTER HEAD CONTROL PANEL
18. LOAD LOCK ISOLATION VALVE
19. PROCESS CHAMBER
20. DC MAGNETRON CONTROLLER
21. RF POWER/VOLTAGE STABILIZER
22. SERVO-MATCH CONTROLLER
23. PROCESS TURBO FREQUENCY CONTROL
24. IN-PROCESS HEATER POWER SUPPLY
25. BROOKS GAS FLOW CONTROLLERS

2.2 Model 4400 System Layout

Figure 2-1 shows a front view of the Perkin-Elmer Model 4400 Production Sputtering System. Each numbered item corresponds to a description, below.

Chapters 5, 6, and 7 contain detailed descriptions (and operating information where applicable) for all 4400-Series subsystems and controls.

2.2.1 Load Lock Lid Activator [ITEM No. 4]

The Load Lock Lid Activator is controlled by two UP/DOWN rocker switches located on the front surface of the load lock. The operator must simultaneously select the same function on each switch in order to move the load lock lid. The load lock lid is interlocked to the MSC, making it impossible to start a process sequence, pump the load lock or open the isolation valve (in the automatic mode only) without first closing the load lock lid.

2.2.2 Target Elapsed Time Indicator [ITEM No. 6]

The target timer is an optional device used to record the number of sputtering-hours (measured to the nearest 1/10 hour) accumulated on each target.

2.2.3 Precision Table Rotation Speed Control [ITEM No. 7]

The precision table rotation speed controller allows the operator to select a table rotation in the range 0 - 10 rpm. Adjustments are made via switches and potentiometers on the front panel of the table drive unit.

The precision table drive also allows the operator to index the pallet within the process chamber (at speeds up to 5 rpm), and to pre-set a desired number of table rotations (at rotation speeds up to 10 rpm).

2.2.4 Ionization Switch Panel [ITEM No. 9]

The ionization gauge switch panel turns ON and OFF the Bayerd Alpert ion gauge tubes automatically. If the system is NOT equipped with a load lock Hi-Vac pump, there are only two (2) ion gauge tubes, either of which may be selected from the DGC-III controller (see Chapter 5).

Systems equipped with a load lock Hi-Vac pump are also equipped with three (3) ion gauge tubes. The DGC-III only allows the operator to choose between two (2) tubes. A rocker switch mounted on the front panel of the ion gauge controller is used to overcome this limitation:

"1" OR "2" SELECTED FROM DGC-III	ROCKER SWITCH POSITION	ION GAUGE TUBE SELECTED
1	N/A	LOAD LOCK
2	RIGHT SIDE IN	PROCESS CHAMBER
2	LEFT SIDE IN	PROCESS CHAMBER CRYO PUMP STACK

NOTE: THE DGC-III I/T BUTTON IS USED TO TOGGLE BETWEEN ION GAUGES AND THERMISTORS. THE SETTINGS DESCRIBED ABOVE APPLY ONLY WHEN ION GAUGES ARE SELECTED.

2.2.5 Load Lock Heater Power Supply [ITEM No. 10]

OPTION

The optional load lock heater elements are powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON VIA MANUAL CONTROL (OVERRIDES MSC).

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 5 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 200 degrees Centigrade is acheived after five (5) minutes.

2.2.6 Process Pressure Regulator [ITEM No. 13]

OPTION

Included as part of the automatic gas option (with the Brooks controller[s]), the process pressure regulator is used a) to servo-control the throttle valve automatically in order to maintain a pre-set pressure level (at a selected gas flow rate) in the process chamber, or b) (in the MANUAL mode) to switch-select one of two throttle valve positions: 100% open or closed to a position which maintains chamber pressure at 10 milliTorr with a 40sccm gas flow.

2.2.7 Load Lock Turbo Pump Frequency Controller [ITEM No. 14]

OPTION

Turbomolecular pump(s) reach operating speeds of about 35,000 rpm and must be slowly ramped up to speed. The turbo pump frequency controller automatically performs this function by multiplying the line frequency at a controlled rate to acheive the desired RPM. A meter on the front panel of this controller indicates the range of turbo speed.

A switch point at 80% of full speed is used to interlock the high vacuum valve.

2.2.8 Water Flow Switches [ITEM No. 15]

Water flow switches are placed in series with the cooling system water lines, and maintain an OPEN switch position as long as water continues to flow through the switch. Interruption of water flow or switch failure causes the switch to CLOSE, which is interpretted by the MSC as a hard error (i.e., an error which aborts the process). Each flow switch is factory pre-set for the specific minimum flow rate recommended for the device being cooled (see service manual for further details).

2.2.9 DC Magnetron Control [ITEM No. 20]

OPTION

Regulates the output power of the 5 or 10 kW DC power supply to a constant volt-amp (VA) product.

2.2.10 RF Power/Voltage Stabilizer [ITEM No. 21]

OPTION

Maintains constant power or voltage for RF sputtering despite considerable variations in AC line voltage, gas pressure, work characteristics, and temperature. Selecting POWER maintains pre-set power while varying the voltage. Selecting VOLTAGE maintains pre-set voltage while varying the power.

2.2.11 Servo Match™ Panel [ITEM No. 22]

OPTION

Automatically servos the RF tuning and load circuits located in the sputter head assembly, adjusting the circuits for minimum reflected power and the load circuit to compensate for the impedence of a target, or selection of a different gas or power level.

2.2.12 Process Chamber Turbo Pump Frequency Controller [ITEM No. 23]

OPTION

Same as Load Lock Turbo Frequency Controller (ITEM No. 14, above).

2.2.13 In-Process Heater Power Supply [ITEM No. 24]

OPTION

The in-process heater element is powered by this supply. It has a three-position switch mounted on the front panel. The positions have the following functions:

AUTO	ON/OFF control via the MSC.
OFF	OFF.
ON	ON.

When the heaters are switched ON, 208 VAC is applied to the heater elements at approximately 8 amps. Substrate temperature is a function of this current and the duration of heat application; nominal maximum heat of 350 degrees Centigrade is acheived after five (5) minutes.

2.2.14 Brooks Automatic Gas Controllers [ITEM No. 25]

OPTION

Independent flow levels of one to three gases are controlled by optional Brooks gas flow controllers. Both process gas pressure and individual gas flow levels are independently programmed via the MSC. Gas flow levels are conveniently displayed on the PE-6100 Data Terminal in sccm (Standard Cubic Centimeters per Minute).

Chapter 5

SYSTEM CONTROLS

Most subsystems and controls are common to all 4400-Series systems, while some are available only on specific models. Each component discussed below may be assumed to be common to ALL systems unless otherwise noted.

The following subsystems are described in this chapter:

5.1 Load Lock

5.2 Process Chamber

5.3 8" Round Sputter Head Assembly (Model 4400)

5.4 Delta™ Sputter Head Assembly (Models 4450/4480)

5.5 Power Supplies

5.6 DGC-III Ion Gauge Controller

5.7 The PE-6100 Data Terminal

5.8 Safety Features

The most important element of the control system, the Main System Controller (MSC), is sufficiently complex to warrant a separate chapter. It is described in Chapter 6.

The Automatic Wafer Handling System (an advanced feature of the Model 4480 Production Sputtering System) is described in Chapter 7.

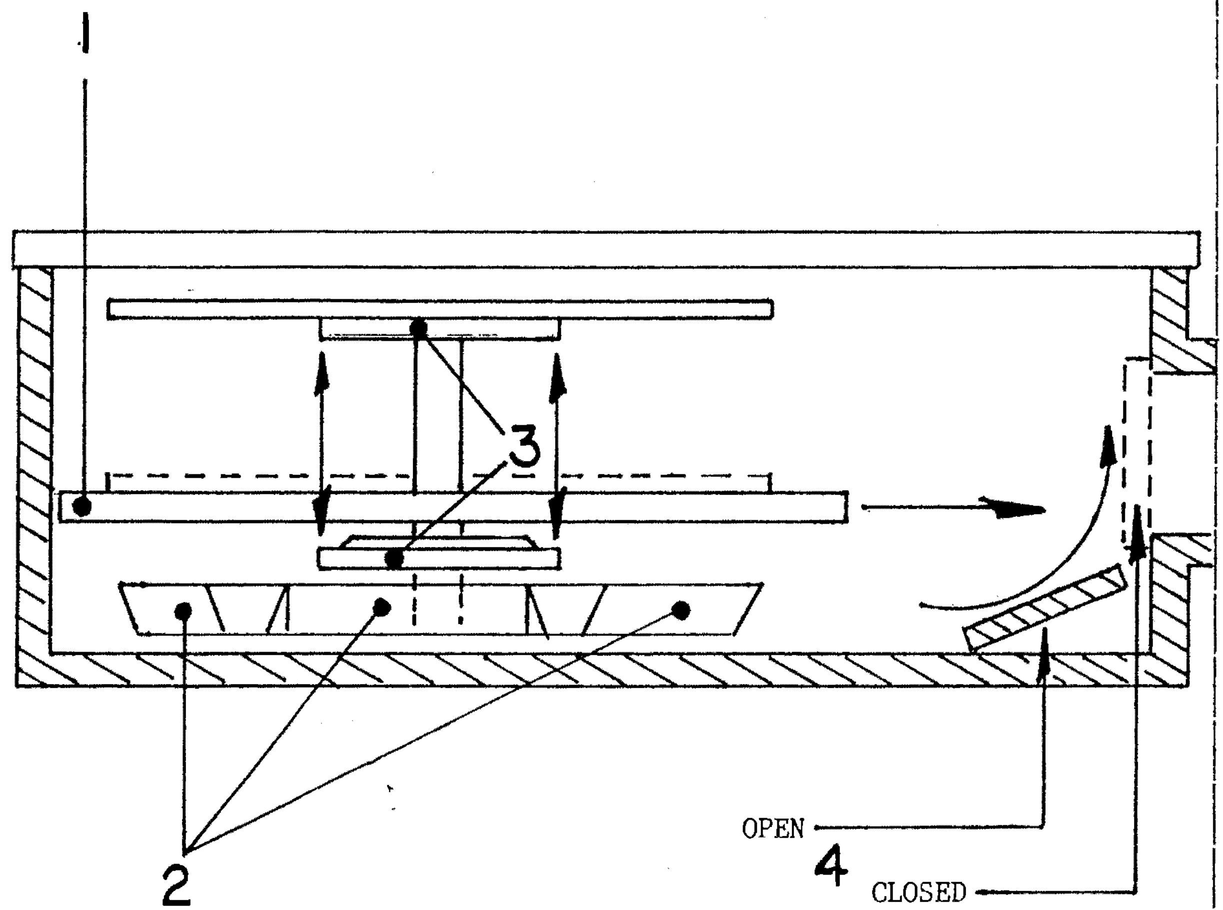


FIGURE 5-1

LOAD LOCK (INTERIOR)

1. SUBSTRATE PALLET CARRIAGE
2. LOAD LOCK RADIANT HEATERS (STANDARD ON MODEL 4480 ONLY)
3. LOAD LOCK ELEVATOR
4. LOAD LOCK ISOLATION VALVE (SHOWING OPEN AND CLOSED POSITIONS)

5.1 System Load Lock

The load lock assembly shown in Figure 5-1 is mounted at the left end of the sputtering system and rests on top of the system main frame, on which the process chamber is also mounted. (On the Model 4480, the load lock is located immediatedly to the right of the automatic wafer handling module cassette chamber.)

The 4400-Series load lock permits the loading, pre-heat processing (optional on Models 4400 and 4450, standard on Model 4480), and unloading of substrates while the process chamber is completely isolated from atmosphere. It is designed specifically for rapid transfer of substrates from atmosphere to high vacuum (5×10^{-7} Torr in less than 3.5 minutes). It also functions to keep the targets and process chamber at high vacuum, thus reducing the possibility of oxidation, condensation, and atmospheric contamination. The load lock helps assure repeatability and makes it unnecessary to perform a target pre-cleaning operation before processing each new batch of substrates for most common sputtered materials.

The load lock chamber is typically rough pumped to 150 milliTorr by the mechanical pump (which is shared with the process chamber vacuum system) and brought to high vacuum by the load lock turbo pump (optional on Models 4400/4450, standard on Model 4480)\ before the load lock isolation valve is opened to allow transfer of the substrate pallet between load lock and process chamber. Operation of the pumps is regulated by the MSC.

5.1.1 Load Lock Heater

The load lock heater consists of quarts lamps, reflectors, and a time-proportional temperature controller. Switching logic is provided by the MSC. Its purpose is to aid in the removal of water vapor from the substrates before they are introduced into the process chamber.

The load lock heater applies heat (up to 200 degrees Centigrade) to a pallet loaded with substrates before transferring the pallet into the process chamber. The ENABLE/CYCLE START command from the MSC turns the heater on automatically while the load lock is brought to high vacuum by its turbomolecular pump (load lock turbo pump optional on Models 4400/4450). When a pre-set time value is met, the heater power supply is turned off and the load lock isolation valve (i.e., door) is opened, allowing the substrate pallet to be transferred into the process chamber.

The load lock heater power supply is mounted on the sputtering system front panel.

5.1.2 Load Lock High Vacuum Pump

The 170 liter-per-second turbomolecular pump is used to remove water vapor and other contaminants from the load lock chamber, producing a higher vacuum in the load lock that allows the process chamber to a) remain cleaner, and b)

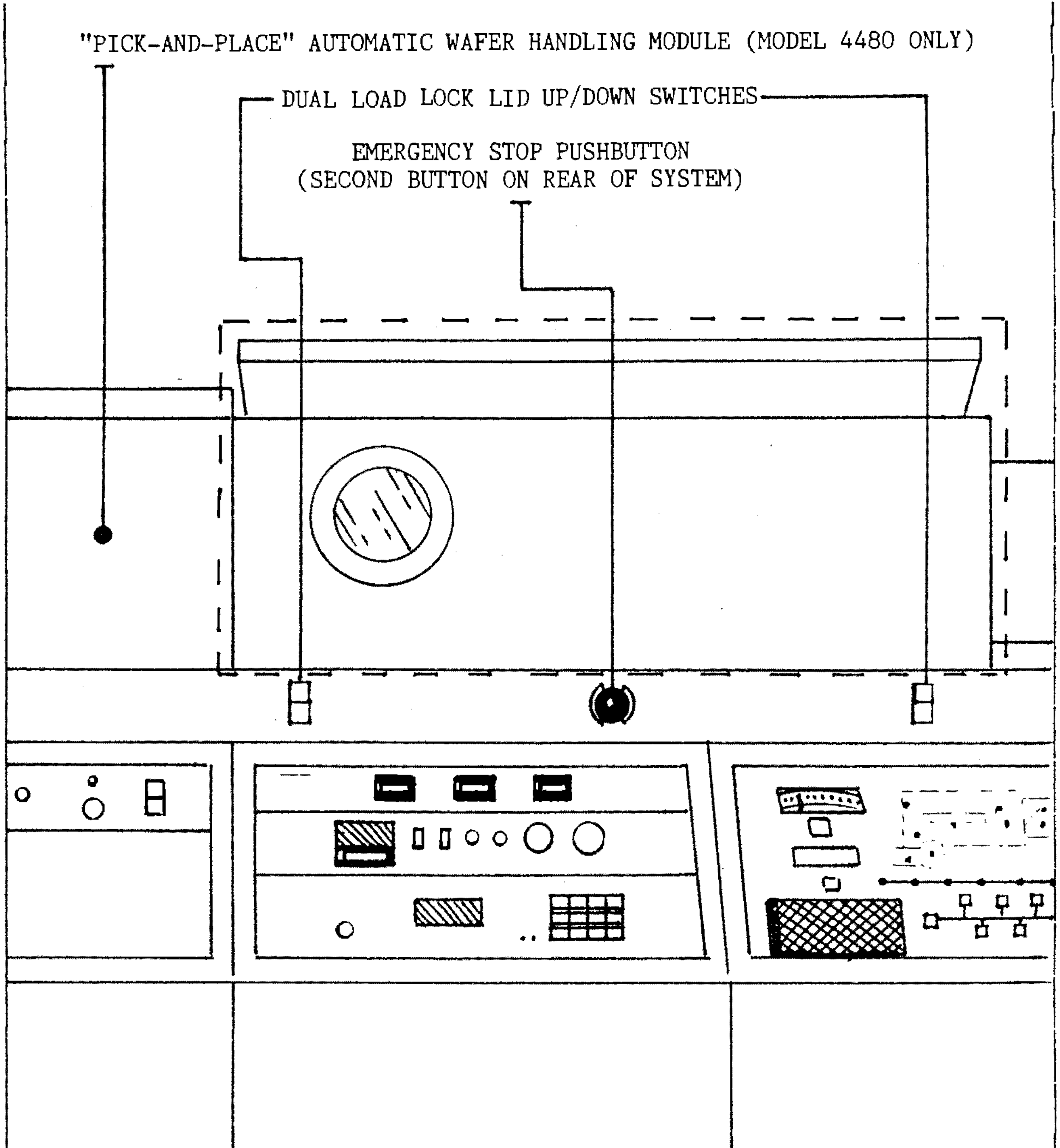


FIGURE 5-2

LOAD LOCK (FRONT VIEW)

(FRONT VIEW)

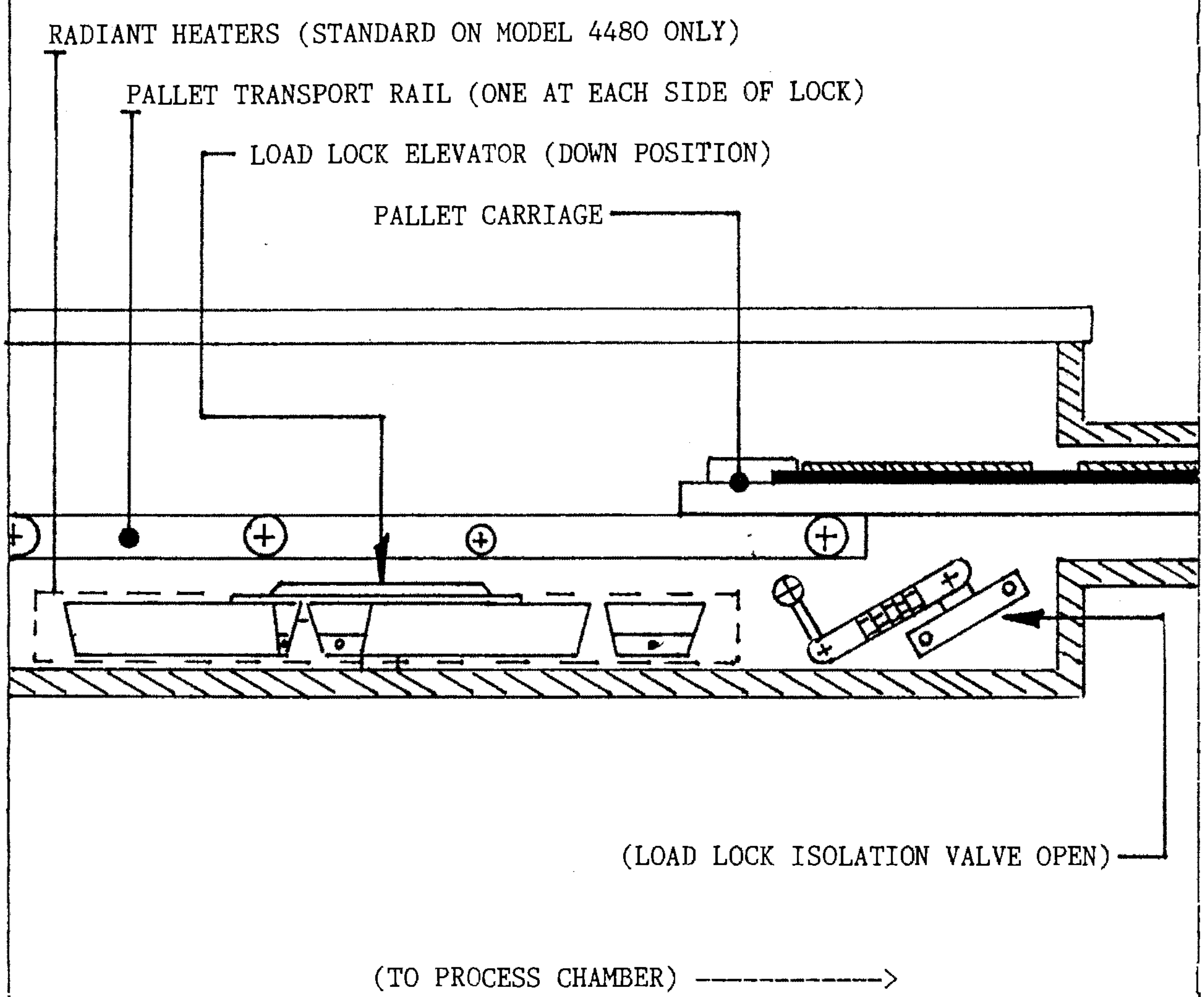


FIGURE 5-3

SUBSTRATE PALLET BEING TRANSFERRED INTO OR OUT OF

THE PROCESS CHAMBER

recover to high vacuum more quickly. In most sputtering processes this can result in a superior, more repeatable product.

5.1.3 Load Lock Lid

Pallets are installed and removed through the load lock lid, which forms the top surface of the load lock assembly. On systems NOT equipped with automatic wafer handling (i.e., Models 4400 and 4450), the load lock lid must be opened each cycle to remove processed wafers and load wafers to be processed.

5.1.3.1 Load Lock Lid UP/DOWN Control Panel

The load lock lid is raised via the LOAD LOCK LID UP/DOWN control, located on the front panel of the load lock assembly (see Figure 5-2). The load lock lid UP/DOWN control is equipped with two identical UP/DOWN rocker switches, mounted at opposite ends of the UP/DOWN control panel. Both switches must be moved to the same position at the same time in order to activate the load lock lid hoist.

5.1.4 Rotating Table Elevator

(See Figure 5-3)

<u>MODELS 4400/4450</u>

A pneumatic elevator automatically raises the pallet to the top of the load lock chamber each time the load lock lid is opened and lowers it each time the operator initiates the load sequence by closing the load lock lid.

<u>MODEL 4480</u>

A stepper motor automatically raises the pallet to the correct position for automatic wafer loading/ unloading ONLY WHEN THE AUTOMATIC WAFER HANDLING SYSTEM IS IN THE 'AUTO' MODE. The elevator may be raised to this same position manually using the manual elevator UP/DOWN toggle switch located on the MSC (MSC must be in the MANUAL key switch position).

During the load operation, the elevator places a loaded pallet on the U-shaped carriage mechanism in the load lock chamber. The carriage transports the pallet through the load lock isolation valve into the process chamber by means of chain drive wheels, and places it on the anode/substrate table. Inside the process chamber, the pallet is lifted off the carriage by the anode/substrate table (when the table moves to its UP position). The carriage then returns to the load lock chamber, and the load lock isolation valve closes. The transport sequence is reversed during the unload operation.

5.1.5 Load Lock Isolation Valve

The load lock isolation valve (also known as the lock isolation valve, or the load lock inner door) consists of an O-ring-sealed door, and is NOT to be confused with the load lock lid. The lock isolation valve separates the load

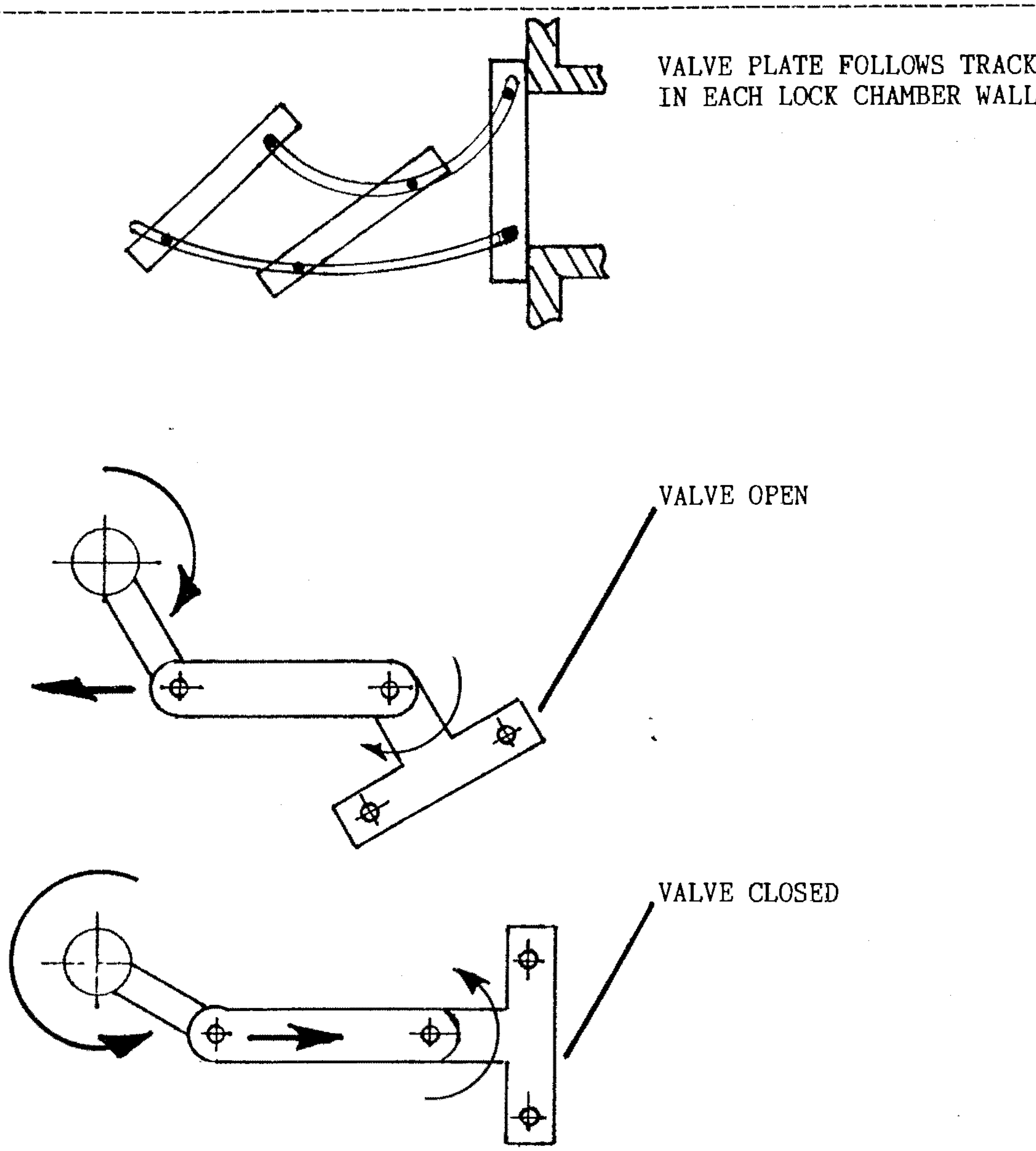
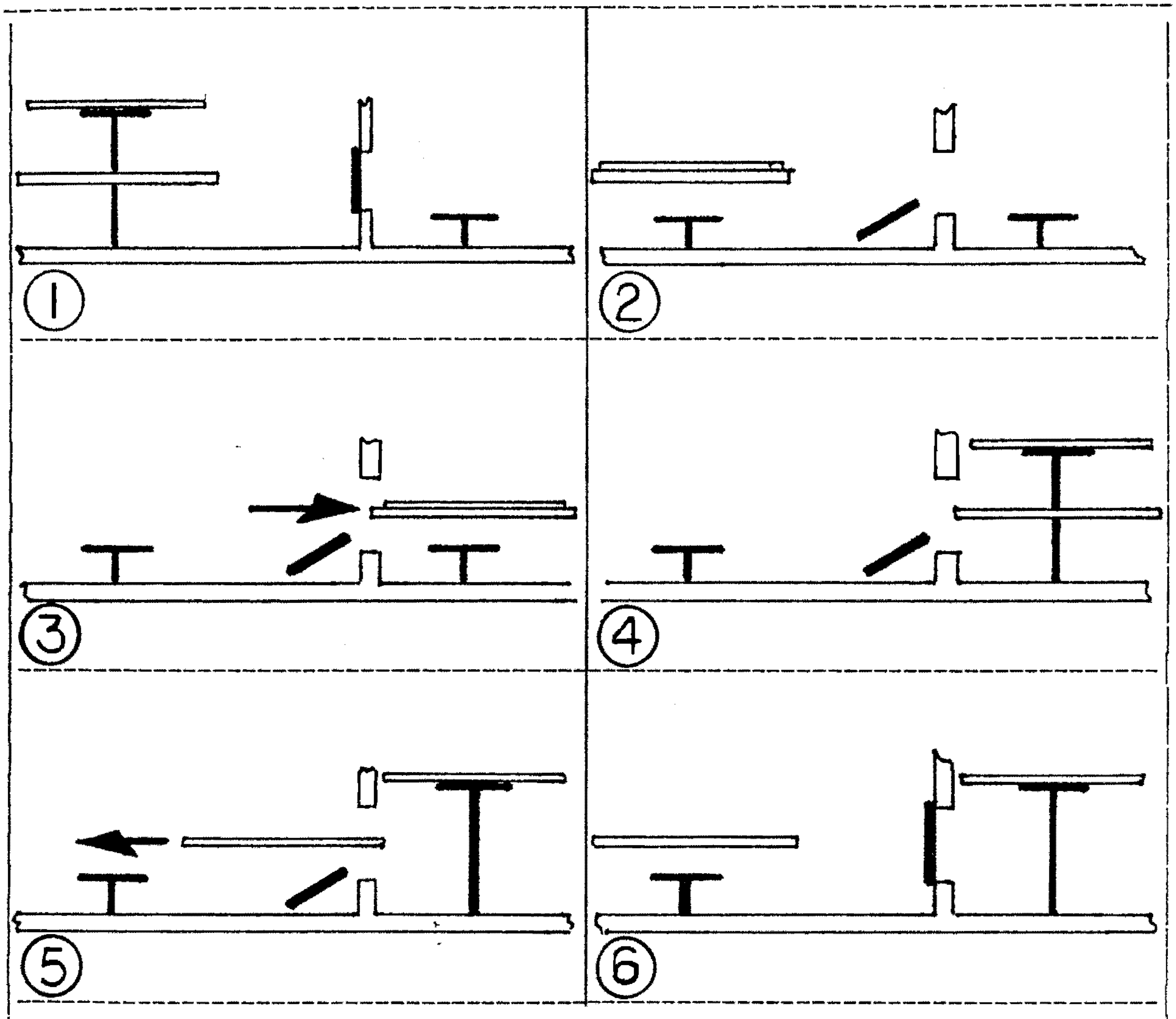


FIGURE 5-4

LOAD LOCK ISOLATION VALVE OPERATION, VIEWED FROM FRONT OF SYSTEM



NOTE

THE LOCK ISOLATION DOOR REMAINS OPEN WHILE THE PALLET CARRIAGE MECHANISM MOVES IN AND OUT OF THE PROCESS CHAMBER.]

FIGURE 5-5

THE PALLET TRANSFER SEQUENCE

lock from the process chamber. The load lock lid is the top surface of the load lock and opens to provide operator access to the interior of the load lock.

When the load lock isolation valve is closed, the load lock may be vented to atmosphere without disturbing the vacuum level of the process chamber. When the load lock is pumped to vacuum, the lock isolation valve remains closed until the vacuum set point is reached, at which time it opens to permit substrate pallet transport. (See Figures 5-4 and 5-5.)

The lock isolation valve is controlled automatically when the Main System Controller (MSC) is in the AUTOMATIC mode. It may be opened and closed under direct operator control when the MSC is in the MANUAL mode, via a toggle switch located on the front panel of the MSC. (Operating Instructions for the MSC are given in Chapter 6.)

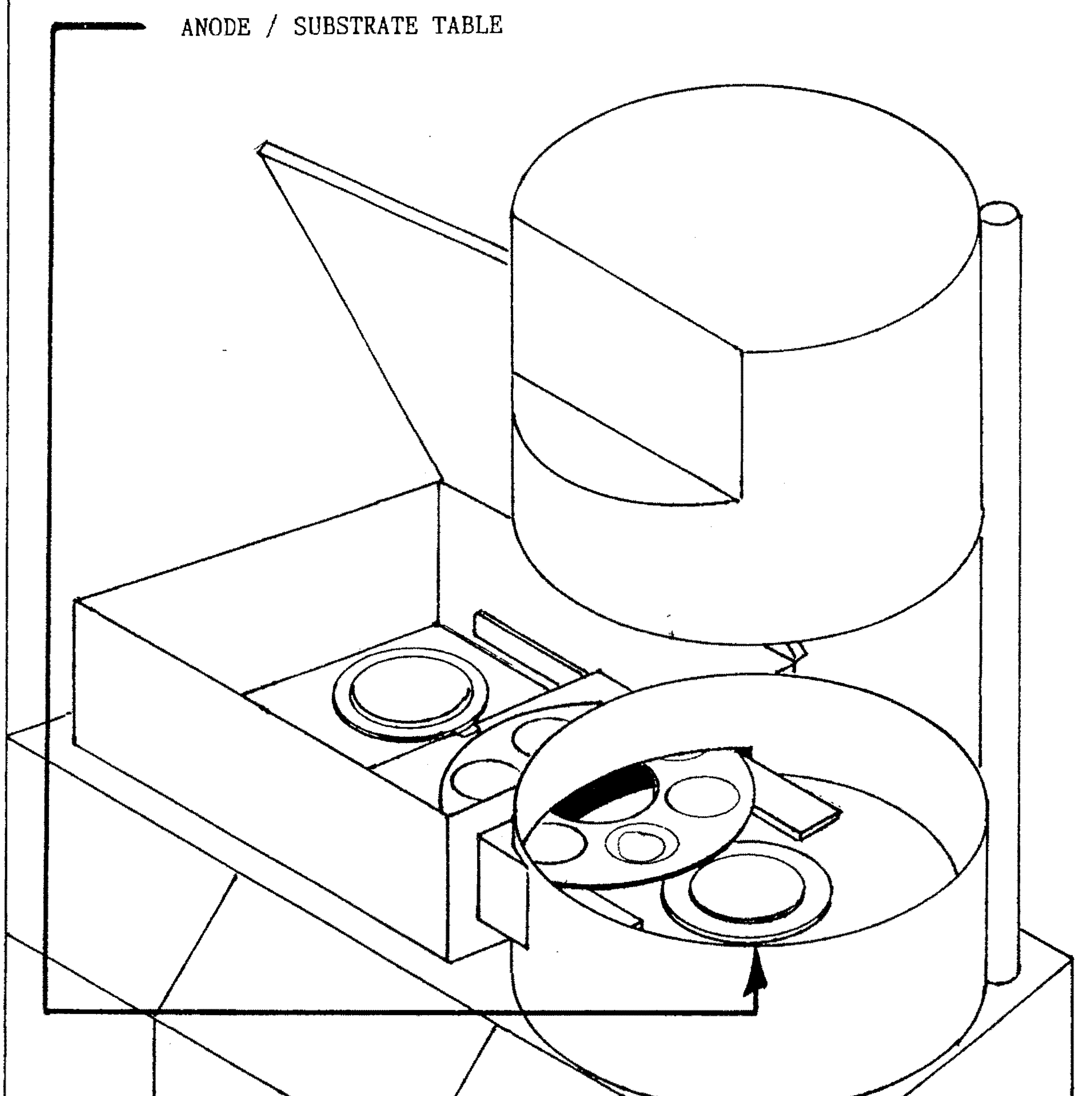
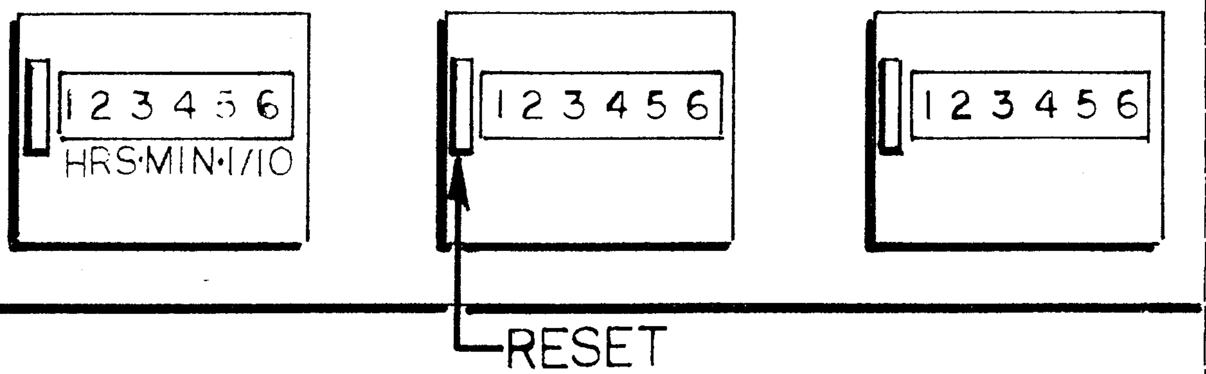


FIGURE 5-6

3/4 VIEW OF 4400-SERIES SPUTTERING SYSTEM (SPUTTER HEAD RAISED)

SHOWING PALLET PASSING THROUGH LOAD LOCK ISOLATION VALVE

TARGET ELAPSED TIME INDICATOR (FOR THREE [3] TARGETS)



PRECISION TABLE ROTATION CONTROL

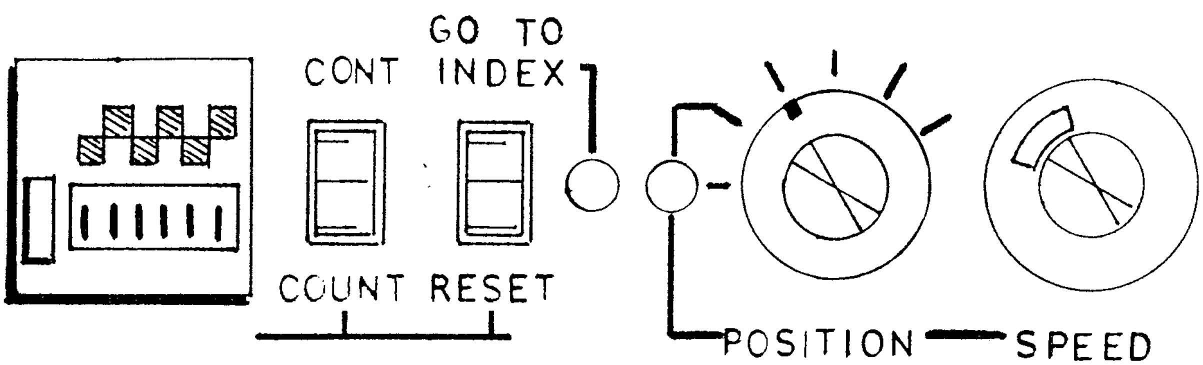


FIGURE 5-7

SYSTEM CONTROLS

5.2 Process Chamber

The process chamber for the 4400-Series systems, shown in Figure 5-6, is a 28" diameter, stainless steel, water-cooled cylinder within which the sputtering and etching operations take place.

5.2.1 Anode/Substrate Table

(See Figure 5-6)

The anode/substrate table consists of an aluminum annular table with a silver-plated, stainless steel ground shield. Normally, the substrate table is continuously rotated during processing by a precision rotation speed control, to provide even wafer-to-wafer coating uniformity. An indexing feature and rotation counter are standard.

5.2.1.1 Precision Table Rotation Speed Control

The precision table drive is mounted on the front panel of the sputtering system (see Figure 5-7). It utilizes a DC motor and a feedback loop to maintain precisely the selected speed. The range for this drive assembly is 3 rph to 10 rpm, and it is suitable for either single- or multi-pass deposition. The precision drive is constant and repeatable from run to run.

Before loading a pallet into the load lock (MANUAL wafer handling) the substrate table must be set at INDEX by placing the table drive controller rocker switch in the GO TO INDEX position. (In the AUTOMATIC wafer handling mode, Indexing is accomplished automatically.) After the pallet is transferred into the process chamber, the table will rise to either the etch or sputter position, and rotation will commence as soon as a process is selected and gas turned on.

When the table drive rocker switch is in the CONTINUOUS position, rotation will continue as long as the ROTATE/STOP rocker switch is in the ROTATE position. When the table drive rocker switch is in the COUNT position and the ROTATE/STOP rocker switch is in the ROTATE position, the table will complete a pre-set number of rotations. After each rotation, the AT INDEX light will momentarily light, and the REV. COUNTER will decrement one digit. Rotation continues until the counter reaches zero. (THE AUTOMATIC INDEXING FUNCTION IS PRECISE ONLY UP TO A ROTATION SPEED OF 5 RPM.)

5.2.2 Meissner Trap Assembly

The Meissner trap is located inside the process chamber, below the annular table. It offers maximum water vapor pumping capability (up to 30,000 liters per second) when liquid nitrogen is circulated through the assembly. This "auxiliary cryo pump" continues to pump even when the main cryo pump (if system is so equipped) is throttled during the sputtering process.

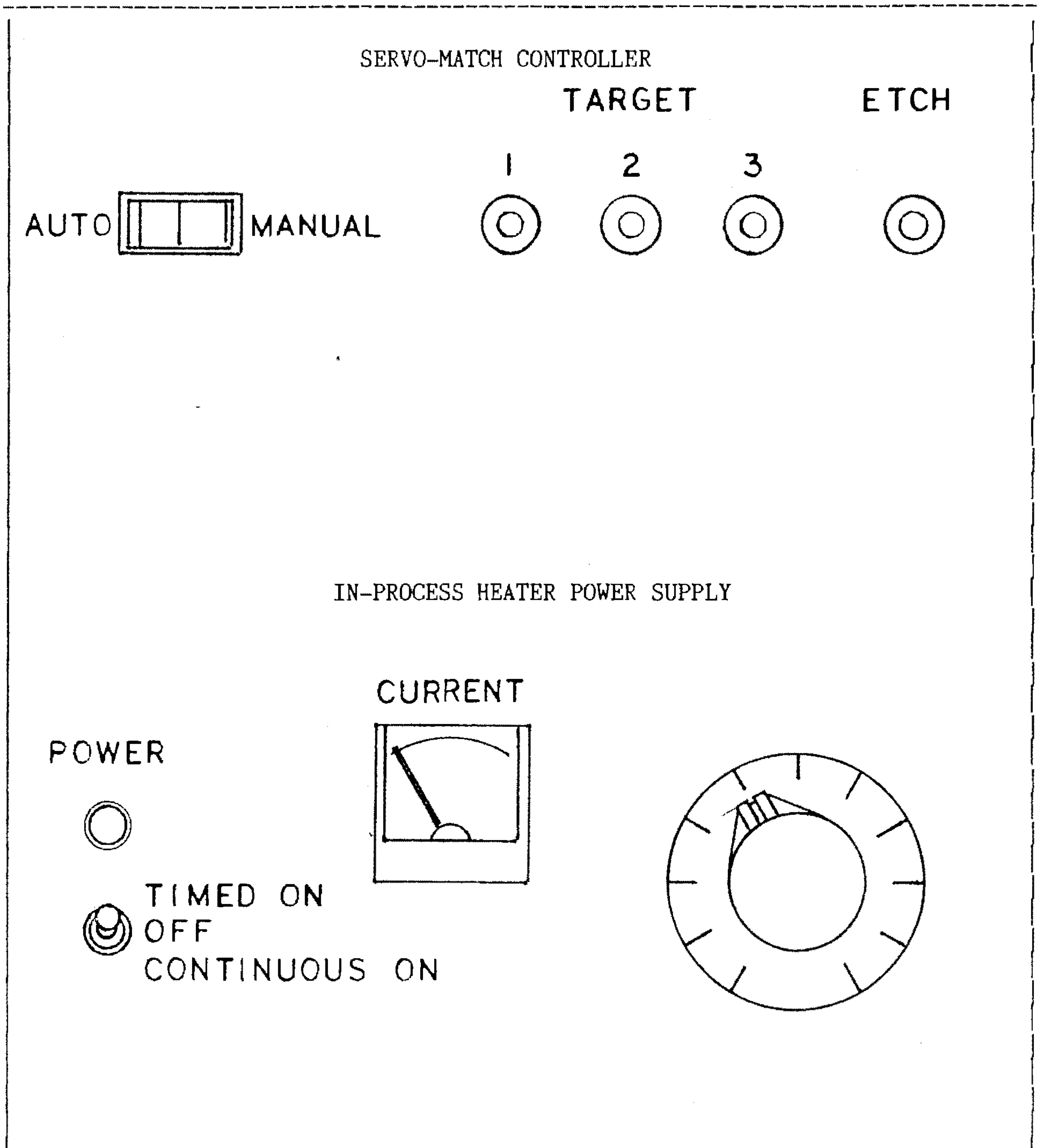


FIGURE 5-8

SYSTEM CONTROLS

LN_2 should not be introduced into the Meissner trap until process chamber pressure falls below 5 x 10^{-7}. A three position LN_2 switch (OFF, LN_2 CONT[inuous], LN_2 Timed) on the MSC regulates the flow. (In the TIMED mode, LN_2 is filled until a sensor determines that the trap is full. Once a FULL signal is received by the MSC, three (3) minutes elapse before the sensor is polled again. Each time LN_2 is added to trip the sensor, a new three (3) minute cycle is initiated.)

The Meissner trap assembly has over 160 square inches of surface area. Its pumping speed of more than 30,000 liters-per-second (with LN_2) for water vapor is computed with a conservative sticking coefficient of 75%. The LN_2 Meissner trap is standard equipment on all 4400-Series Production Sputtering Systems. A special coil for Freon™ "Polycold" is available as an option.

Removing water vapor allows the system to deposit low resistivity, highly specular aluminum alloy films such as aluminum-silicon or aluminum-silicon-copper.

A Meissner Hot Purge system minimizes chamber venting cycle time by accelerating the warming of the trap to prevent moisture condensation on the cold trap when it is exposed to atmosphere. Purging is accomplished using heated dry nitrogen.

5.2.3 In-Process Substrate Heater

A process chamber heater is available to provide substrate heating immediately before, during, or after deposition. In some cases, this can enhance film adhesion and provide control of grain size and stoichiometry.

<u>HEATER FOR MODEL 4400</u>

Optionally installed in target position No. 4, the radiant heater produces a process chamber temperature of 350 degrees Centigrade.

<u>HEATER FOR MODELS 4450/4480</u>

Optionally installed in any target position (but usually in Position 3), the radiant quartz heater REPLACES a cathode assembly. The heater produces process chamber temperatures of 350 degrees Centigrade.

The in-process heater power supply is mounted on the sputtering system front panel (see Figure 5-8).

5.2.4 Shutters and Deposition Shields

(See Figure 5-9)

Shutters are metal plates that are moved as necessary to separate the anode/substrate table from any or all of the cathodes. The shutters are closed during target pre-cleaning to protect the anode/substrate table, and during sputter-etching to protect the cathodes.

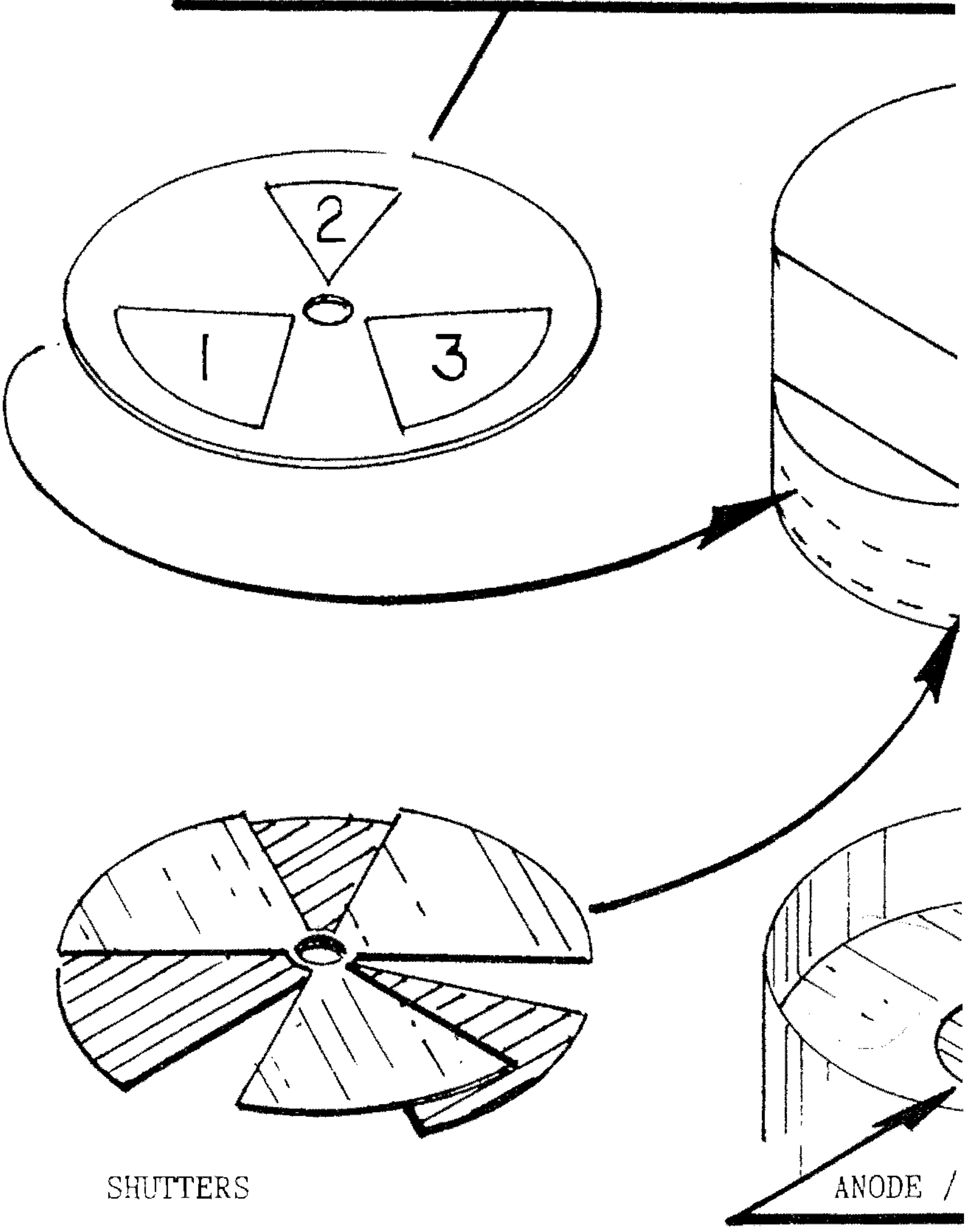


FIGURE 5-9

SPUTTER HEAD FROM MODEL 4450 OR 4480 (DELTA CATI
SHOWING VERTICAL ARRANGEMENT OF CATHODES AND SHI
THE ANODE / SUBSTRATE TABLE.

Deposition shields prevent sputter deposition in areas where deposits could adversely affect system operation (see Item 2, Figure 5-9). They also improve process uniformity in 4450 and 4480 systems, since shapers are mounted directly to each shutter opening. As the shields become coated with sputtered material, they can easily be removed and exchanged for clean shields, with a minimum of down time (see Appendix A, "Periodic Maintenance").

5.2.5 View Ports

(See Figures 5-9 and 5-10)

The view port, a 6" O.D. flange with a 3-1/2" clear view into the process chamber, permits the operator to monitor the process chamber and to take immediate action should any problem arise. Sputtered material is deposited on an internal Pyrex™ glass which may be replaced, as required, when deposition shields are exchanged. (Pyrex™ is used in order to protect the viewer's eyes from potentially dangerous ultraviolet radiation.) The load lock is also equipped with a view port.

5.2.6 Hoist Mechanism

(See Figure 5-9)

The 4400-Series systems are equipped with a heavy-duty, self-locking, electro-mechanical hoist to permit the processing chamber to be opened easily. A hoist interlock safety switch prevents the hoist from being activated when the process chamber is under vacuum (the hoist can ONLY be activated once the chamber is vented to atmosphere).

The hoist is actuated via an UP/DOWN toggle switch located on the front panel of the MSC.

5.2.7 Emergency Stop Pushbutton

(See Figure 5-10)

Depressing an Emergency Stop pushbutton , located on the front and rear of the sputtering system, on the RF generator (if any), and 10kW DC power supply (if any), immediately closes all gate valves and turns the main system circuit breaker OFF. Every component in the system is turned OFF, including the RF generator(s), DC power supply(ies), and all pumps.

RESET the system following an Emergency Stop from the wall-mounted main utility box.

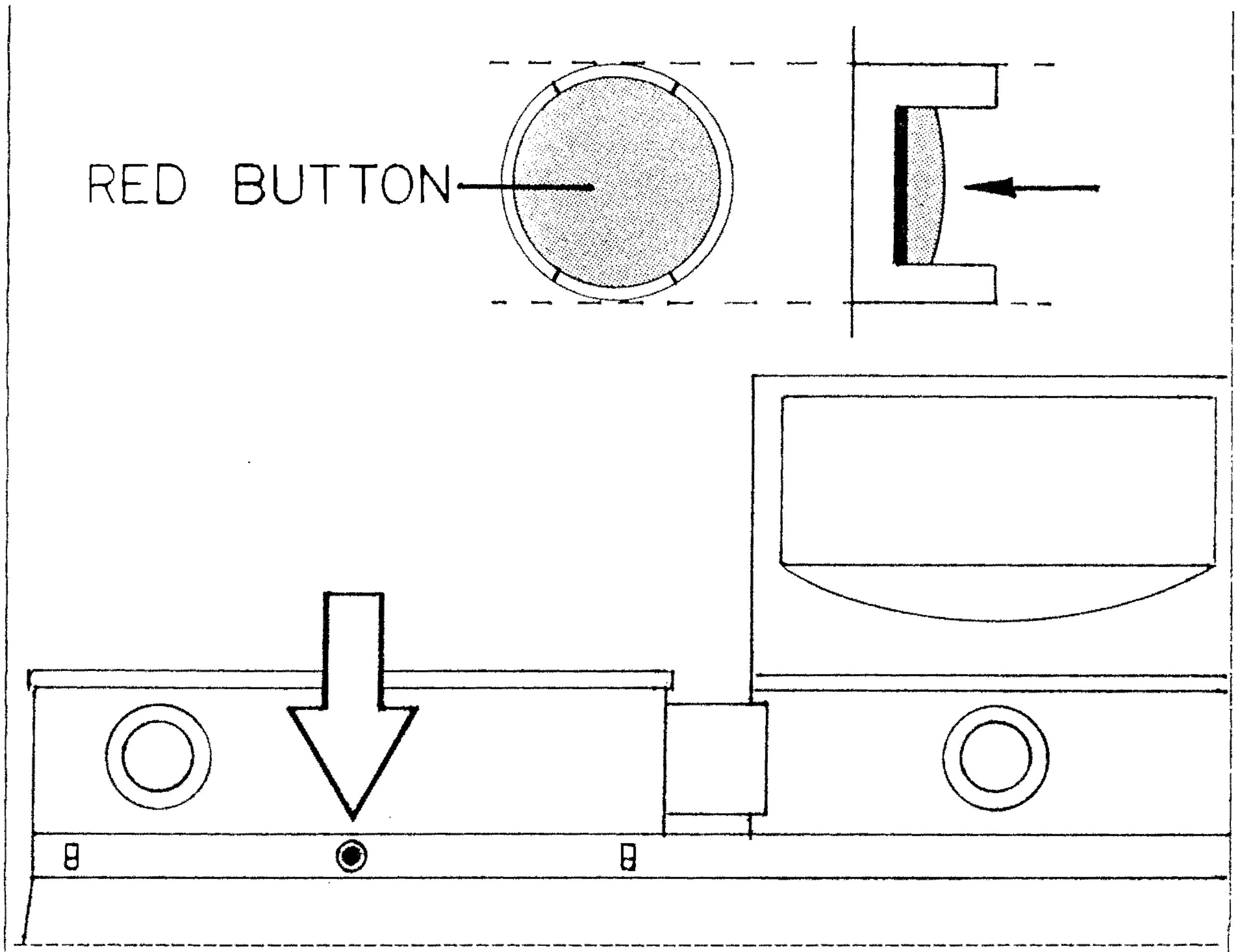


FIGURE 5-10

EMERGENCY STOP PUSHBUTTONS

LOCATED ON THE FRONT AND REAR OF THE SYSTEM, ON THE RF GENERATOR (IF SYSTEM SO-EQUIPPED), AND ON THE 10KW DC POWER SUPPLY (IF SYSTEM SO-EQUIPPED), THESE BUTTONS ARE TO BE DEPRESSED MANUALLY BY THE SYSTEM OPERATOR IN THE EVENT OF FIRE, FLOODING, OR DANGER OF ELECTROCUTION. (OPENS WALL-MOUNTED MAIN CIRCUIT BREAKER.)

CAUTION

IF THE SYSTEM IS LEFT IN THE POWER-DOWN MODE FOR LONGER THAN FIVE(5) MINUTES, THE PROCESS CHAMBER CRYO PUMP (IF THE SYSTEM IS SO EQUIPPED) WILL HAVE TO BE REGENERATED. CRYO PUMP REGENERATION TAKES ABOUT FOUR (4) HOURS.

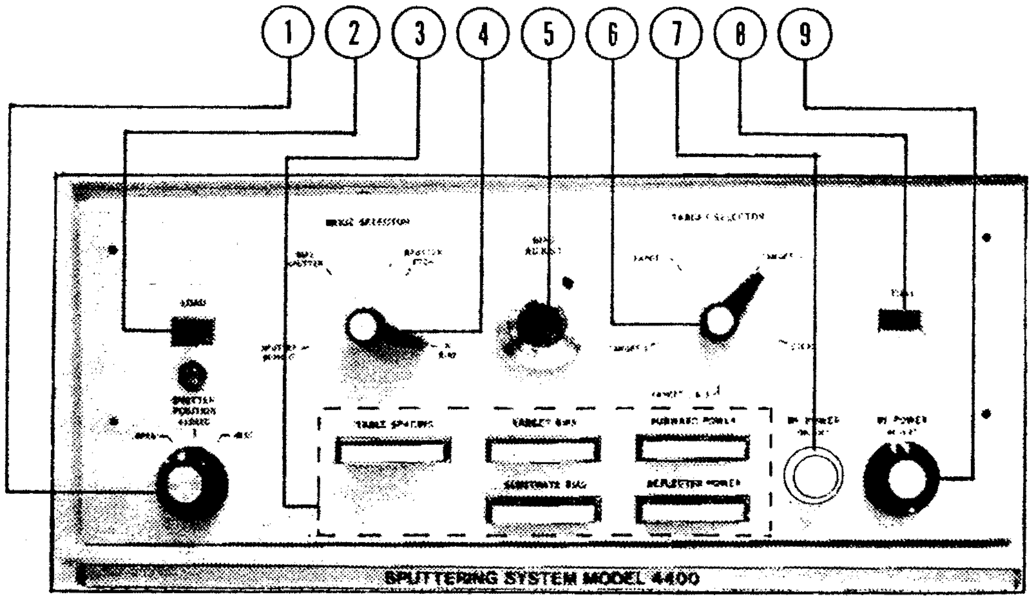


FIGURE 5-11

MODEL 4400 SPUTTER HEAD FRONT PANEL

1. SHUTTER POSITION SELECTOR
2. LOAD TUNE SWITCH
3. ANALOG METERS
4. MODE SELECTOR SWITCH
5. BIAS ADJUST CONTROL
6. TARGET SELECTOR SWITCH
7. RF POWER ON / OFF PUSHBUTTON
8. TUNE SWITCH
9. RF POWER ADJUST CONTROL

5.3 Sputtering Head Assembly - Model 4400

5.3.1 Control Panel

The Model 4400 system sputter head assembly includes a complete range of controls to regulate the system parameters affecting the sputtering and etching process. Adjusting the system to produce the desired result requires a certain amount of experimentation. Some experimentation with a specific machine at various settings (using sample or reject wafers) should suffice to determine the correct settings for any given process.

The following controls and indicators are located on the control panel of the sputter head assembly (see Figure 5-11).

5.3.1.1 Shutter Position Switch [ITEM No. 1]

Allows the shutter to be closed during the sputter etch mode, and open to the selected target or targets for sputter deposition.

5.3.1.2 Load Control Switch [ITEM No. 2]

The load control switch drives a motor which controls the setting for the RF load tuning coil. It is used in conjunction with the TUNE switch. Both switches, used together, match (manually) the RF power to the load. They are overridden by the Servo-Match™ controller when the system is operated in the automatic tune mode.

5.3.1.3 Table Spacing Meter[ITEM No. 3]

Measures the distance between the substrate table and the target surface on a scale from 0" - 5".

5.3.1.4 Target Bias Meter [ITEM No. 3]

Measures the voltage applied to the target.

5.3.1.5 Substrate Bias Meter [ITEM No. 3]

Measures the voltage applied to the substrate table.

5.3.1.6 Forward Power Meter [ITEM No. 3]

Measures the total power output of the RF generator. (A 2kW meter is installed if a 2kW power supply is to be used; 3kW for a 3kW power supply.)

5.3.1.7 Reflected Power Meter [ITEM No. 3]

Measures the amount of RF power reflected back from the sputter head assembly or substrate table to the RF generator, due to impedence mismatching between the power supply and load. For best results, reflected power should be no more than 25 watts at maximum load.

5.3.1.8 Mode Selector [ITEM No. 4]

Allows selection of the following operating modes:

Sputter Deposit — [RF OR DC] RF or DC power is applied to the selected target. The substrate table is grounded. The Target Bias meter displays RF or DC power applied to the target.

Bias Sputter — [RF ONLY] Most RF power is applied to the target, but a small amount of RF power (up to 10%) can be applied to the substrate table. Consequently, substrates also are bombarded by ions, but to a much lesser degree than is the target. In many cases this technique yields higher quality deposits and better step coverage than RF sputtering with grounded substrates. Bias is read on the RF BIAS meter.

Sputter Etch — [RF ONLY] RF power (1 kW maximum) is applied to the substrate table, and material is removed (etched away) from the substrate by ion bombardment. Self-bias is displayed on the TARGET BIAS meter.

5.3.1.9 BIAS ADJUST CONTROL [ITEM No. 5]

Active only in the BIAS SPUTTER operating mode. Adjusts percentage of RF power applied to the substrate table. Varying amount of power varies negative self-bias on the table. Bias is displayed on the SUBSTRATE BIAS meter (-500V full scale). Substrate bias is normally in the range 0 - 10% of target bias.

5.3.1.10 Target Selector Switch [ITEM No. 6]

Connects output of the matching circuit to any of the four (4) targets and/or the substrate table. The target selector switch has five positions. In the TARGET 1 position, RF power is applied to TARGET 1 (the target on the left as viewed from the front of the system). This switch allows power to be applied to any of the three targets separately (or using the power splitting option, to targets 1 and 3 simultaneously). TARGET 2 is the rear target. TARGET 3 is on the right. Target 4 is in front. In the ETCH position, RF power is applied to the substrate table.

5.3.1.11 RF Power Switch [ITEM No. 7]

Activates the RF power supply to couple the RF power to the sputtering head assembly (or substrate table). The generator is interlocked so that power cannot be applied while the chamber is at atmosphere.

5.3.1.12 Tune Control Switch [ITEM No. 8]

The tune control switch drives a motor which controls the setting for the RF tuning capacitor. It is used in conjunction with the LOAD switch. Both switches are used together to match the RF power to the load manually. They are overridden by the Servo-Match™ controller when it is operated in the automatic tune mode.

5.3.1.13 RF Power Adjust Control [ITEM No. 9]

Governs power output from the RF power generator.

5.3.2 Cathodes

The cathode is a negatively-charged electrode, the source of the material sputtered onto the substrates. The cathode assembly consists of the target itself, a backing plate, insulators, cooling tubes, and the necessary electrical connections. Target materials are attached to the target backing plates using a solder-bonding technique.

Models 4450/4480 are designed to use Delta™ cathodes. The Model 4400 uses 8" round RF or DC cathodes, which may also be adapted for use with the Models 4450/4480.

Target-changing, using either Delta™ or 8" round cathodes, is a simple procedure which may be performed by the operator in only a few minutes.

5.3.3 Shutters

Shutters are disks or plates (depending on target configuration) mounted on the sputter head assembly and actuated from the sputter head assembly control panel. They are used to separate the target(s) from the substrate pallet during sputter etching, to prevent material removed from the substrates from contaminating the target(s). They also are closed for target pre-cleaning (short duration ONLY) prior to sputter deposition.

Shutters are also used to open the desired target(s) selectively to the substrates for sputtering.

5.3.4 Dark Space Shields

The dark space shield surrounds the target assembly at a distance of 1/8" from the target to prevent plasma from being generated on the sides of the targets. It focuses the discharge and provides grounding surfaces for the discharge.

5.3.5 Cross-Contamination Shields - Models 4450/4480

Standard on all 4400-Series systems, these prevent material sputtered from one target from contaminating other targets.

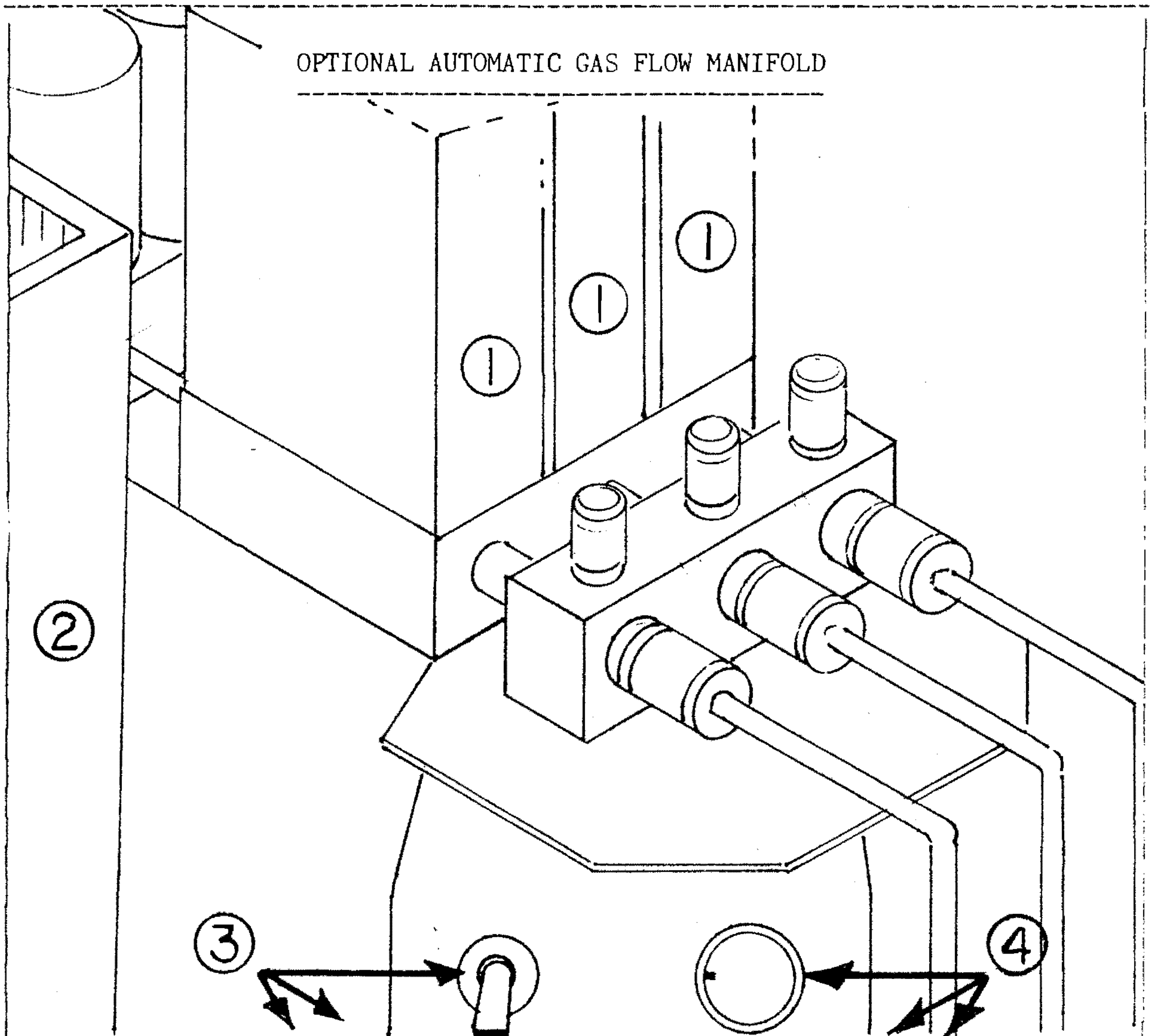


FIGURE 5-12

OPTIONAL BROOKS AUTOMATIC GAS FLOW SYSTEM

1. BROOKS GAS FLOW CONTROLLERS (3)
2. SPUTTERING HEAD HOIST
3. MANUAL GAS ON / OFF VALVES (3)
4. MANUAL MICROMETER VALVES (3)

5.3.6 Shapers

In the 4400-Series systems, using 8" round DC or RF magnetron targets creates a circular, symmetrical deposition pattern. Substrates are typically placed on the annular substrate table and rotated continuously beneath the target during deposition. Uniformity is achieved by "shaping" the vapor flux with shields (shapers) through which have been cut specially designed apertures. Shapers are always used when sputtering from 8" round targets.

Shapers are available as an option for the Model 4400.

Shapers are designed to be quickly and easily removed for replacement or cleaning whenever the process chamber is vented.

5.3.7 Brooks 1, 2, or 3 Automatic Gas Flow Controllers

(See Figure 5-12.)

Brooks automatic gas controllers are available as options for all 4400-Series systems. This option allows the operator to program desired flow levels of one or more gases into the process chamber via the MSC, as part of an automatic sequence. Brooks controllers are mounted to the right rear of the sputter head assembly, behind the manual gas flow valves.

Included as part of the Automatic gas control option is an automatic pressure controller, which is mounted in the front panel of the system main frame. The automatic pressure controller allows the operator to program a desired process chamber pressure level, which is maintained by a servo-actuated throttle valve. (In systems not equipped with this option, or when the automatic pressure controller is switched OFF, the operator may move the throttle to either of two positions via toggle switches. The two positions are OPEN and CLOSED, where CLOSED means closed against a mechanical stop pre-adjusted to yield a desired pressure at a given gas flow level (typically 40 sccm at 10 milliTorr).

5.3.8 Plasma Igniter

The Plasma igniter emits an intense stream of electrons from a hot filament to ignite the plasma. When the sensor detects the absence of plasma after RF power is turned on, it activates the plasma igniter. As soon as the plasma ignites, the sensor deactivates the plasma igniter.

5.3.9 RF CONTROLS

5.3.9.1 RF Impedance Matching Networks

(See Figure 5-11.)

The impedance matching network is located in the top of the sputter head assembly. This network matches impedance of the cathode/discharge/anode (substrate table) system to the standard 50 ohm impedance of the coaxial line, which brings power from the RF generator. Without a proper match, the RF generator cannot deliver power for the sputtering process. Instead, reflected RF travel back in the coaxial cable, causing standing waves. The result is heating of the cable. If RF reflected power continues at a high level for an extended period of time, the sputtering head and/or RF generator may be damaged.

The matching network is designed to allow independent adjustment in matching the real and imaginary parts of the impedance. A proper matching can be achieved even with wide variations in deposition parameters such as target size, target-to-substrate distance, argon pressure, etc.

Impedance matching is controlled by the LOAD and TUNE controls (see Figure 5-11, ITEMS 2 and 8).

The 4400-Series systems are supplied with RF power by a generator external to the sputtering system. The output of the generator is 50 ohms so that the power can conveniently be transmitted via a 50 ohm impedance coaxial cable. Since the impedance of the plasma within the process chamber is different from that of the cable (and may vary during the sputtering process) an electronic network, called the matching network, is located in the sputtering head Two of the components in the matching network, the load capacitor and the tuning capacitor, are adjustable to match the impedance between the output of the RF generator and the plasma.

5.3.9.2 Servo-Match™ Controller

The Servo-Match™ controller drives the motors that move these variable components in the matching network to minimize the reflected power and maximize the amount of RF energy transmitted from the RF generator (forward power).

All operator controls are located on the sputter head assembly control panel, and all electrical connections are made at the rear panel. A single printed circuit board contains the entire circuitry. All power, logic, and control signals are obtained through the control cable. A sensor box measures the phase relationship between the current and voltage in the RF cable.

The Servo-Match™ controller can be operated either manually or automatically. In the MANUAL mode, the matching impedance can be adjusted by means of the tune and load switches located on the sputter head (see TUNE switch; LOAD switch). In the AUTOMATIC mode, the controller network matches impedance automatically.

5.3.9.3 Tuning Capacitor and Motor

The tuning circuitry automatically moves the tuning capacitor to minimum reflected power by sensing the phase relationship between the voltage and current in the coaxial cable that transmits power from the generator to the sputter head. If the voltage leads the current, the controller runs the motor in one direction; if the voltage lags the current, it runs the motor in the other direction. When the voltage and current are in phase, the phase detector stops the tuning motor.

5.3.9.4 Load Capacitor and Motor

The load coil is pre-set via the potentiometers on the front panel. When a target is changed or a new operating mode is selected, the corresponding potentiometer sets the value of the load coil. The load matching circuit is driven by a position-servo system. Load matching is performed before tuning. The load matching circuit DOES NOT automatically adjust for reflected power.

5.3.9.5 RF Programmable Power/Voltage Stabilizer

The programmable power stabilizer regulates the level of RF power or voltage delivered to the selected target. It maintains constant power for RF sputtering and etching processes despite variations in AC line voltage, gas pressure, work characteristics, and temperature.

A 2-position toggle switch at the lower right front of the power/voltage stabilizer control panel allows the operator to select POWER or VOLTAGE. If POWER is selected, RF power will be maintained at the operator-preset level by automatically varying the voltage. If VOLTAGE is selected, RF voltage will be maintained by varying power.

The programmable power stabilizer operates in the MANUAL or PROGRAM modes. (MANUAL and PROGRAM modes refer to the operating mode of the MSC, which is described in Chapter 6.

Manual Mode	The power stabilizer may be either ON or OFF. When it is ON, the stabilized power adjust dial controls the RF power to the sputter head assembly. When it is OFF, the RF power is controlled manually by the RF power adjust potentiometer on the system meter panel, but no stabilization operations are performed.
Program Mode	Control of RF power is transferred to the MSC or to the RF power adjust knob on the sputter head assembly control panel.

5.3.10 Gas Metering Valves (3)

(See Figure 5-12.)

Located on the right side of the sputter head assembly, the manual gas metering assembly consists of a stainless steel needle valve equipped with a precision micrometer head for accurate and repeatable settings. (Turning the micrometer head clockwise reduces the flow of gas.) The proper setting is determined empirically and depends upon a) the desired argon pressure, and b) the adjustment of the throttle valve. On systems equipped with manual gas only, the throttle valve is factory-preset to a mechanical stop for 40 sccm at at a pressure of 10 milliTorr. (On manual gas systems, the operator can select THROTTLE OPEN or THROTTLE CLOSED [to the 10 mT/40 sccm position]).

An gas shut-off solenoid valve is connected in series with the gas metering valve. During operation, the metering valve is set to produce the desired gas working pressure, and the shut-off valve stops and starts the flow of gas without changing the metering valve setting. The shut-off valve is actuated by the gas control on the automatic pressure controller (included with the Brooks gas control option).

The automatic gas option (which may be installed to control one (1), two (2), or three (3) gases) consists of Brooks Model 5058 flow controllers and a servo-operated throttle valve. As in manual gas systems, the throttle is factory-preset for 10 mT/40 sccm. A typical 3-gas arrangement is:

GAS 1	NITROGEN, 0 - 100 SCCM
GAS 2	NITROGEN, 0 - 10 SCCM
GAS 3	NITROGEN, 0 - 10 SCCM

The operator selects a desired pressure and flow rate for one or more gases via programmed data cards (all models, or optionally via the data terminal keyboard on Model 4480), and the throttle servos to maintain the desired chamber pressure.

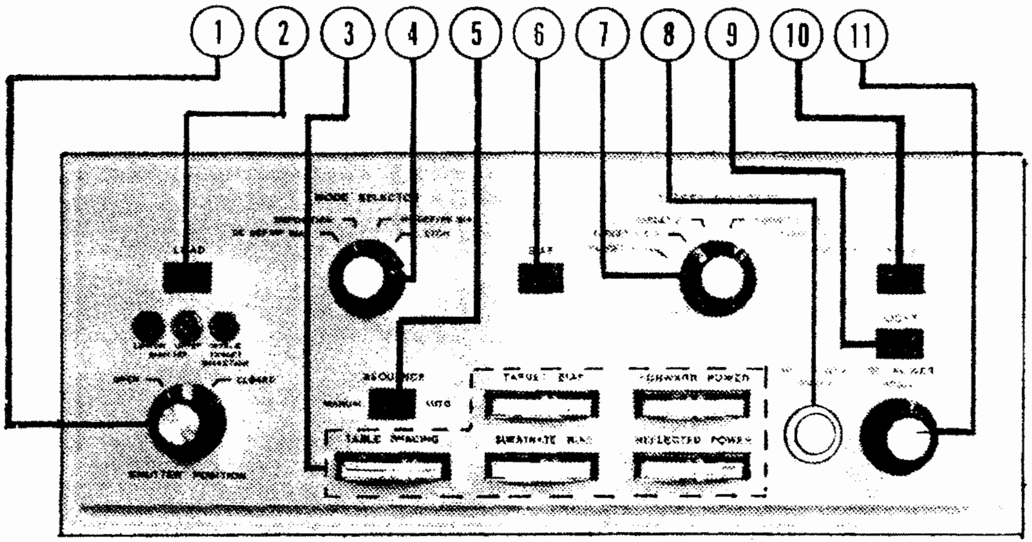


FIGURE 5-13

MODELS 4450 / 4480 SPUTTER HEAD FRONT PANEL

1. SHUTTER POSITION SELECTOR
2. LOAD TUNE SWITCH
3. ANALOG METERS
4. MODE SELECTOR SWITCH
5. SEQUENCE SWITCH
6. BIAS SWITCH
7. TARGET SELECTOR SWITCH
8. RF POWER ON / OFF PUSHBUTTON
9. LIGHT SWITCH
10. TUNE SWITCH
11. RF POWER ADJUST CONTROL

5.4 Sputtering Head Assembly - Models 4450/4480

5.4.1 Control Panel

The sputter head assembly (Models 4450/4480) includes a complete range of controls to regulate the system parameters affecting the sputtering process. Adjusting the system to produce the desired result requires a certain amount of experimentation. Some experimentation with a specific machine at various settings (using sample or reject wafers) should suffice to determine the correct settings for any given process.

The following controls and indicators are located on the control panel of the sputter head assembly (see Figure 5-13).

5.4.1.1 Shutter Position Switch [ITEM No. 1]

Allows the shutter to be closed during the sputter etch mode, and open to the selected target or targets for sputter deposition. When the sputter head front panel AUTO/MANUAL switch is in the automatic position, shutters automatically are moved to the proper position for the selected operation (i.e., CLOSED for etch and pre-sputtering, OPEN to the correct target(s) for target burn-in and sputter deposition).

5.4.1.2 Load Tune Switch [ITEM No. 2]

The load tune switch drives a motor which controls the setting for the RF load tuning circuit. It is used in conjunction with the TUNE switch. Both switches, used together, match (manually) the RF power to the load. They are overridden by the Servo-Match™ controller when the head is operated in the automatic tune mode.

5.4.1.3 Table Spacing Meter[ITEM No. 3]

Measures the distance between the substrate table and the target surface on a scale from 0" - 5".

5.4.1.4 Target Bias Meter [ITEM No. 3]

Measures the voltage applied to the target.

5.4.1.5 Substrate Bias Meter [ITEM No. 3]

Measures the voltage applied to the substrate table.

5.4.1.6 Forward Power Meter [ITEM No. 3]

Measures the total power output of the RF generator. (A 2kW meter is installed if a 2kW power supply is to be used; 3kW for a 3kW power supply.)

5.4.1.7 Reflected Power Meter [ITEM No. 3]

Measures the amount of RF power reflected back from the sputter head assembly or substrate table to the RF generator, due to impedence mismatching between the power supply and load. For best results, reflected power should be no more than 25 watts at maximum load.

5.4.1.8 Mode Selector [ITEM No. 4]

Allows selection of the following operating modes:

Sputter Deposit	[RF OR DC] RF or DC power is applied to the selected target. The substrate table is grounded. The Target Bias meter displays RF or DC power applied to the target.
Bias Sputter	[RF ONLY] Most RF power is applied to the target, but a small amount of RF power (up to 10%) can be applied to the substrate table. Consequently, substrates also are bombarded by ions, but to a much lesser degree than is the target. In many cases this technique yields higher quality deposits and better step coverage than RF sputtering with grounded substrates. Bias is read on the RF BIAS meter.
Sputter Etch	[RF ONLY] RF power (1 kW maximum) is applied to the substrate table, and material is removed (etched away) from the substrate by ion bombardment. Self-bias is displayed on the TARGET BIAS meter.

5.4.1.9 Sequence Switch - Models 4450/4480 [ITEM No. 5]

The sequence switch is used to switch load commands for manual or automatic remote operation (THE SEQUENCE SWITCH MUST BE IN THE AUTO POSITION IN ORDER TO PRODUCE AUTOMATIC SEQUENCES VIA THE MSC).

5.4.1.10 BIAS ADJUST SWITCH [ITEM No. 6]

Active only in the BIAS SPUTTER operating mode. Adjusts percentage of RF power applied to the substrate table. Varying amount of power varies negative self-bias on the table. Bias is displayed on the SUBSTRATE BIAS meter (-500V full scale). Substrate bias is normally in the range 0 - 10% of target bias.

5.4.1.11 Target Selector Switch [ITEM No. 7]

Connects output of the matching circuit to any of the THREE (3) targets and/or the substrate table. The target selector switch has five positions. In the TARGET 1 position, RF power is applied to TARGET 1 (the target on the left as viewed from the front of the system). This switch allows power to be applied to any of the three targets separately (or using the power splitting option, to targets 1 and 3 simultaneously). TARGET 2 is the rear target. TARGET 3 is on the right. In the ETCH position, RF power is applied to the substrate table.

5.4.1.12 RF Power Switch [ITEM No. 8]

Activates the RF power supply to couple the RF power to the sputtering head assembly (or substrate table). The generator is interlocked so that power cannot be applied while the chamber is at atmosphere.

5.4.1.13 Tune Control Switch [ITEM No. 10]

The tune control switch drives a motor which controls the setting for the RF tuning capacitor. It is used in conjunction with the LOAD switch. Both switches are used together to match the RF power to the load manually. They are overridden by the Servo-Match™ controller when it is operated in the automatic tune mode.

5.4.1.14 RF Power Adjust Potentiometer [ITEM No. 11]

Governs power output from the RF power generator.

5.4.2 Cathodes

The cathode is a negatively-charged electrode, the source of the material sputtered onto the substrates. The cathode assembly consists of the target itself, a backing plate, insulators, cooling tubes, magnets (if a magnetron cathode), and the necessary electrical connections. Target materials are attached to the target backing plates using a solder-bonding technique.

Models 4450/4480 are designed to use Delta™ cathodes. The Model 4400 uses 8" round RF or DC cathodes, which may also be adapted for use with the Models 4450/4480.

Target-changing, using either Delta™ or 8" round cathodes, is a simple procedure which may be performed by the operator in only a few minutes.

5.4.3 Shutters

Shutters are disks or plates (depending on target configuration) mounted on the sputter head assembly and actuated from the sputter head assembly control panel. They are used to separate the target(s) from the substrate pallet during sputter etching, to prevent material removed from the substrates from contaminating the target(s). They also are closed for target pre-cleaning (short duration ONLY) prior to sputter deposition.

Shutters are also used to open the desired target(s) selectively to the substrates for sputtering.

5.4.4 Dark Space Shields

The dark space shield surrounds the target assembly at a distance of 1/8" from the target to prevent plasma from being generated on the sides of the targets. It focuses the discharge and provides grounding surfaces for the discharge.

5.4.5 Cross-Contamination Shields

Standard on all 4400-Series systems, these prevent material sputtered from one target from contaminating other targets.

5.4.6 Shapers

In the 4400-Series systems (using 8" round DC or RF magnetron targets), the shapers create a circular, symmetrical deposition pattern. Substrates are typically placed on the annular substrate table and rotated continuously beneath the target during deposition. Uniformity is achieved by "shaping" the vapor flux with shields (shapers) through which have been cut specially designed apertures. Shapers are always used when sputtering from 8" round targets.

Shapers are available as an option for the Model 4400.

Shapers are designed to be quickly and easily removed for replacement or cleaning whenever the process chamber is vented.

5.4.7 Brooks 1, 2, or 3 Automatic Gas Flow Controllers

(See Figure 5-12.)

Brooks automatic gas controllers are available as options for all 4400-Series systems. This option allows the operator to program desired flow levels of one or more gases into the process chamber via the MSC, as part of an automatic sequence. Brooks controllers are mounted to the right rear of the sputter head assembly, behind the manual gas flow valves.

Included as part of the Automatic gas control option is an automatic pressure controller, which is mounted in the front panel of the system main frame. The automatic pressure controller allows the operator to program a desired process chamber pressure level, which is maintained by a servo-actuated throttle valve. (In systems not equipped with this option, or when the automatic pressure controller is switched OFF, the operator may move the throttle to either of two positions via toggle switches. The two positions are OPEN and CLOSED, where CLOSED means closed against a mechanical stop pre-adjusted to yield a desired pressure at a given gas flow level (factory-preset for 40 sccm at 10 milliTorr).

5.4.8 Plasma Igniter

The Plasma igniter emits an intense stream of electrons from a hot filament to ignite the plasma. When the sensor detects the absence of plasma after RF power is turned on, it activates the plasma igniter. As soon as the plasma ignites, the sensor deactivates the plasma igniter.

5.4.9 RF CONTROLS

5.4.9.1 RF Impedance Matching Networks

(See Figure 5-13.)

The 4400-Series systems are supplied with RF power by a generator external to the sputtering system. The output of the generator is 50 ohms so that the power can conveniently be transmitted via a 50 ohm impedance coaxial cable. Since the impedance of the plasma within the process chamber is different from that of the cable (and may vary during the sputtering process) an electronic network, called the matching network, is located in the sputtering head Two of the components in the matching network, the load capacitor and the tuning capacitor, are adjustable to match the impedance between the output of the RF generator and the plasma.

The matching network is designed to allow independent adjustment in matching the real and imaginary parts of the impedance. A proper matching can be achieved even with wide variations in deposition parameters such as target size, target-to-substrate distance, argon pressure, etc.

Impedance matching is controlled by the LOAD and TUNE controls (see Figure 5-13, ITEMS 2 and 10).

5.4.9.2 Servo-Match™ Controller

The Servo-Match™ controller drives the motors that move the variable components in the matching network to minimize the reflected power and maximize the amount of RF energy transmitted from the RF generator (forward power).

All operator controls are located on the sputter head assembly control panel, and all electrical connections are made at the rear panel. A single printed circuit board contains the entire circuitry. All power, logic, and control signals are obtained through the control cable. A sensor box measures the phase relationship between the current and voltage in the RF cable.

The Servo-Match™ controller can be operated either manually or automatically. In the MANUAL mode, the matching impedance can be adjusted by means of the tune and load switches located on the sputter head (see TUNE switch; LOAD switch). In the AUTOMATIC mode, the controller network matches impedance automatically.

5.4.9.3 Tuning Capacitor and Motor

The tuning circuitry automatically moves the tuning capacitor to minimum reflected power by sensing the phase relationship between the voltage and current in the coaxial cable that transmits power from the generator to the sputter head. If the voltage leads the current, the controller runs the motor in one direction; if the voltage lags the current, it runs the motor in the other direction. When the voltage and current are in phase, the phase detector stops the tuning motor.

5.4.9.4 Load Capacitor and Motor

The load matching circuit is pre-set via the potentiometers on the front panel. When a target is changed or a new operating mode is selected, the corresponding potentiometer must be adjusted to the value of the load matching circuit. The load matching circuit is driven by a position-servo system. Load matching is performed before tuning. The load matching circuit DOES NOT automatically adjust for reflected power.

5.4.9.5 RF Programmable Power/Voltage Stabilizer

The programmable power stabilizer regulates the level of RF power or voltage delivered to the selected target. It maintains constant power for RF sputtering and etching processes despite variations in AC line voltage, gas pressure, work characteristics, and temperature.

A 2-position toggle switch at the lower right front of the power/voltage stabilizer control panel allows the operator to select POWER or VOLTAGE. If POWER is selected, RF power will be maintained at the operator-preset level by automatically varying the voltage. If VOLTAGE is selected, RF voltage will be maintained by varying power.

The programmable power stabilizer operates in the MANUAL or PROGRAM modes. (MANUAL and PROGRAM modes refer to the operating mode of the MSC, which is described in Chapter 6.

Manual Mode	The power stabilizer may be either ON or OFF. When it is ON, the stabilized power adjust dial controls the RF power to the sputter head assembly. When it is OFF, the RF power is controlled manually by the RF power adjust potentiometer on the system meter panel, but no stabilization operations are performed.
Program Mode	Control of RF power is transferred to the MSC or to the RF power adjust knob on the sputter head assembly control panel.

5.4.10 Gas Metering Valves (3)

(See Figure 5-12.)

Located on the right side of the sputter head assembly, the manual gas metering assembly consists of a stainless steel needle valve equipped with a precision micrometer head for accurate and repeatable settings. (Turning the micrometer head clockwise reduces the flow of gas.) The proper setting is determined empirically and depends upon a) the desired argon pressure, and b) the adjustment of the throttle valve. On systems equipped with manual gas only, the throttle valve is factory-preset to a mechanical stop for 40 sccm at at a pressure of 10 milliTorr. (On manual gas systems, the operator can select THROTTLE OPEN or THROTTLE CLOSED [to the 10 mT/40 sccm position]).

An gas shut-off solenoid valve is connected in series with the gas metering valve. During operation, the metering valve is set to produce the desired gas working pressure, and the shut-off valve stops and starts the flow of gas without changing the metering valve setting. The shut-off valve is actuated by the gas control on the automatic pressure controller (included with the Brooks gas control option).

The automatic gas option (which may be installed to control one (1), two (2), or three (3) gases) consists of Brooks Model 5058 flow controllers and a servo-operated throttle valve. As in manual gas systems, the throttle is factory-preset for 10 mT/40 sccm. A typical 3-gas arrangement is:

GAS 1	NITROGEN, 0 - 100 SCCM
GAS 2	NITROGEN, 0 - 10 SCCM
GAS 3	NITROGEN, 0 - 10 SCCM

The operator selects a desired pressure and flow rate for one or more gases via programmed data cards (all models, or optionally via the data terminal keyboard on Model 4480), and the throttle servos to maintain the desired chamber pressure.

5.5 Power Supplies

WARNING

THE OPERATING VOLTAGES WITHIN THE RF GENERATOR AND DC POWER SUPPLY ARE POTENTIALLY LETHAL. OPERATIONS REQUIRING THE CONNECTION, DISCONNECTIÒN, OR DISASSEMBLY OF RF GENERATORS MUST BE PERFORMED BY QUALIFIED ELECTRICAL TECHNICIANS, FOLLOWING THE PROCEDURES SET FORTH IN THE SERVICE MANUAL FOR THE SPUTTERING SYSTEM AND THE SERVICE MANUAL FOR THE PARTICULAR POWER SUPPLY. SUCH OPERATIONS ARE NOT THE FUNCTION OF SYSTEM OPERATORS.

4400-Series systems are typically provided with one or more of the following optional power supplies, depending on the application:

1. RF Generator, 1, 2, or 3 kW (3kW unit available only for Models 4450/4480 equipped with Delta™ cathodes.)

2. DC Magnetron, 5 or 10 kW (10kW unit available only for Models 4450/4480 equipped with Delta™ cathodes.)

NOTE

An RF generator will be required if sputter etching is to be performed, even if no RF sputter deposition will be performed. THE MAXIMUM POWER LIMIT FOR SPUTTER ETCH IS ONE (1) KW.

5.5.1 RF Generators

The RF power generators used with the 4400-Series systems include a crystal controlled exciter section and a single stage linear power amplifier. Complete overload protection and remote operation are standard features. Harmonic and other spurious radiation is reduced in accordance with FCC regulations and OSHA standards.

CAUTION

THE POWER TUBE DEVELOPS HIGH TEMPERATURES DURING OPERATION, FOR WHICH REASON THE GENERATOR MUST BE LOCATED FAR ENOUGH FROM ALL SURFACES TO ALLOW AN UNOBSTRUCTED FLOW OF COOL AIR THROUGH ITS REAR VENT. DO NOT PLACE OBJECTS ON THE VENTILATING GRILL ON TOP OF THE GENERATOR.

5.5.1.1 Specifications for RF Generators:

Operating Frequency	13.56 MHz
Frequency Stability	+/- 2 kHz
Output Impedence	52 Ohms (Standing wave ratio not to exceed 3:1. Reflected power not to exceed 25%.)
Exciter	7.8 MHz, crystal controlled oscillator with internal buffer/doubler.

5.5.1.2 Safety Interlock Switches

Safety interlock switches are provided as a standard feature of all 4400-Series sputtering systems. They ensure operator and system protection during RF and DC sputtering operations. RF and/or DC power cannot be turned ON if water flow, sputtering module cover, and power supply door interlocks are not in a safe condition. In addition, process gas must be ON, and the main power supply circuit breaker for each power supply being used must be ON.

When the circuit breaker on the RF generator is turned ON, the green pilot light above the breaker (on the front door panel of the cabinet) is lit and the cooling fan in the power supply cabinet begins operating.

CAUTION

BEFORE TURNING THE RF GENERATOR MAIN POWER CIRCUIT BREAKER ON, ADJUST THE POWER ADJUST CONTROL (LOCATED ON THE SPUTTERING MODULE FRONT PANEL) TO THE MINIMUM POWER SETTING (I.E., FULLY COUNTER CLOCKWISE). DO NOT APPLY POWER TO ANY TARGET UNTIL THE SYSTEM IS AT VACUUM (AT OR BELOW 50 MILLITORR).

After the main circuit breaker for the RF generator is turned ON, wait at least 90 seconds before applying RF power.

RF power is applied in one of two ways:

<u>APPLYING RF POWER MANUALLY</u>

1. Place the sequence switch (Models 4450/4480 only) in the MANUAL position.

2. Check that the TARGET SELECTOR and MODE SELECTOR switches are properly positioned for RF deposition.

3. Adjust the RF power selector dial for the desired power.

4. Depress the RF ON pushbutton located on the sputtering module front panel. (If the light in the button does not turn ON, depress the button again. If it still does not light, check the interlock circuits described above.)

NOTE

To prolong life of the power tubes, allow the generator to operate for five minutes in the RF OFF mode before switching OFF the RF generator main power circuit breaker.

5.5.2 Programmable DC Magnetron Power Supplies

The 5 and 10 kW programmable DC magnetron power supplies regulate the output power to a constant volt-amp (VA) product (10kW unit available only for Models 4450/4480 equipped with Delta™ cathodes). The VA constant is programmed into the power supply either via a) the manually operated potentiometer located on the power supply front panel, or b) a remotely controlled programming voltage source.

For 5 kW units, the design load value is 30 - 70 ohms with a current limit set at 12.9 amps; for 10 kW units it is 25 - 70 ohms with a current limit set at 20 amps.

The load resistance required to develop the rated maximum power in the 5 kW unit is 30 - 70 ohms; in the 10 kW unit it is 25 - 70 ohms. This value varies during operation.

5.5.2.1 Specifications for DC Magnetron

INPUT	1. 208 VAC - 230 VAC, 3-phase, 4-wire, 60 Hz. 200 VAC, 3-phase, 4-wire, 50 Hz. 380 VAC, 3-phase, 4-wire, 50 Hz. 2. Connector: Arrow/Hart No. 6535, 480 V, 30 Amp. Mate: Arrow/Hart No. 6534.
OUTPUT	1. Current: Max. 12 Amp. 2. Voltage: Open circuit approx. 800 VDC 3. Protected for short circuits and plasma discharges.

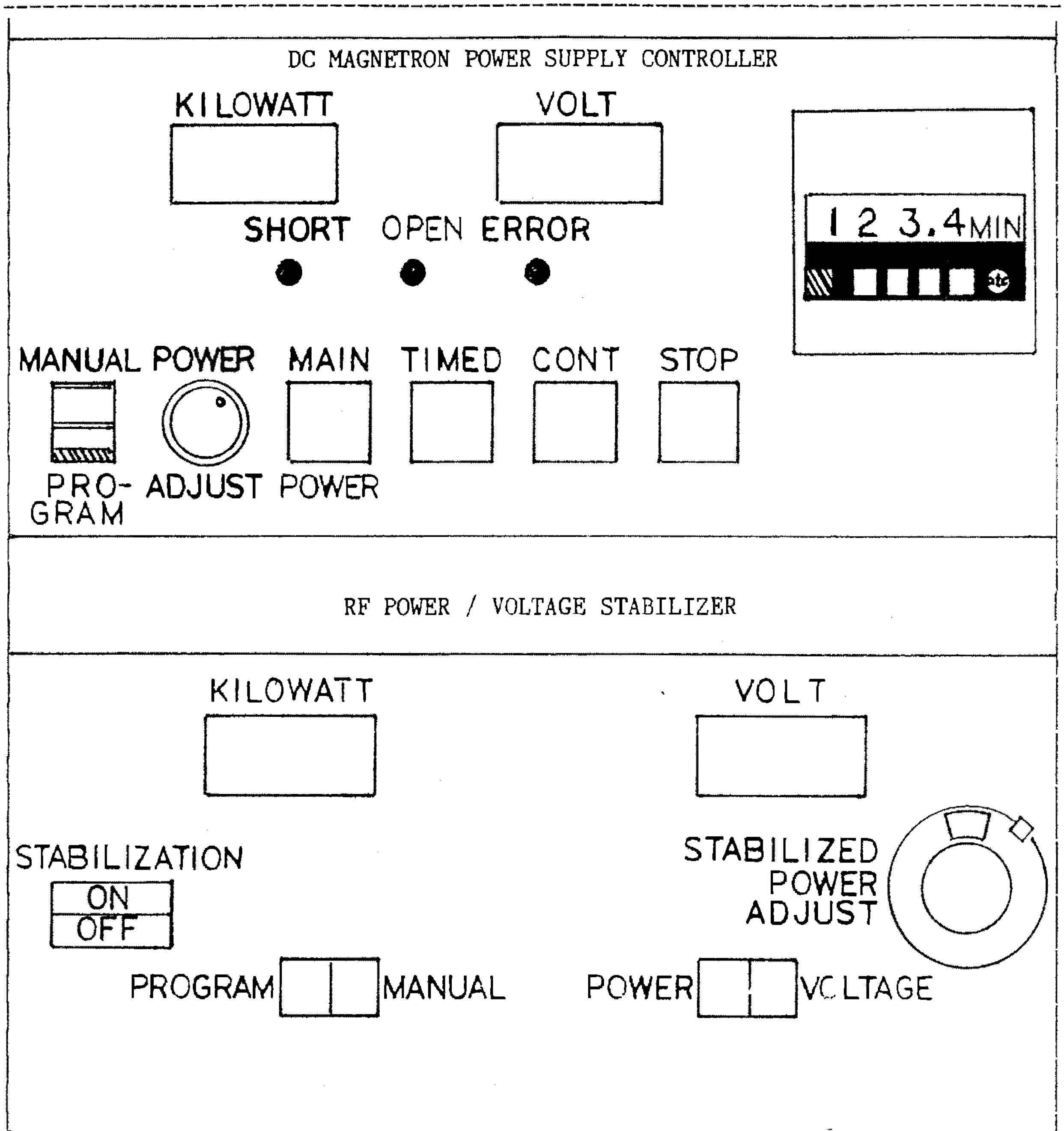


FIGURE 5-14

SYSTEM CONTROLS

METERING
1. Voltage: 0 - 1000 VDC.
2. Current: 0 - 15 Amp.

The following controls and indicators are found on the front panel of both 5 and 10 kW supplies (see Figure 5-14):

Kilowatt and Volt Digital Readouts
Display the respective levels as developed by the power supply.

Three Light Emitting Diodes
Labeled SHORT, OPEN, and ERROR, the three light emitting diodes (LEDs) provide indicators of conditions existing at output terminals of the power supply, as follows:

SHORT Short circuit appearing across the output

OPEN Open circuit appearing at the output

ERROR Appears when the output VA product does not match the programmed level (manual or programmed inputs)

Digital Timer Sets the duration of the DC deposition time. Power supply turns OFF when timer reaches zero.

MANUAL/PROGRAM Switch
Selects the operating mode of the power supply (i.e., whether the VA constant is read from the front panel potentiometer or from a remote source).

Power Adjust Knob Sets the desired VA level (for MANUAL mode operation).

Main Power Light Illuminates when the circuit breaker on the rear panel of the power supply is turned ON, indicating that the supply is ready for use.

TIMED Pushbutton Initiates DC deposition and starts the timer running.

CONT[inuous] Pushbutton
Turns ON the high voltage.

STOP Pushbutton Turns OFF high voltage.

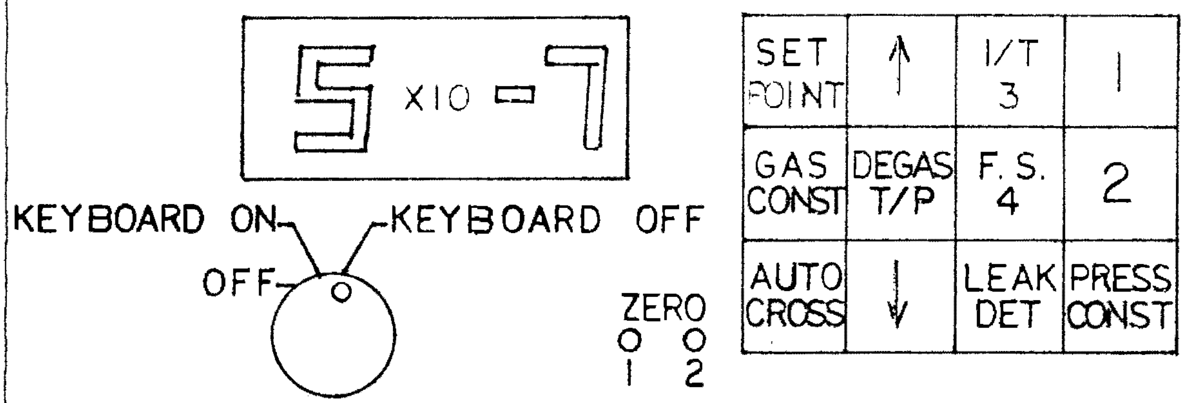


FIGURE 5-15

DGC-III DIGITAL ION GAUGE CONTROLLER

5.6 DGC-III Ion Gauge Controller

The DGC-III is used to select pressure set points, to monitor pressure via ion or thermistor tube, to automatically select an ion tube or thermistor, depending on pressure, to de-gas ion tubes, and to leak test vacuum chambers.

5.6.1 Controls and Indicators

(See Figure 5-15)

KEYBOARD / POWER KNOB
Select power ON/OFF, keyboard ON/LOCKED. In the keyboard LOCKED mode, depressing keys has no effect. This feature is used to prevent accidental keyboard entries.

ZERO KEY
Depressing this key resets the thermistor gauges to zero. (The ion gauges are zeroed automatically.)

COMMAND ENTRY KEYPAD
Used to select the many special functions of the DGC-III controller. Keypad functions are described below:

Set Point
Depressing the Set Point key takes the DGC-III out of the operating mode and prepares it to change one of the set point values. After depressing the Set Point key, depress one of the following: 1, 2, 3 (which doubles as the I/T key), or PRES CNTL, to determine if Set Point 1, 2, or 3, or the PRES CNTL set point will be adjusted.

UP and DOWN
After the controller has been instructed which set point to adjust, as described above, the UP and DOWN keys are used to increase or decrease the value of that particular set point. Pressing the UP key momentarily, for instance, will cause the value displayed on the digital display (i.e., the value of the set point being adjusted) to INCREASE by 1/10th of a unit. Depressing and holding the UP key will cause the value to increase slowly at first, then increase rapidly. If the value is allowed to increase more than desired, it can be corrected using the DOWN key. DEPRESSING ANY KEY OTHER THAN UP OR DOWN WILL ENTER THE CHANGED VALUE INTO MEMORY, AND RETURN THE DGC-III TO NORMAL OPERATION.

I/T (Ion/Thermistor)
Depressing this key toggles the sensing function from ion tube to thermistor tube, or from thermistor tube to ion tube. For example, if the DGC-III is monitoring Ion Gauge 2 when the I/T key is selected, it will stop monitoring that gauge and begin monitoring Thermistor Gauge 2. (IF THE SET POINT KEY HAS JUST BEEN SELECTED, THE I/T KEY WILL

FUNCTION AS A 3 (i.e., will cause the DGC-III to allow changes to the value of Set Point 3.)

1 and 2 — Depressing the 1 key causes the DGC-III to begin monitoring (ion or thermistor) Gauge 1. Depressing the 2 key causes the DGC-III to begin monitoring (ion or thermistor) Gauge 2. (IF THE SET POINT KEY HAS JUST BEEN SELECTED, THE 1 AND 2 KEYS WILL INSTRUCT THE DGC-III TO ALLOW CHANGES TO THE VALUE OF SET POINT 1 OR SET POINT 2, RESPECTIVELY.)

Auto Cross — The Auto Cross function is ON if either the Gauge 1 or Gauge 2 indicator LED is flashing. Depressing the AUTO CROSS key will toggle the function (i.e., turn it ON if it was off, or OFF if it was on). When Auto Cross is ON, the DGC-III will automatically select the gauge (ion or thermistor) that is correct for the actual pressure level of the chamber in which pressure is being measured (in other words, the DGC-III will save the operator the trouble of pressing the I/T key to switch from thermistor tube to ion tube when pressure falls below 1×10^{-2} Torr, or vice versa).

Pres Cntl — Not Used.

Gas Const — The sensitivity of ion and thermistor tubes changes as the molecular composition of the vacuum environment changes. Depressing the GAS CONST key causes the DGC-III to allow changes to the Gas Constant. As soon as the GAS CONST key is depressed, the current value of the Gas Constant is displayed on the digital display. Valid Gas Constant values are 2 (hydrogen), 4 (helium), 16 (methane), 18 (water), 28 (nitrogen or air), 40 (argon), and 99 (xenon). Pressing any key OTHER than UP or DOWN enters the new Gas Constant into memory and returns the DGC-III to its normal operating mode. (The MULTIPLIER indicator LED will light whenever a Gas Constant OTHER than 28 (nitrogen) is selected.)

T/P (Torr or Pascal) — THE T/P KEY BECOMES ACTIVE ONLY WHEN THE DGC-III IS IN THE "SET GAS CONSTANT" MODE (see above). Depressing this key toggles the digital display between readings in Torr and readings in Pascal. The digital display will show an "A" for Pascal and a "C" for Torr. (The MULTIPLIER indicator LED will light whenever Pascal is selected.)

De-Gas — Depressing the DEGAS key initiates a timed de-gas procedure for the CURRENTLY SELECTED ion tube. De-gas power will be turned OFF when the counter reaches 9.9, if the operator depresses the DEGAS key a second time, or if emission current regulation fails. (The de-gas command will be rejected if no ion tube is currently ON, or if pressure exceeds 1×10^{-2} Torr.)

F.S. — Not used.

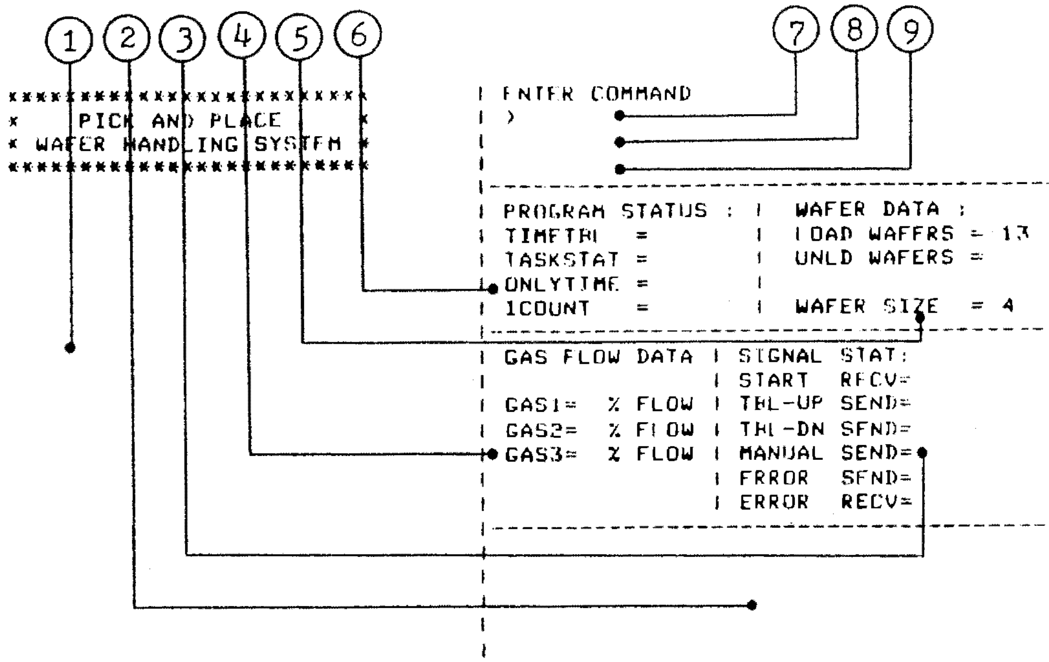


FIGURE 5-16

PE-6100 DATA TERMINAL DISPLAY (SIMULATED)

1. PICK-AND-PLACE COMMANDS AND ERROR MESSAGES
2. MSC (MAIN SYSTEM CONTROLLER) MESSAGES
3. STATUS OF COMMUNICATIONS LINES (PICK-AND-PLACE TO MSC)
4. EITHER "GAS FLOW" OR "TABLE HOME" OR "WAFER HANDLING" INFORMATION
5. WAFER SIZE, AND NUMBER OF WAFERS TO LOAD / UNLOAD DURING NEXT CYCLE
6. PROGRAM STATUS
7. COMMAND LINE (OPERATOR COMMANDS APPEAR HERE AS TYPED)
8. RESPONSE LINE (COMPUTER RESPONDS TO COMMANDS IN THIS SPACE)
9. ECHO LINE (DISPLAYS PREVIOUS OPERATOR COMMAND)

5.7 The PE-6100 Data Terminal

All 4400-Series Production Sputtering Systems are equipped with a PE-6100 Data Terminal. The CRT screen is used to display gas flow information (all systems equipped with the Brooks automatic gas control option), error messages, and wafer handling information (Model 4480 only).

Except as used with the Model 4480 Automatic Wafer Handling system (see Chapter 7), there are no provisions at this time to allow the system operator to enter data via the PE-6100 keyboard.

5.7.1 Powering Up the PE-6100 Terminal

The PE-6100 typically remains powered up so long as the sputtering system is powered up (i.e., other than for major service operations). The PE-6100 Data Terminal may be switched ON or OFF at any time without disrupting system operation, using the ON/OFF toggle switch mounted on the left side of the data terminal housing.

5.7.2 The CRT Display

Figure 5-16 shows a typical CRT display during a wafer handling routine. Notice that the screen is divided into seven (7) distinct areas, each of which contains a different type of information. Note also that one of the areas is used to display information related to three (3) different operations: wafer handling, pallet HOME position indexing, and process gas flow levels — according to which operation is in progress.

5.8 Safety Features

5.8.1 Safety Interlock Switches

Safety interlock switches are provided as a standard feature incorporated into all systems. They ensure operator and system protection during RF and DC sputtering. If any of the interlocks are not properly activated, RF and DC power cannot be turned ON.

5.8.1.1 Sputter Module Cover Switches

All safety covers must be in place.

5.8.1.2 RF Generator Doors

Both front and rear doors must be in place and closed.

5.8.1.3 DC Power Supply Cover Panels

All side panels must be in place on the DC power supply.

5.8.2 Water Flow Switches

Adequate water flow for cooling must be provided. Water flow switches are located in the front of the system main frame, lower right side.

Water flow switches provide fail-safe monitoring of water flow in the range 0.1 - 10.0 gallons per minute (gpm). The turbine portion of the flow switch is installed in series with the outlet water line of the component being protected. Water passing through the switch housing rotates a paddle wheel, generating a voltage which is detected by the solid-state sensing module. If the voltage indicates a flow rate BELOW the pre-set value, a relay in the sensing module de-energizes, turning the protected device OFF immediately.

5.8.3 Logic Interlocks

The MSC checks for the following conditions before allowing the operator to initiate sputtering operations:

5.8.3.1 RF Power Supply Output Power

The RF power supply main power circuit breaker must be ON.

5.8.3.2 DC Power Supply Output Power

The DC power supply main power circuit breaker must be ON.

5.8.3.3 Gas Mode

The gas mode must be ON to supply sputtering gas to the process chamber.

Chapter 6

THE MAIN SYSTEM CONTROLLER - MSC

The Main System Controller (referred to throughout this manual as the MSC) is conveniently located in the upper center bay of the sputtering system main frame.

The MSC allows the operator to control system operation in three (3) ways:

1. After entering process instructions into MSC computer memory via data cards (explained in Section 6.5 of this chapter) or via the PE-6100 Data Terminal keyboard (Model 4480 only -- explained in section 7.4 of the next chapter) , the operator may initiate a complete sequence of operations simply by depressing the ENABLE and CYCLE START pushbuttons simultaneously.

2. By simultaneously depressing the ENABLE pushbutton and any other of the square shaped AUTOMATIC SEQUENCE pushbuttons (explained in Section 6.3 of this chapter), the operator may initiate a standard system function, such as pumping the process chamber to high vacuum, transferring the substrate pallet from the process chamber to the load lock, venting the system, etc.

3. By selectively positioning the MANUAL CONTROL toggle switches (explained in Chapter 8), an EXPERIENCED operator may directly control all pumping, venting, and mechanical motion functions. THE MANUAL CONTROL MODE ALLOWS THE OPERATOR TO PERFORM POTENTIALLY DANGEROUS OPERATIONS. THIS MODE IS FOR THE USE OF PROCESS ENGINEERS AND SERVICE PERSONNEL ONLY.

The Perkin-Elmer MSC is a solid state, microprocessor based unit capable of providing either automatic or manual control of the 4400-Series Production Sputtering Systems. It is equipped with a 30 step, user programmable memory designed to store process instructions. Process instructions are commands, entered into the MSC via operator-encoded data cards, which control some or all of the following system functions:

- Gas Control
- Pressure Control
- Load Lock Control
- Target Selection
- Process Mode Selection
- Deposition and Etch Voltage/Power Settings

- Deposition/Etch Time
- Pallet Loading/Unloading (*)
- Pumpdown and Vent Control (*)
- Automatic Wafer Handling (*)

The functions marked with an asterisk (*) are provided by the MSC whether or not a process sequence is entered via data cards. These functions can be initiated via a program sequence using data cards, or by depressing the ENABLE pushbutton in conjunction with the appropriate function pushbutton: UNLOAD, PUMP, VENT, etc.

NOTE

Some of the automatic functions of the MSC (i.e., automatic target selection, automatic sputtering mode selection) cannot be performed by the Model 4400, since that system's sputtering module is not designed for automatic operation.

NOTE

The MSC is programmed to control all possible system configurations, regardless of which options actually have been installed on a given system. For this reason, there may be switches on the MSC that have no application for the system being operated.

6.1 Operating the MSC

(See Figure 6-1 for locations of components.)

The MSC provides either MANUAL (all systems) or AUTOMATIC (all systems, but to varying degrees) control of the sputtering system. In the AUTOMATIC and PROGRAM modes, software interlocks protect the system from improper operation. Because no such interlocks function in the MANUAL mode, the operator must be familiar with the procedures described in this section before attempting to operate the system in the MANUAL mode.

CAUTION

BEFORE TURNING ON A.C. POWER TO THE SPUTTERING SYSTEM, CHECK THAT THE MSC IS IN THE MANUAL MODE.

6.1.1 Key Switch - MSC

The MSC can be key-locked into any of three modes: MANUAL, PROGRAM, or AUTO. During normal process operation the system should be locked in the AUTO mode. The AUTO mode keeps the current set of process instructions stored in memory, allows two-button process cycle initiation, and protects the system against illegal operations through intrinsic software interlocks. The key switch positions and the functions associated with each position are summarized in Table 6-1.

A RESET function is also provided. The RESET key switch position is spring-loaded (i.e., momentary closure).

Selecting RESET, by turning the key switch to the far left position and then releasing it, causes the MSC computer to re-initialize (i.e., to abort all operations in progress. If the carriage and/or pallet is/are not in the load lock when the RESET is performed, the operator will have to re-position them using the MANUAL mode before proceeding with another automatic sequence. If the MSC is powered down, stored process instructions will be lost; in this case, re-load data cards before proceeding.

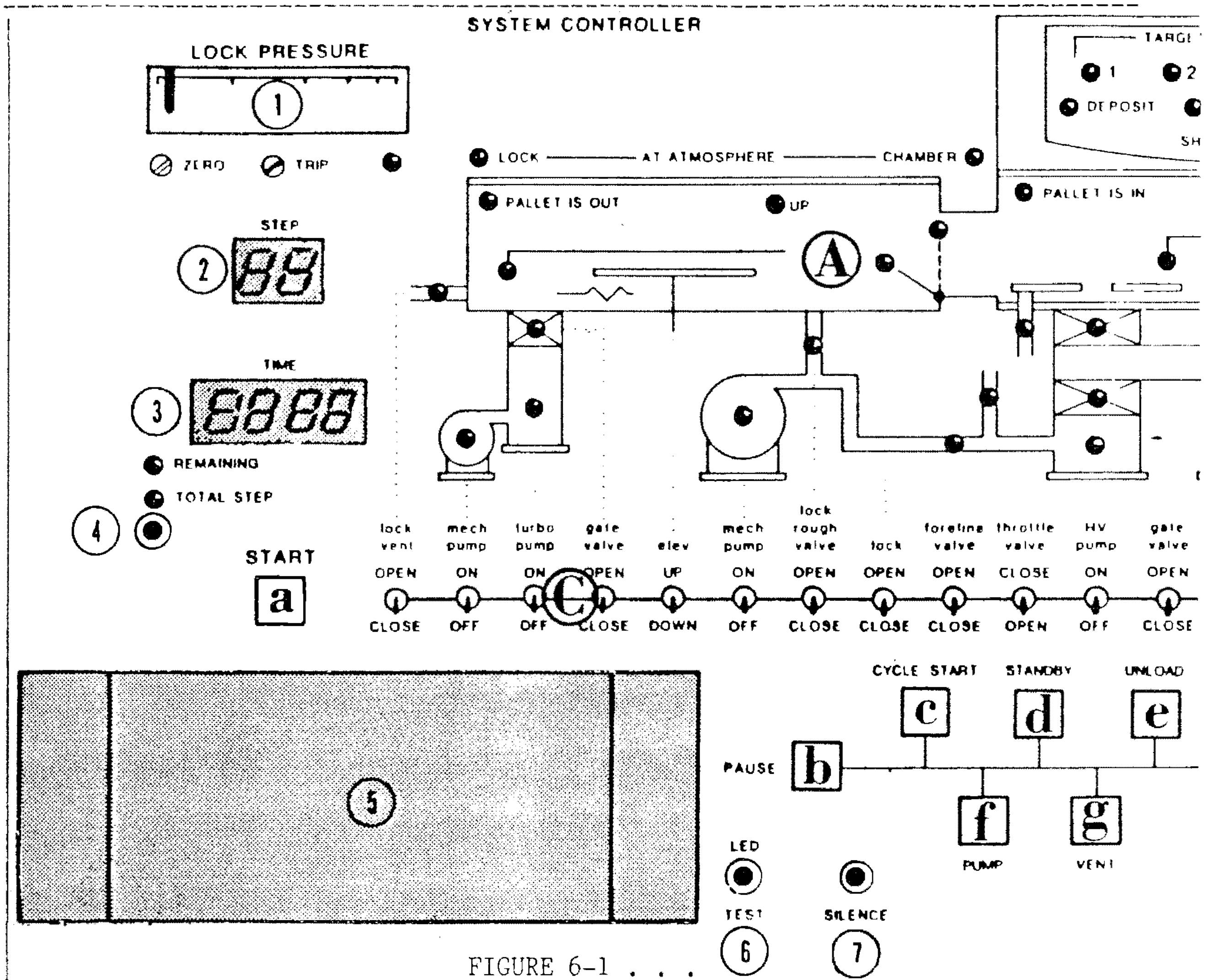
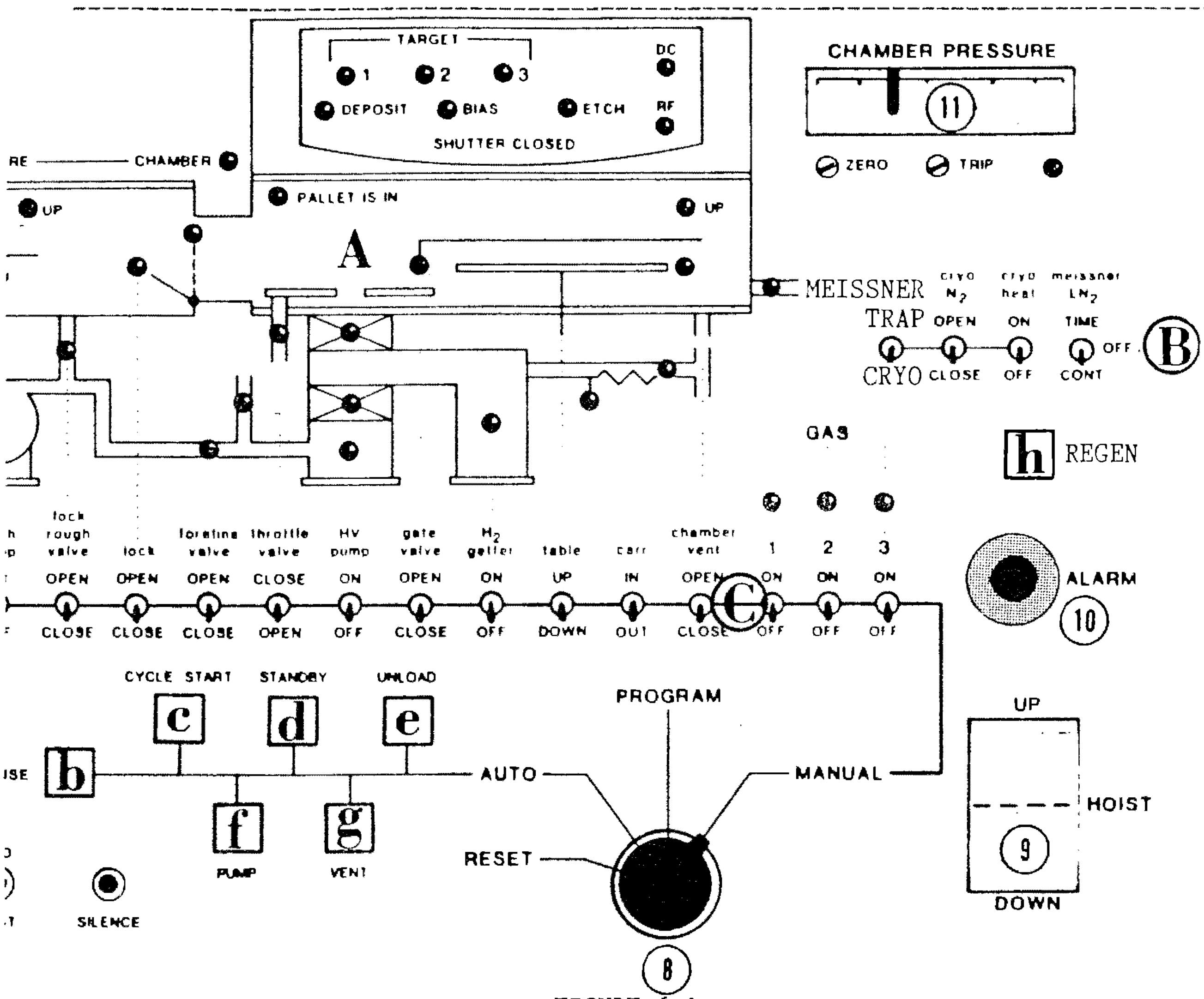


FIGURE 6-1 . . .

MAIN SYSTEM CONTROLLER FRONT PANEL

1. LOAD LOCK PRESSURE ANALOG GAUGE
2. "STEP NUMBER" DIGITAL DISPLAY
3. "TIME REMAINING" / "TOTAL TIME" DIGITAL DISPLAY
4. "TIME REMAINING" / "TOTAL TIME" SELECTOR PUSHBUTTON
5. DATA CARD READER
6. LED TEST PUSHBUTTON
7. ALARM SILENCE PUSHBUTTON
8. MODE SELECTOR KNOB
9. SPUTTERING HEAD HOIST ACTUATOR SWITCH
10. AUDIBLE ALARM TRANSDUCER
11. PROCESS CHAMBER PRESSURE ANALOG GAUGE



. . . FIGURE 6-1

MAIN SYSTEM CONTROLLER FRONT PANEL

A. SYSTEM LAYOUT WITH LED INDICATORS

B. TOGGLE SWITCHES FOR MANUAL CRYO OR MEISSNER FUNCTIONS

C. TOGGLE SWITCHES FOR MANUAL SYSTEM CONTROL

AUTOMATIC FUNCTION PUSHBUTTONS

a. ENABLE	b. PAUSE	c. CYCLE START	d. STANDBY
e. UNLOAD	f. PUMP	g. VENT	h. REGEN

TABLE 6-1
KEY SWITCH POSITIONS

Key Switch Position	Function
MANUAL	Service mode; no active interlocks. allows direct operator control of all pumping, venting, and mechanical motion system functions. (See Chapter 8 of this manual for details of MANUAL operation.)
PROGRAM	Normal mode for inputting data card programs. In the PROGRAM mode, the CYCLE START button is active. Simultaneously depressing the ENABLE and CYCLE START buttons in the PROGRAM mode causes the MSC to single-step through the current set of process instructions, allowing variables to be verified. (Data card programming instructions are given in Section 6.5 of this chapter.)
AUTO	Normal operational mode for automatic process control. A process sequence stored in memory can be initiated (once the load lock lid has been lowered) by simultaneously depressing the CYCLE START and ENABLE buttons located on the front panel of the MSC. (Chapter 7 of this manual is devoted to AUTOMATIC system operation via the MSC.)
RESET	Resets the MSC computer and aborts any operation in progress. Pallet and carriage must be repositioned in load lock manually if they are not there, before proceeding with automatic sequences.

6.2 Manual Operation

(Chapter 8 of this manual is devoted to manual system functions.)

With the exception of the gas servo and pressure control sub-systems, and regeneration of Meissner trap and cryo pump (which must be controlled automatically), most of the functions of the sputtering system can be performed when the key switch is set to the MANUAL mode. Sequences such as pumping, venting, and pallet transport can be initiated by operating the MSC toggle switches individually.

CAUTION

ONLY PROCESS ENGINEERS OR SERVICE PERSONNEL THOROUGHLY FAMILIAR WITH SPUTTERING SYSTEM OPERATION SHOULD OPERATE SYSTEMS IN THIS MODE, HOWEVER, AS THERE ARE NO ACTIVE SOFTWARE INTERLOCKS TO PROTECT SYSTEM AND OPERATOR FROM THE RESULTS OF OPERATOR ERROR.

THE FUNCTIONS OF ALL MSC TOGGLE SWITCHES ARE LISTED IN IN TABLE 6-2.

TABLE 6-2
FRONT PANEL CONTROLS

ITEM	FUNCTION
PANEL METERS	
Analog Meter	Chamber pressure reading in milliTorr.
Analog Meter	Load Lock pressure reading in milliTorr.
DIGITAL DISPLAY	
2-Digit	Step or sequence number.
4-Digit	Clock, time remaining, or total time per step (operator selectable).
POTENTIOMETERS	
Chamber Zero	Resets the meter to zero.
Chamber Trip	Selects the chamber vacuum set point.
Lock Zero	Resets the meter to zero.
Lock Trip	Selects the lock vacuum set point.
2-POSITION TOGGLE SWITCHES	
Chamber Vent	Turns ON and OFF nitrogen vent gas.
Mechanical Roughing Pump	Turns ON and OFF roughing pump.
[Process] Chamber Gate Valve	Opens and closes chamber gate valve.
Foreline/Cryo Regen Valve	Opens and closes foreline / cryo pump regeneration valve.
Meissner Trap/ Cryo [Regenerate]	Determines which regeneration cycle will be initiated when the REGEN and ENABLE pushbuttons are depressed.
Cryo N_2 Heat	Turns ON and OFF cryo pump nitrogen heater.

...TABLE 6-2 CONTINUED

High Vacuum Pump	Turns ON and OFF Hi-Vac pump.
Throttle Valve	Opens throttle valve or closes throttle valve against a pre-set stop (typically 10% open).
Process Gas 1	Turns ON and OFF process gas 1
Process Gas 2	Turns ON and OFF process gas 2
Process Gas 3	Turns ON and OFF process gas 3
Lock Mechanical Pump	Turns ON and OFF load lock mechanical roughing pump.
Lock Turbo Pump	Turns ON and OFF load lock turbomolecular pump.
Lock Gate Valve	Opens and closes load lock gate valve.
H_2 Getter Pump	Not Used.
Lock Isolation Valve	Opens and closes the lock separating the load lock and the process chamber (i.e., the lock door through which the pallet is transferred from lock to chamber).
Elevator UP/DOWN	Raises and lowers the load lock pallet elevator.
Lock Roughing Valve	Opens and closes the load lock roughing valve.
Lock Vent Valve	Opens and closes the load lock vent valve.

<u>3-POSITION TOGGLE SWITCHES</u>

LN2 TIMED/CONT/OFF	Controls flow of liquid nitrogen coolant to the Meissner trap. (Center switch position = OFF)
Carriage IN/OUT	Moves pallet transport carriage in and out of the process chamber. (Center switch position = NO ACTION)
Table UP/DOWN	Raises and lowers the process chamber substrate table. (Center switch position = NO ACTION)

<u>ROCKER SWITCHES</u>

Hoist UP/DOWN	Raises and lowers the sputter module hoist (cannot be activated if chamber is under vacuum).

...TABLE 6-2 CONTINUED

MINIATURE BUTTON SWITCHES

Time Remaining/Total Step Time	Changes 4-digit display from one mode to the other.
LED Test	Causes all LED indicators to light, for testing.
Silence	Silences system audible alarm when depressed together with ENABLE.

LED INDICATORS

Chamber Vent	Lights when venting nitrogen is ON.
Mechanical Roughing Pump	Lights when roughing pump is ON.
Foreline/Cryo Regen Valve	Lights when valve is OPEN.
Cryo Vent Valve	NOT CURRENTLY USED.
Cryo N_2 Valve	Lights when valve is OPEN.
Cryo N_2 Heater	Lights when heater is ON.
Chamber Gate Valve	Lights when valve is OPEN.
Throttle Valve	Lights when valve is CLOSED.
Process Gas 1	Lights when valve is OPEN.
Process Gas 2	Lights when valve is OPEN.
Process Gas 3	Lights when valve is OPEN.
Meissner LN2	Lights when valve is OPEN.
Lock Mechanical Pump	Lights when pump is ON.

...TABLE 6-2 CONTINUED

Lock Turbo Pump	Lights when pump is ON.
Lock Gate Valve	Lights when valve is OPEN.
Chamber Hi-Vac Pump	Lights when pump is ON.
H_2 Getter	Not Used.
Lock Isolation Valve OPEN	Lights when door is OPEN.
Lock Isolation Valve CLOSED	Lights when door is CLOSED.
Table UP	Lights when chamber substrate table is UP.
Table DOWN	Lights when chamber substrate table is DOWN.
Elevator UP	Lights when load lock elevator is UP.
Elevator DOWN	Lights when load lock elevator is DOWN.
Carriage IN	Lights when pallet transport carriage is IN CHAMBER.
Carriage OUT	Lights when pallet transport carriage is IN LOAD LOCK.
Lock Roughing Valve	Lights when valve is OPEN.
Lock Vent Valve	Lights when valve is OPEN.
Lock at Atm.	Lights when lock pressure = atmospheric pressure.
Chamber at Atm.	Lights when chamber pressure = atmospheric pressure.
Lock Trip	Lights when load lock vacuum reaches set point.
Chamber Trip	Lights when load chamber vacuum reaches set point.
Pallet IN	Lights when pallet is in the process chamber. The MSC assumes pallet is OUT upon initialization (either power-up or reset). This is the "defined" starting position. The PALLET IN indicator is illuminated after the MSC performs a LOAD sequence, automatically or via manual toggle switches.

...TABLE 6-2 CONTINUED

Pallet OUT	Lights when pallet is in the load lock (see PALLET IN, above).
Target 1	Lights when Target 1 is selected via MSC output lines.
Target 2	Lights when Target 2 is selected via MSC output lines.
Target 3	Lights when Target 3 is selected via MSC output lines.
Target 4	(Model 4400 only.) Not Yet Available.
Etch	Lights during ETCH mode.
Deposit	Lights during deposit.
Bias	Lights during deposit with bias.
RF	Lights when RF power is ON.
DC	Lights when DC power is ON.
Time Remaining	Indicates that digital display shows time remaining in step.
Total Step Time	Indicates that digital display shows total step time.

AUTOMATIC SEQUENCE PUSHBUTTONS

ENABLE	PAUSE	
CYCLE START	STANDBY	Explained in Section 6.3, "Automatic Operation."
UNLOAD	PUMP	
VENT	REGEN	

END TABLE 6-2

6.3 Automatic Operation

The MSC can operate automatically when the key switch is in the AUTO position. Depressing the ENABLE and CYCLE START buttons simultaneously in the AUTO mode will initiate processing according to the current program in memory. Depressing ENABLE along with another of the AUTOMATIC SEQUENCE buttons (i.e., UNLOAD, PUMP, VENT, etc.) will initiate the desired automatic sequence.

A description of the AUTOMATIC SEQUENCE button functions follows. These functions are summarized in Table 6-3.

6.3.1 CYCLE START

The CYCLE START button is active in the AUTO and PROGRAM modes. In the AUTO mode it serves the following functions:

- MODEL 4480 USING AUTOMATIC WAFER HANDLING (Pick-and-Place switch in AUTO position)

  * Starting a process sequence, as follows: Load one empty and one full cassette into place in the cassette chamber, as described in Chapter 5. Close the cassette chamber lid. Place the key switch in the AUTO position, and simultaneously depress the ENABLE and CYCLE START buttons. The automatic wafer handling system will load the first batch of wafers onto the substrate pallet, then the wafers will be transferred to the process chamber and processed according to process instructions currently in memory, without further operator assistance.

  * Removing the substrate pallet from the process chamber following a sputter deposition or etch process (IN THE AUTOMATIC WAFER HANDLING MODE ONLY, processed substrates are retained in the process chamber under Hi-Vac until ENABLE and CYCLE START are depressed).

- MODEL 4480 USING MANUAL WAFER HANDLING (Pick-and-Place switch in MANUAL position)

  * Starting a process sequence, as follows: Load the sustrate pallet and place it in the load lock. Close the load lock lid. Place the key switch in the AUTO position, and simultaneously depress the ENABLE and CYCLE START buttons. The sequence of process instructions currently in memory will be executed, after which the pallet is tranferred to the load lock (which is then vented).

In the PROGRAM mode, it performs the following function:

- Place the key switch in the PROGRAM position, then depress the ENABLE and CYCLE START buttons simultaneously. The MSC will run through the set of process instructions currently in memory, one step at a time. At each step, the operator can check parameter values, make changes as necessary, or simply proceed to the next step by depressing the CYCLE button once more. (During PROGRAM mode operation, the front panel of the MSC provides a visual display stepnumber and timing information.)

- The PROGRAM sequence is identical to an AUTOMATIC sequence, except that the clock timer does not count down and the MSC does not automatically proceed from step to step.

6.3.2 STANDBY

The STANDBY button has three distinct functions:

STANDBY BEFORE PROCESS
Press ENABLE, CYCLE START to initiate a process sequence. Then depress ENABLE, STANDBY. The substrate pallet will be loaded into the process chamber BUT NOT PROCESSED (i.e., the system stands by) until operator repeats the ENABLE, CYCLE START command.

LOAD LOCK PUMP
Pressing ENABLE, STANDBY with the chamber at Hi-Vac, load lock vented, and no work in progress causes the load lock to pump down to vacuum, after which the system stands by for further instructions.

STANDBY AFTER PROCESS
While the pallet is in transit from the process chamber to the load lock, depress AND HOLD the ENABLE and STANDBY buttons until the pallet comes to rest in the load lock. This will override the automatic load lock venting that usually follows an unload sequence. The pallet will therefore remain in the load lock under vacuum, while the system stands by for further instructions.

NOTE

If the ENABLE, STANDBY command is given too early or too late, the load lock may begin an unwanted vent sequence. Depressing ENABLE, STANDBY after the load lock has begun to vent will cause the vent valve to close, and the load lock to pump to vacuum (after which the system stands by for further instructions).

6.3.3 UNLOAD

CAUTION

THE UNLOAD COMMAND WILL ABORT A RUNNING PROCESS. USE THIS COMMAND WITH CARE.

Pressing the ENABLE and UNLOAD buttons simultaneously causes the pallet to be unloaded from the process chamber.

The UNLOAD command may be selected any time the pallet is STATIONARY in either the process chamber or the load lock; it overrides the current process instruction and unloads the pallet, after which the load lock is vented.

6.3.4 PUMP

Pressing ENABLE and PUMP buttons simultaneously causes the process chamber to pump down to high vacuum, after which the load lock chamber is vented.

6.3.5 VENT

Pressing the ENABLE and VENT buttons simultaneously causes the system to vent to atmosphere (load lock and process chamber), where it awaits further instructions.

WARNING

THE 4400-SERIES SYSTEMS ARE NOT DESIGNED FOR USE WITH DANGEROUS GASES SUCH AS SILANE, ARSINE, ETC. TRACES OF PROCESSING GAS ARE VENTED INTO THE ATMOSPHERE SURROUNDING THE SYSTEM WHENEVER THE SYSTEM IS VENTED.

6.3.6 PAUSE

NOTE

The PAUSE function is NOT the same as the STANDBY function. PAUSE is used to temporarily halt a process cycle, while STANDBY is used as described above, to retain the load lock and/or process chamber under vacuum following pallet unloading.

6.3.6.1 ENABLE and PAUSE

Pressing the ENABLE and PAUSE buttons simultaneously halts execution of the current process (stops all "active elements" and POWER), retains all process instructions, and leaves the software pointer at the current process step. This allows the operator to stop a process, perform tests or measurements, and resume processing. To re-start the process, depress CYCLE START and ENABLE buttons simultaneously.

6.3.6.2 PAUSE after ALARM

In the event of a system or sequence malfuntion, an alarm is sounded. If the malfuntion is a "soft error" (see the chapter on Troubleshooting), the process will PAUSE rather than ABORTing. After remedying the cause of the error, the operator re-starts the process from the beginning by simultaneously depressing the ENABLE and CYCLE START buttons (if pallet is in the load lock) or by returning the pallet to the load lock manually (if pallet is not already there).

TABLE 6-3
FUNCTIONS OF AUTOMATIC SEQUENCE PUSHBUTTONS

CONTROL SWITCH	FUNCTION
ENABLE/CYCLE START (AUTO)	Begins with pallet loaded (load lock at atmospheric pressure) and chamber at vacuum. Initiates current instruction set.
ENABLE/CYCLE START (PROGRAM)	Allows for visual check of sequence by permitting "single-stepping" through the instruction set.
ENABLE/STANDBY	Actuated before an instruction set is initiated, causes the load lock to pump to vacuum and system to await further instructions. Actuated after CYCLE START, causes pallet to remain under vacuum inthe process chamber after processing, after which the system awaits further instructions. Actuated after UNLOAD, causes pallet to remain under vacuum in load lock and system to await further instructions.
ENABLE/UNLOAD	Causes pallet to be unloaded from process chamber and sent to load lock. Overrides any ongoing process cycle.
ENABLE/PUMP	Pumps process chamber to high vacuum from atmosphere, and vents load lock to atmosphere.
ENABLE/VENT	Vents process chamber and load lock to atmosphere.
PAUSE (ALARM)	Indicates system or process malfuntion by sounding an audible alarm and lighting the PAUSE button. Silence alarm by depressing the ENABLE and SILENCE buttons simultaneously. Re-start process by depressing CYCLE START and ENABLE buttons simultaneously (after condition has been cleared and system returned to the ready state, with pallet in the load lock).
ENABLE/PAUSE	Halts process execution WITHOUT power. Re-start process by depressing CYCLE START and ENABLE buttons simultaneously.

In the AUTO mode, some functions CANNOT be initiated while a process cycle is being executed. Table 6-4 summarizes functions as (A) active during process execution, (I) inactive during process execution, or (N/A) inapplicable, since funtion is already implemented.

TABLE 6-4
ACTIVE AND INACTIVE FUNCTIONS DURING PROCESS CYCLE

CYCLE IN PROCESS	CAN INITIATE ___ FUNCTION?						
	CYCLE START	UNLOAD	STANDBY	PAUSE ALARM	PUMP	VENT	PROCESS INSTRUCTIONS
CYCLE START	N/A	A	A	A	I	I	A
UNLOAD	I	N/A	A	A	I	I	I
STANDBY	A	A	N/A	I	I	A	I
PAUSE ALARM	A	A	I	N/A	I	I	A
PUMP	I	I	I	I	N/A	A	I
VENT	I	I	I	I	A	N/A	I

6.4 Programmed System Operation

Setting the key switch to the PROGRAM position permits instructions to be loaded via the data card reader (see section on Data Cards, below).

6.4.1 Setting Parameters

In the program mode, the ENABLE and CYCLE START buttons are depressed simultaneously to send to the MSC the first process step. At this time, all parameters associated with the first step can be verified. To advance each subsequent step to the MSC, depress the ENABLE and CYCLE START buttons again. Check the front panel display each time to verify proper program execution via the step number, time, and subsystems accessed by each program step.

6.4.2 Running the Process

Once a program has been loaded from the PROGRAM mode, place the key switch in the AUTO position. Depressing ENABLE and CYCLE START buttons simultaneously will execute the instruction set in current memory.

NOTE

Initiating any automatic sequence requires that the ENABLE button be depressed simultaneously with the appropriate FUNCTION button.

6.5 Programming the MSC

The MSC is designed to provide fully automatic operation of 4400-Series systems via three types of programs:

1. Those which are intrinsic to the MSC (i.e., the system software). These programs are stored on PROMs and control the operation of the MSC itself.

2. Those which are operator selectable via pushbuttons: CYCLE START, STANDBY, UNLOAD, PUMP, VENT,and PAUSE.

3. Those which are individually programmed by the operator. The MSC follows these specific instructions when controlling a sputtering process. Process instructions may be stored for future use on data cards. Process instructions include STANDBY, ETCH, TARGET PRE-CLEAN, SPUTTER DEPOSIT, BIAS DEPOSIT, LOAD LOCK HEAT, CHAMBER HEAT, and REPEAT.

The programs in group 1 are resident on PROMs, and comprise the internal instructions that govern the interaction between the MSC and the rest of the sputtering system. They provide the foundation for monitoring and controlling all phases of system operation so that the operator need not be concerned with the minute details of running the system. The only way a user can affect these programs is to remove and replace existing PROMs.

The programs in group 2 are the FUNCTIONS initiated by depressing the ENABLE button in conjunction with another FUNCTION button. These programs cannot be modified by editing or by inputting new information.

Descriptions of the group 2 functions and instructions for their use are given in the preceding section.

The programs in group 3 are referred to, throughout this manual, as PROCESS INSTRUCTIONS, to avoid confusion between these user-programmable functions and other, non-user-programmable ones. Process instructions are entered via data cards (see Figure 6-2), which are programmed by punching holes in the card with a suitable device. (Punched holes must be exactly one-quarter ince (1/4") in diameter.)

NOTE

> **Process instructions may alternatively be entered via the PE-6100 Data Terminal keyboard (Model 4480 only). Instructions for keyboard entry of process instructions are given in Section 7.4.**

A set of instructions from a single data card is referred to as a PROCESS STEP. Each data card (and consequently, each process instruction) is assigned a STEP NUMBER. Data cards may be fed into the data card reader in any order; the computer arranges the process instructions in the correct order based on the step number programmed onto each card. If two cards bear the same step number, the one entered LAST will override the prior instruction.

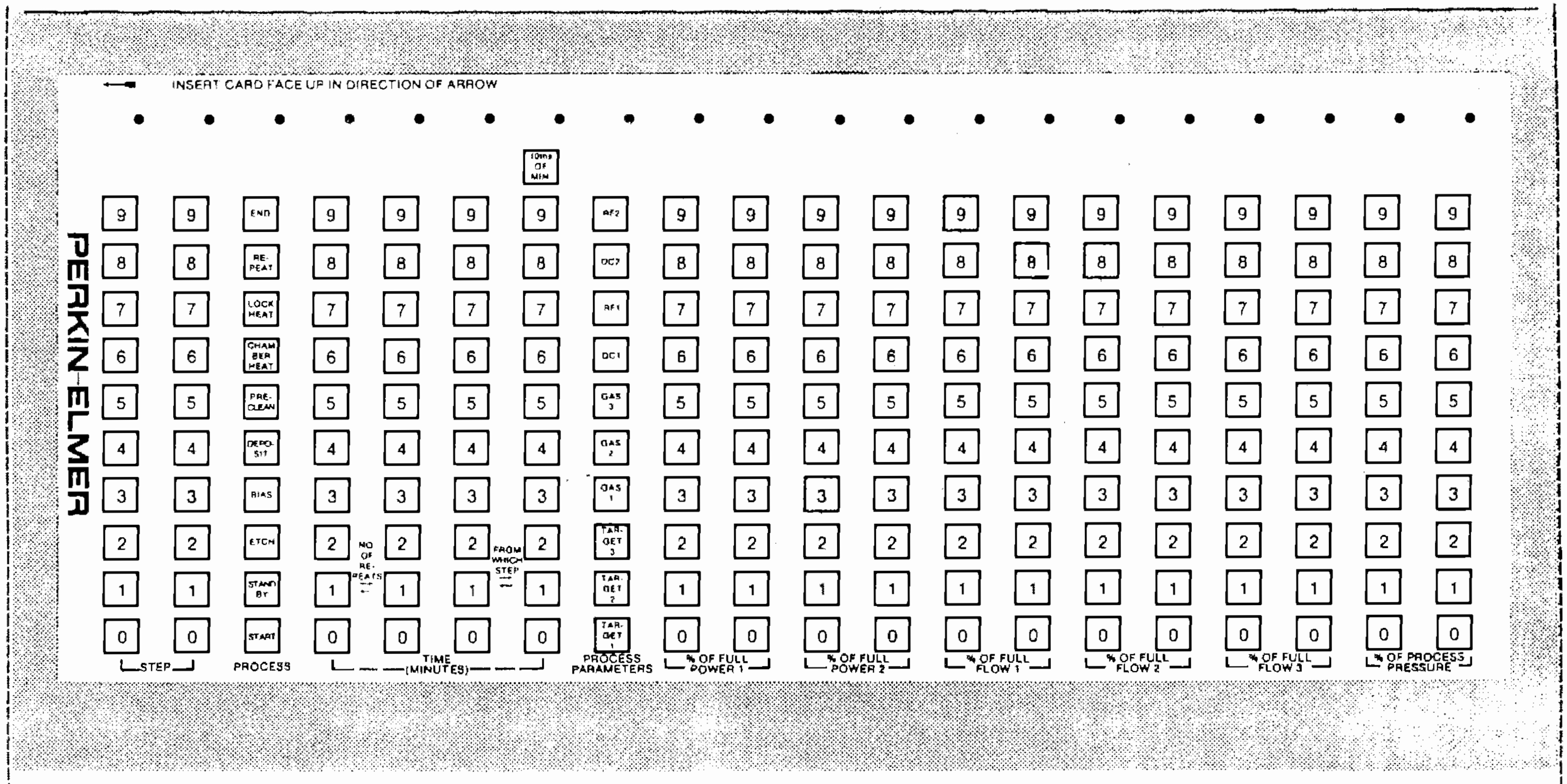


FIGURE 6-2

PROGRAMMABLE DATA CARD

PUNCH ONE-QUARTER INCH (1/4") HOLE IN APPROPRIATE BOXES
USE ONE DATA CARD FOR EACH PROCESS STEP

The card reader is mechanical in operation: the user supplies the motive force by feeding the card into the slot at the top of the reader and grasping it as it emerges at the bottom to pull it through in a smooth, continuous motion. Data will be accepted properly if cards are fed into the reader with the printed side toward the operator, and with the row of evenly-spaced timing holes toward the left edge of the card reader.

The MSC interprets process instructions using the body of information contained in the group 1 programs. For example, when an operator instructs the MSC to perform an ETCH function, it is not necessary to tell the MSC how an ETCH is performed. All of this necessary information is pre-programmed into the system.

The operator creates a string of process steps (sequentially numbered), each of which is a PROCESS: ENABLE, STANDBY, ETCH, BIAS, DEPOSIT, PRE-CLEAN, CHAMBER HEAT, LOCK HEAT, REPEAT, END. The MSC asks the operator to assign values for some PROCESS PARAMETERS (e.g., a percentage of total power to apply during DC sputtering, duration of a process, type and flow rate of sputtering gas, etc.).

IF ANY FIELD REQUIRING A NUMERICAL ENTRY IS NOT USED, THAT FIELD SHOULD BE "NULLED" WITH A "OO" ENTRY.

6.5.1 User Programmable Processes

6.5.1.1 The START Process

Not yet available. Will allow the operator to start a cycle from a step other than STEP 1.

6.5.1.2 The STANDBY Process

The STANDBY instruction is typically included in a process program when the user wishes to halt process sequence temporarily without terminating it. While the operation is in the STANDBY mode, the operator may choose to continue process gas flow or to terminate gas flow and have the Hi-Vac pump continue pumping the process chamber.

The following parameters must be assigned values when programming a STANDBY step:

- Step Number
- Standby mode
- Gas Selection (if no gas is selected, PUMPING mode is default condition)
- Duration

6.5.1.3 The ETCH Process

In the ETCH mode, the shutters are closed and power is applied to the substrates to prepare the surface for subsequent deposition.

The following parameters must be assigned values when programming a ETCH step:

- Step Number
- Etch Mode
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]
- Duration
- Power Level(s)

6.5.1.4 The DEPOSIT Process

In the DEPOSIT mode, material from one or two targets is deposited upon the substrates.

Sputter deposition requires that values be entered for all six parameters:

- Step Number
- Deposit Mode
- Target Selection [select manually for Model 4400]. Operators of Model 4450/4480 systems may select one or two targets from which to deposit material.
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]. Depending on the power source for the selected target, punch either "DC1" or "RF 1." If a second target is to be used simultaneously, punch either "DC 2" or "RF 2," and the power source for which the second target has been custom-strapped.
- Duration
- Power Level(s)

6.5.1.5 The BIAS Process

The BIAS instruction is selected if RF bias sputtering is desired. In this case, the RF power will be applied to the substrate table while either DC or RF power is applied to the selected target(s).

6.5.1.6 The PRE-CLEAN Process

In the PRE-CLEAN mode, the shutters are closed to protect the substrates.

The following parameters must be assigned values when programming a PRE-CLEAN step:

- Step Number
- Pre-Clean Mode
- Target Selection [select manually for Model 4400]
- Gas Selection
- Mode (RF or DC) [select manually for Model 4400]
- Duration
- Power Level(s)

NOTE

The pre-clean mode may be used before sputter deposition ONLY IF THE TARGET IS NOT NEW OR BADLY CONTAMINATED. For more thorough cleaning, use the burn-in procedure described in Chapter 1.

6.5.1.7 The CHAMBER HEAT Process

Selectable only on systems equipped with the in-process heater option, a CHAMBER HEAT command turns ON the radiant heater mounted in the process chamber for a specified period of time.

The following parameters must be assigned values when programming a CHAMBER HEAT step:

- Step Number
- Chamber Heat Mode
- Target Select
- Duration

NOTE

If table rotation is also desired, select any gas at "00" percent flow.

6.5.1.8 The LOCK HEAT Process

Selectable only on systems equipped with the load lock heater option, a LOCK HEAT command turns ON the radiant heater mounted in the load lock for a specified period of time.

The following parameters must be assigned values when programming a LOCK HEAT step:

- Lock Heat Mode (must be the first step)
- Step Number
- Duration

6.5.1.9 The REPEAT Process

The REPEAT instruction tells the MSC to perform a given set of steps within the process sequence a specified number of times. The operator must specify: FROM which step to begin repeating and NUMBER of repeats. For example: The REPEAT instruction appears on the data card numbered STEP 15, and calls for 4 repeats starting at STEP 10. When the process sequence is initiated, steps 1 through 14 will be performed, after which step 15 will cause steps 10, 11, 12, 13, and 14 to be performed an ADDITIONAL four (4) times.

6.5.1.10 The END Process

The END instruction terminates a sputtering process. If the system is a Model 4480 with the automatic wafer handling system in the AUTOMATIC mode, the pallet remains in the process chamber until the operator enters the ENABLE/CYCLE START command. If the system is not equipped with automatic wafer handling, or is equipped with but is not currently using automatic wafer handling, the pallet will be UNLOADED into the load lock, which is then vented to atmosphere.

No additional parameters need be specified for an END step, although all unused parameters should be "nulled" with zeroes.

CONTROLS AND INDICATORS (Continued)

CONTROL	FUNCTION
AUTO CROSS	This key enables the gauge to automatically switch between the Ion Tube and the Thermistor Tube. If the pressure rises above the maximum pressure for the Ion Tube in use, the gauge will autimatically switch to the Thermistor Tube as if the operator had pressed the "I/T" Key. Likewise, as the pressure drops below 1 x 10^{-2}, the gauge will select the Ion Tube. The tube number (i.e., 1 or 2) will not change. Pressing **"AUTO CROSS"** a second time will turn the function off. **AUTO CROSS** is on if the **GAUGE 1** or **GAUGE 2 LED** on the display is flashing.
PRES CNTL	The **PRESSURE CONTROL** option is activated with this key. When **PRESSURE CONTROL** is turned ***on***, the DGC will adjust the Piezoelectric Valve to maintain the vacuum system at a selected pressure. The **PRESSURE CONTROL** is turned ***off***, (and the valve forced closed) by pressing **"PRES CNTL"** a second time. This key is also used to set the **PRESSURE CONTROL Setpoint** while in the Setpoint Set Mode.
GAS CONST	The sensitivity of the Ion and Thdermistor Gauge Tubes changes as a function of the type or types of gases in the vacuum system. A gas correction factor is entered into the gauge by pressing **"GAS CONST"**. The mass number of the selected gas is then displayed. It is adjusted by using the "UP" and "DOWN" Keys. Valid mass numbers are: 2 (hydrogen), 4 (helium), 16 (methane), 18 (water), 28 (nitrogen or air), 40 (argon) and 99 (xenon). The selected gas is locked in by pressing any key other than "UP" or "DOWN". When a gas constant other than nitrogen (28) is selected, the multiplier **LED** will light.
T/P	This key selects **TORR** or **PASCAL** for the unit of dislplay. While the gauge is in the Set Gas Constant Mode (see above) pressing the **"T/P" Key** will alternate between **TORR** and **PASCAL** or **"C" for TORR.** Whenever **PASCAL** is selected, the **MULTIPLIER LED** will be lit.

CONTROLS AND INDICATORS (Continued)

CONTROL	FUNCTION
DEGAS	Pressing the **"DEGAS" Key** initiates a timed DEGAS of the Ion Tube which is operating. The display will count up to 9.9 then shut off the **DEGAS Power.** A **"d"** will by displayed to inform the operator that the DGC is in the **DEGAS Mode**. The **DEGAS** may be shut off before the end of the cycle by pressing the key again. The cycle will also be aborted if the emission current falls out of regulation. The **DEGAS Command** will be rejected if an Ion Tube is not turned on or if the pressure is too high.
F. S.	By pressing the **"F.S."**, the **FORELINE SENTRY Function** is turned ***on.*** Operation of the **FORELINE SENTRY** may be verified by observing the display. The display will flash an **"FS"** (every 5 seconds). To turn the **FORELINE SENTRY** ***off***, press the **"F.S."** again.
LEAK DET	This key turns the **LEAK DETECTOR Function *on/off.*** It is also used in conjunction with the "Set Point " Key to control the Emission Mode.

OPERATING PROCEDURES

IONIZATION GAUGE PRESSURE MEASUREMENT

Turn the DGC on by rotating the gauge selection knob to the type of Ion Gauge which has been connected to the DGC. The DGC will power-up set to Thermistor #1 (this mode is equivalent to Ion Tube Off) and the display multiplier set for Nitrogen and Torr. To turn Ion Gauge #1 on, press the "I/T" (Ion/Thermistor) Key. The ION TUBE Lamp will light. After auto-ranging has been completed, the display will show the pressure in Torr corrected for Nitrogen (air). **NOTE: If the DGC cannot obtain sufficient emission to run the tube, or if it senses a pressure that is too high, it will shut down the gauge tube and return to the Thermistor. When this occurs, 10 rapid beeps will be sounded.**

Other than air is the predominant gas in the system, it is possible to alter the correction constant for that gas.

TABLE 4
GAS CORRECTION CONSTANTS

Mass	Gas	Multi Factor Ion	Multi Factor Thermistor
2	Hydrogen	1.830	0.769
4	Helium	6.040	1.000
16	Methane	0.700	0.625
18	Water	0.800	0.833
28	Nitrogen (air)	1.000	1.000
40	Argon	0.713	1.670
99	Xenon	0.326	3.120

NOTE: The correction constant for oxygen is the same as that of nitrogen, 1.00. Therefore, if oxygen is the predominant gas in the system, set the gas correction constant to Mass 28.

While in the set **"GAS CONST" Mode**, it is also possible to change the display units from Torr to Pascal (Torr reading x 133 = Pascal). To do this, press the **"T/P"** (Torr/Pascl) Key. The display will alternate between *"C" for Torr* and *"A" for Pascal* every time **"T/P"** is pressed. Lock in the desired setting by pressing **"GAS CONST"** a second time.

Whenever the display unit is Pascal or a correction constant other than nitrogen (Mass 28) is in effect, the MULTIPLIER LED will be lit. This is a ***warning*** to the operator that the display is being modified and the operator should be aware of the modification. To check the correction constant and the display units, simply press "GAS CONST", observe the status and press "GAS CONST" again.

LEAK DETECTOR

The **LEAK DETECTOR** is based on the principal that the Ionization and Thermistor Tubes have different sensitivities for different species of gas. A leak generally consists of air entering the system. The gauge will be displaying the pressure within the vacuum system which will consist mostly of air plus some background gases. If the leak site is probed with a gas, such as Helium, the probe gas will replace air as the major gas in the system. The *gas will be different* but the *pressure will be the same.* Since the Ion Tube has 1/6 the sensitivity for helium than it has for air, the displayed pressure reading will drop. This assumes that the pumping speed for helium is the same as that of air; however, this is usually not the case.

This means that other system characteristics, such as pumping speed, must be considered when selecting a probe gas. A little experimentation on the system with a controlled leak may be helpful. The leak detector sensitivity cannot be generalized.

To operate the leak detector, allow the system pressure to stabilize. Press "LEAK DET". The DGC will sample the system pressure and refer to this value as the base pressure. An "ld" will bbe displayed in the exponent to indicate that the gauge is in the leak detector mode. The mantissa will display the absolute value of the difference in pressure between the base value and the current value multiplied by 10 (using the exponent from the base value as the reference). The larger this reading becomes, the more often the beeper will beep.

Probe the suspect area of the vacuum system while observing the audio and / or visual indicators. If an increase in the indication is noticed, the leak may have been located. Remove the probe gas. A decrease in reading should be observed. Repeat. To exit the leak detector mode press "LEAK DET" a second time. It may be necessary to hold the key down for a few seconds until the Leak Detector finishes beeping. Note that as the system pressure drifts, this will have the effect of increasing the reading. It may be necessary to exit and then re-enter the leak checking mode to re-establish a new value for the base pressure. To do this simply press **"LEAK DET", "LEAK DET".**

EMISSION CURRENT CONTROL

The DGCIII's microprocessor automatically selects the emission current for a particular pressure. The **MAXIMUM EMISSION CURRENT** is either 4 ma. for a nude tube or 10 ma. for a glass tube. As the pressure increases, it is *necessary* to reduce the Emission Current to keep the gauge tube in a linear range. The **BASIC EMISSION CURRENT** is multiplied by 1.0, 0.1, or 0.01, depending on the pressure, to arrive at the actual Emission Current.

If the **AUTOMATIC EMISSION CONTROL** is *not desired*, it can be fixed by using computer interface commands or the keyboard. To use the keyboard, press **"SET POINT", "LEAK DET"**. The display will show 0.0 x 10 - E and can be adjusted using the UP and DOWN arrows. Table 5 lists the various possible values and the Emission Modes. The full Automatic Mode is 0.0, 0.1 fixes it at x 0.01, 0.2 fixes it at x 0.1 at 10^{-5} Torr and Lower, and 0.3 fixes it at x 1.0 at 10^{-7} Torr and Lower. The value may be locked in by pressing "SET POINT" a second time.

TABLE 5
EMISSION CONTROL MODES

Display	Computer Interface Command	Mode Automatic	Glass Tube Current	Nude Tube Current
0.0	MA	Auto	Max=10 ma.	Max=4 ma.
0.1	ML	x 0.01	0.1 ma.	0.04 ma.
0.2	MM	x 0.1	1 mm below 10^{-4}	0.4 ma. below 10^{-4}
0.3	MH	x 1.0	10 ma. below 10^{-6}	4.0 ma. below 10^{-6}

Depending on the Mode, the actual Emission Current can be determined from Table 6 as follows:

1. Set the DGC to Torr, Mass 28. The multiplier light will be off.

2. Determine whether the pressure is rising or falling. As th pressure is falling, the Emission Current Change will occur at 6.9 in a given decade. *For example:* If the pressure is falling and the Emission is x 0.01, the Emission will change to x 0.1 at 6.9×10^{-7}.

3. If the pressure is rising, it will switch to the next lower Emission at 1.0 in the given decade. *For example:* If the Emission is x 0.1 and the pressure is rising from 5.0×10^{-7}, the Emission will switch to x 0.01 at 1.0×10^{-4}. When the pressure is rising, the Emission will never increase.

The Automatic Emission Selection provides hystersis to prevent Emission Change Oscillations.

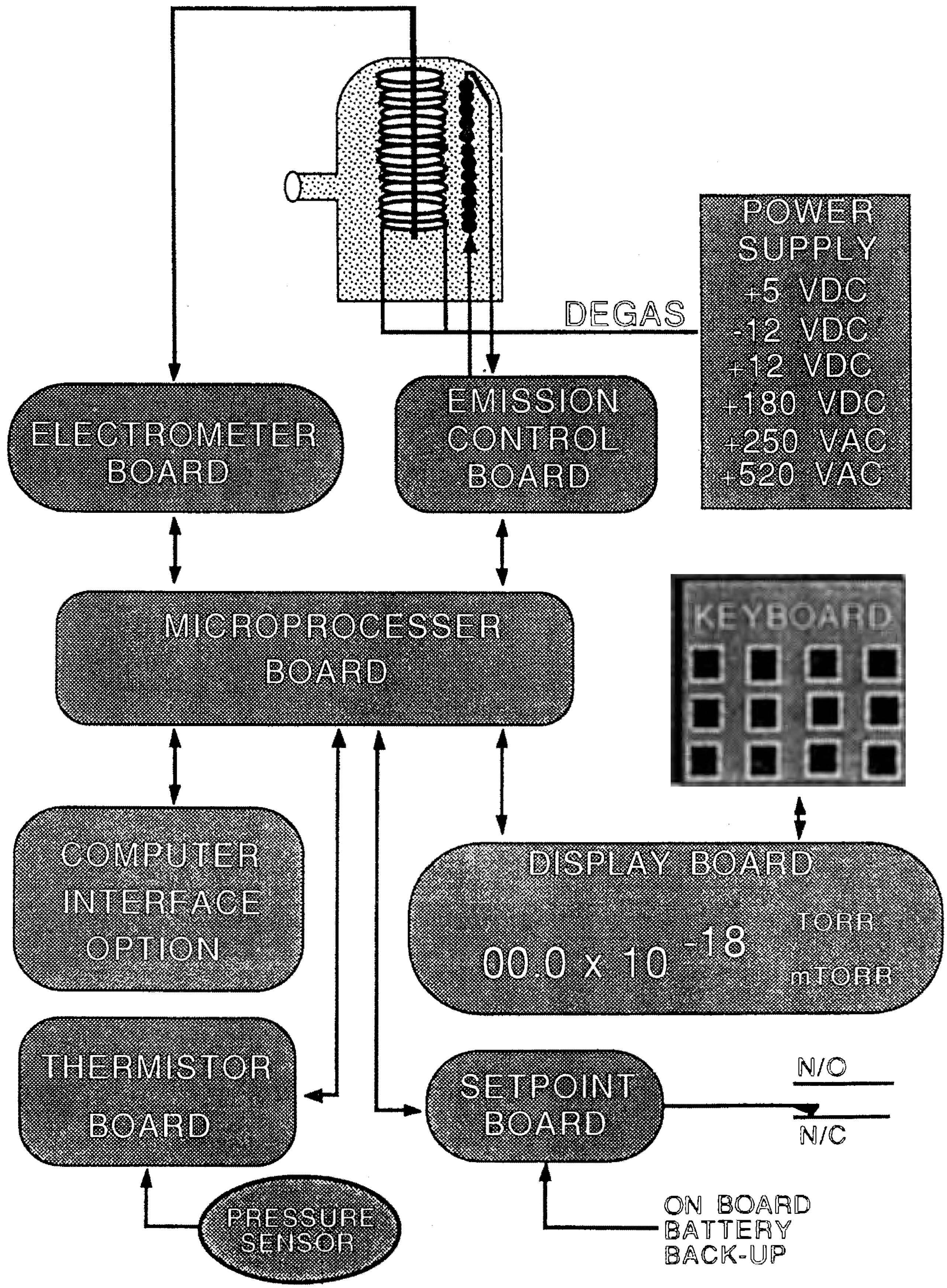
TABLE 6
EMISSION MODES

	Automatic		Fixed		
Pressure	**Falling**	**Rising**	**x0.01**	**x0.1**	**x1.0**
10^{-2}	0.01	0.01	0.01	0.01	0.01
10^{-3}	0.01	0.01	0.01	0.01	0.01
10^{-4}	0.01	0.01	0.01	0.01	0.01
10^{-5}	0.01	0.1	0.01	0.1	0.1
10^{-6}	0.01	0.1	0.01	0.1	0.1
10^{-7}	0.1	1.0	0.01	0.1	1.0
10^{-8}	0.1	1.0	0.01	0.1	1.0
10^{-9}	1.0	1.0	0.01	0.1	1.0
10^{-10}	1.0	1.0	*	0.1	1.0
10^{-11}	1.0	1.0	*	*	1.0

*** Pressure reading may be inaccurate due to insufficient electrometer current.**

OPERATING PROCEDURES - OPTIONS
THERMISTOR OPTION MODE #605-0601

The Thermistor Option permits the measurement of pressures from 1×10^{-3} to 9.9×10^{-1} Torr. Either one or two seperate Thermistor Tubes may be used. The Thermistor Option Board, Model #605-061, must be installed to use the Thermistor Option.


DEGAS
POWER SUPPLY
+5 VDC
-12 VDC
+12 VDC
+180 VDC
+250 VAC
+520 VAC
ELECTROMETER BOARD
EMISSION CONTROL BOARD
MICROPROCESSER BOARD
KEYBOARD
COMPUTER INTERFACE OPTION
DISPLAY BOARD
00.0 x 10 -18
TORR
mTORR
THERMISTOR BOARD
SETPOINT BOARD
N/O
N/C
PRESSURE SENSOR
ON BOARD BATTERY BACK-UP

PRECISION TABLE ROTATION CONTROLLER

Schem: 221-719-000
940-6162-001
221-744-900

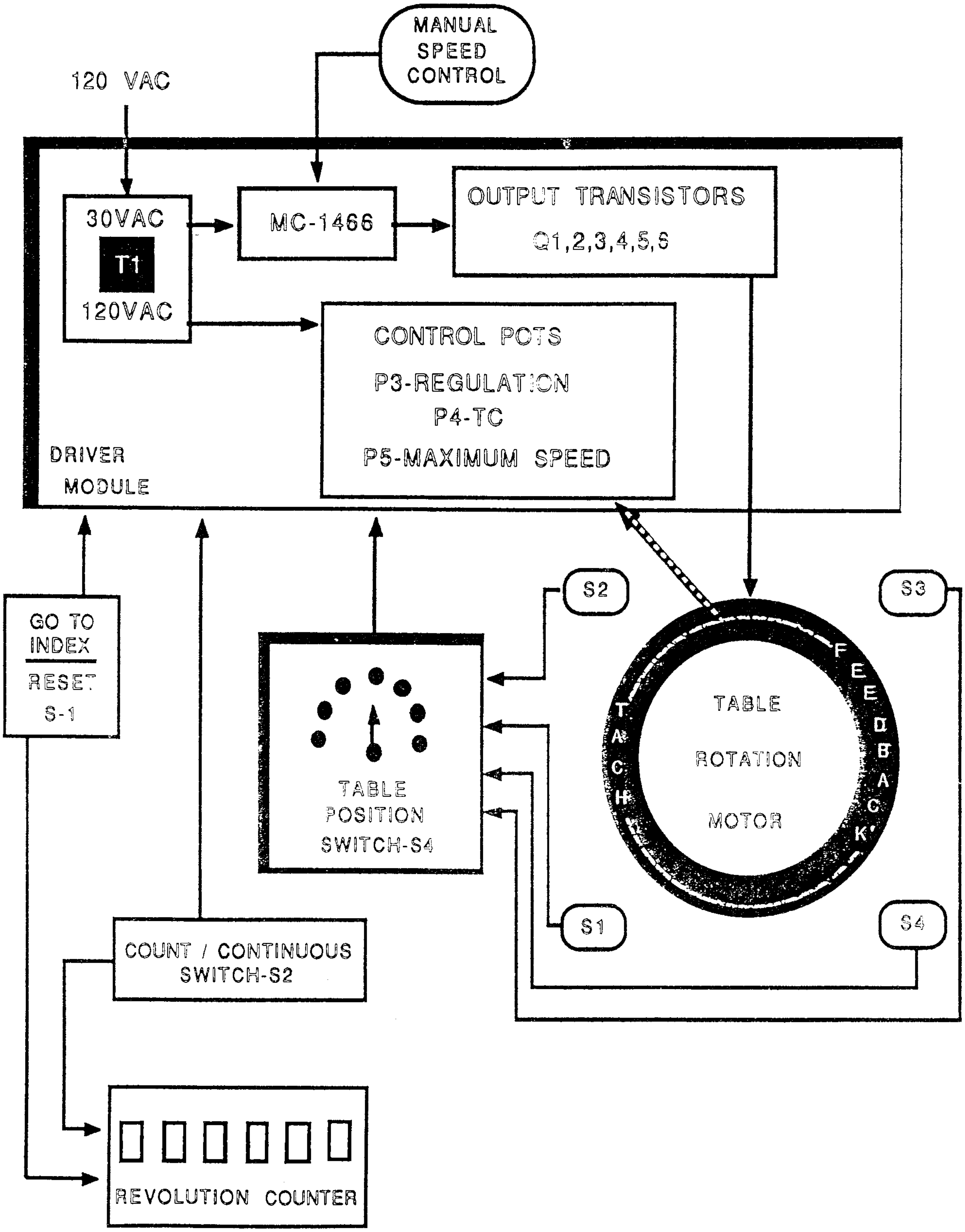
Assy: 940-6161-001
221-719-200
221-719-100
940-1036-001

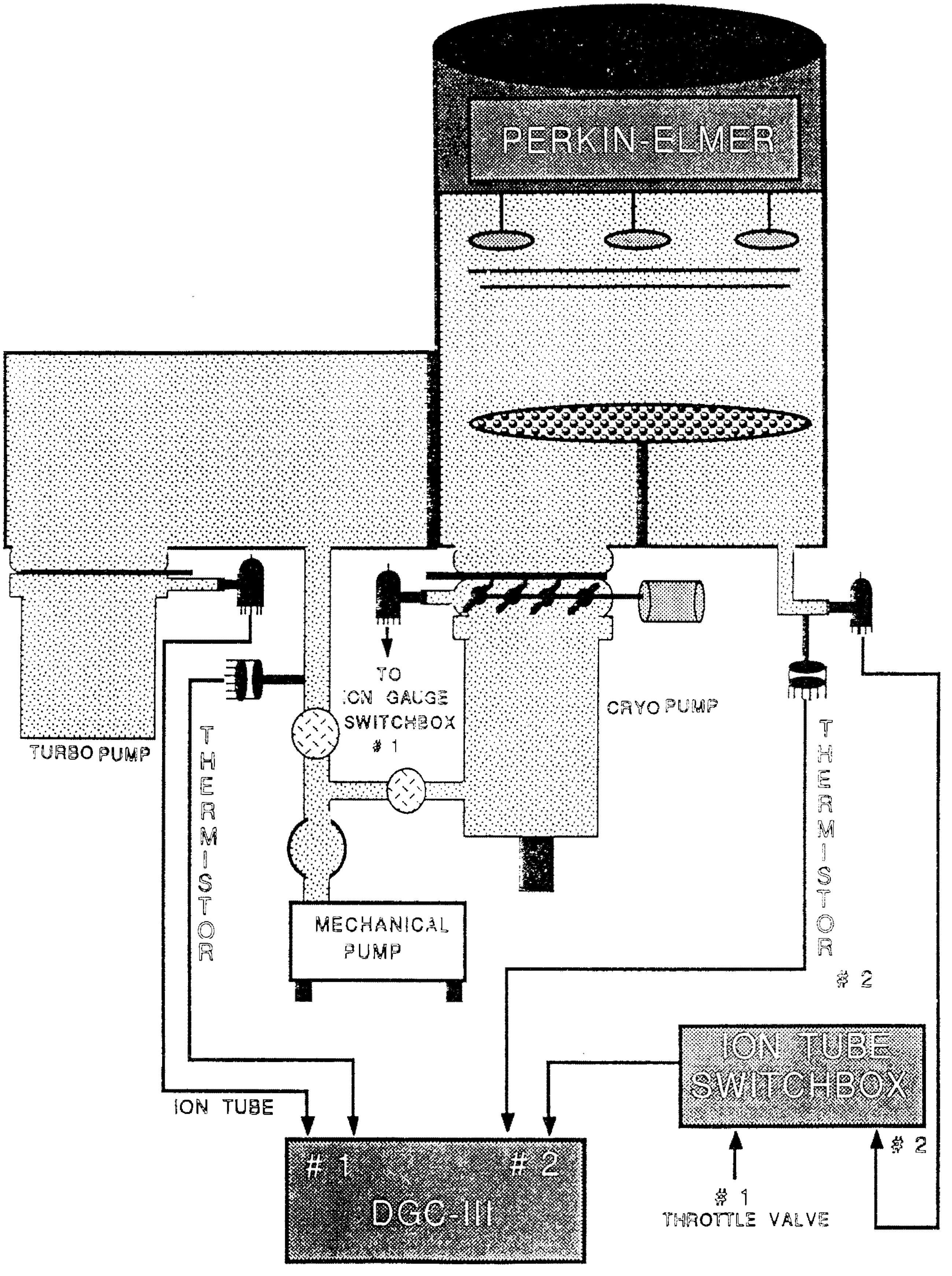
The **PRECISION TABLE ROTATION CONTROLLER** precisely rotates the chamber table at a speed calibrated in RPM on the low setting. The RPM can be adjusted on the front of the controller.

FRONT PANEL CONTROLS AND INDICATORS

REVOLUTION COUNTER	Counts the revolutions of the chamber table.
CONTINUOUS / COUNT	CONTINUOUS - The table continually turns until either the MSC turns the table off, or you turn the table off with the stop switch. COUNT - Counts down the table revolutions and stops the table when "0" is reached.
GO TO INDEX / RESET	GO TO INDEX - Used when the table has stopped. When depressed, the table will rotate untill position #1 has been reached. RESET - Resets the counter.
AT INDEX LAMP	This lamp is illuminated when the table is in position #1.
ROTATION LAMP	This lamp is illuminated when the table is rotating.
ROTATION SWITCH	STOP - The table will not rotate unless the MSC commands it to. ROTATION - The table will rotate continuously. #1 TO #4 - The table will stop at position #1 - #4.
ROTATION SPEED	Controls the speed of the table calibrated in RPM's. (The speed range is controlled at the box under the system. The ranges are HIGH & low. Low is calibrated in RPM's).

PRECISION TABLE ROTATION CONTROLLER




PERKIN-ELMER
TURBO PUMP
THERMISTOR
TO
ION GAUGE
SWITCHBOX
1
CRYO PUMP
THERMISTOR
2
MECHANICAL
PUMP
ION TUBE
SWITCHBOX
ION TUBE
1
2
DGC-III
2
1
THROTTLE VALVE

FRONT PANEL CONTROLS

The following list of switches are located on the Main System Controller front panel. Each switch has an led or indicator to identify the condition associated with the switch. From left to right, they are:

CONTROL	FUNCTION
Lock Vent	Turns on/off the Load Lock N_2 vent gas.
Mech Pump	Turns on/off the Turbo Mechanical Pump.
Turbo Pump	Turns on/off the Turbo Pump.
Gate Valve	Opens/Closes the Turbo Gate Valve.
Elev	Raises/Lowers the Load Lock Elevator.
Mech Pump	Turns on/off the Mechanical Roughing Pump.
Lock Rough Valve	Opens/Closes the Load Lock Roughing Valve.
Lock	Opens/Closes the Load Lock Isolation Valve.
Foreline Valve	Opens/Closes the Foreline Valve. This valve is currently used for the Cryo Regeneration Cycle.
Throttle Valve	Opens/Closes the throttle valve.
HV Pump	Turns on/off the Chamber Hi-Vac Pump. Cryo or Diffusion Pump.
Gate Valve	Opens/Closes the Chamber Gate (Hi-Vac) Valve.
H2 Getter	Turns on/off the H2 Getter Pump.

Table	Raises/Lowers the Chamber Table. The center position is off.
Carr	Insert/Remove the carriage to/from the Load Lock/Chamber. The center position is off.
Chamber Vent	Opens/Closes the Chamber N_2 Vent valve.
Gas 1	Turns on/off Gas 1 flow.
Gas 2	Turns on/off Gas 2 flow.
Gas 3	Turns on/off Gas 3 flow.
Meissner/Cryo	Selects the Meissner Trap or Cryo Pump for regeneration. **NOTE:** ***Keep this switch in the Meissner position. Two consecutive meissner regenerations are recommended.***
Cryo N_2	Opens/Closes the Chamber Cryo Pump N_2 Valve.
Cyro Heat	Turns on/off the Cryo Pump Nitrogen Heater.
Meissner LN_2	***TIME*** - The LN_2 is on for a preset amount of time. ***CON'T*** - The LN_2 is on until the sensor is tripped.Center position is off.

Enable/Regen (AUTO)	This pushbutton is used in conjunction with the Meissner/Cryo switch to start a regeneration cycle.
The automatic cycles are as follows:	**MEISSNER** 1. The LN_2 is turned off. 2. The heater is turned on. 3. The N_2 gas is turned on. 4. This cycle lasts for approximately 15 min. **CRYO** 1. The chamber hi-vac valve closes. 2. The compresser turns off. 3. The N_2 gas & heat turn on for 90 min. 4. The N_2 & heat turn off. 5. The foreline valve opens for 45 min. 6. The foreline valve closes. 7. The compresser turns on. 8. Cooldown takes approximatly 90 min.
Enable/Cycle Start (AUTO)	Loads the pallet into the chamber for processing. Processing starts.
Enable/Cycle Start (PROGRAM)	Allows the operator to single step through the stored process instructions. **CAUTION - Their associated outputs will turn on.**
Enable/Standby (AUTO)	Places the controller in a standby condition.
Enable/Unload (AUTO)	Unloads the pallet from the chamber to the Load Lock. "Pallet Is In" LED must be illuminated.
Pause (ALARM)	A malfunction has occurred. The controller is paused and the alarm is sounded.
Enable/Pause (AUTO)	Stops the process and turns off the RF or or DC power.
Enable/Pump (AUTO)	Pumps the process chamber to Hi-Vac and Vents the Load Lock to atmosphere.

Enable/Vent (AUTO)	Vents the chamber and Load Lock to atmosphere.
Key Switch (RESET)	Resets the Main System Controller computer and aborts any operation in progress. **CAUTION-*DO NOT HOLD IN THE RESET POSITION.***
Key Switch (AUTO)	The Auto position is used in conjuction with Pause, Cycle Start, Standby, Unload, Pump, and Vent pushbuttons.
Key Switch (PROGRAM)	The Program position is used for storing the card data in memory.
Key Switch (ENABLE-MANUAL)	The Manual position is used for manually operating the sputtering system. **NOTE:** ***THERE ARE NO INTERLOCKS IN THIS MODE. BEFORE ENTERING THIS MODE, CHECK THE FRONT PANEL SWITCHES FOR THERE CORRECT POSITIONS.***
Hoist	Raises/Lowers the chamber head.
Led Test	Turns on all the front panel led's and indicator lamps.
Silence	Silences the alarm.
Enable/Remaining-Total Step	Changes the display from total time remaining to total steps.

STANDBY MODE (AUTO)

The standby mode can be used specifically at four different times; they are:

A. WHILE THE LOADLOCK IS PUMPING

ACTION: Depress the enable and standby pushbuttons at the same time.

RESULT: The loadlock will pump down and wait for the next instruction.

B. BEFORE THE PROCESS STARTS

ACTION: Depress the enable and standby pushbuttons at the same time.

RESULT: The pallet will load into the chamber and wait for the next instruction.

C. AFTER THE PROCESS STARTS

ACTION: Depress the enable and standby pushbuttons at the same time.

RESULT: The process step will be held and waits for the next instruction.

D. AFTER THE PROCESS ENDS

ACTION: Depress the enable and standby pushbuttons at the same time.

RESULT: The pallet will transfer to the loadlock, come to a rest and wait for the next instruction.

RESTART: Depress the enable and cycle start pushbuttons at the same time.

PAUSE MODE (AUTO)

The pause mode is used whenever a process is in progress.

ACTION: Depress the enable and pause pushbuttons at the same time.

RESULT: The process is halted at the current step.

RESTART: Depress the enable and cycle start pushbuttons at the same time.

UNLOAD MODE (AUTO)

This mode will unload the pallet from the chamber.

CONDITIONS: The "Pallet Is In" led must be lit. If this condition is not met, type in "CPC" on the keyboard and depress return.

ACTION: Depress the enable and unload pushbuttons at the same time.

RESULT: The pallet will transfer from the process chamber to the loadlock and loadlock venting will occur.

PUMP MODE (AUTO)

The Pump Mode will pump the process chamber from atmosphere to Hi-Vac, and will vent the loadlock to atmosphere.

ACTION: Depress the enable and pump pushbuttons at the same time.

RESULT: The lock isolation valve will open. The roughing valve will open, pumping down the loadlock and chamber to the chamber trip setpoint on the MSC (Typically 75-100 mt.). At this point the lock isolation valve will close, the roughing valve will close and crossover to hi-vac will occur. The loadlock will then vent to atmosphere.

VENT MODE (AUTO)

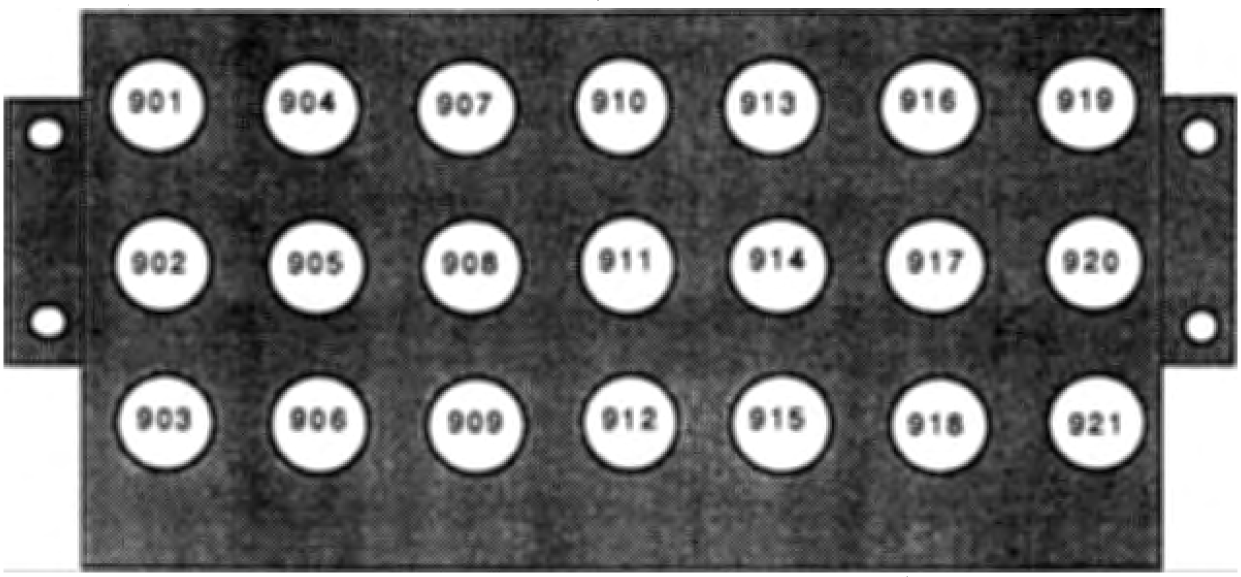
The Vent Mode will vent the process chamber and loadlock to atmosphere.

ACTION: Depress the enable and vent pushbuttons at the same time.

RESULT: The loadlock & chamber hi-vac valve will close. The two vent valves will open purging clean dry nitrogen into the chamber & loadlock venting them to atmosphere.

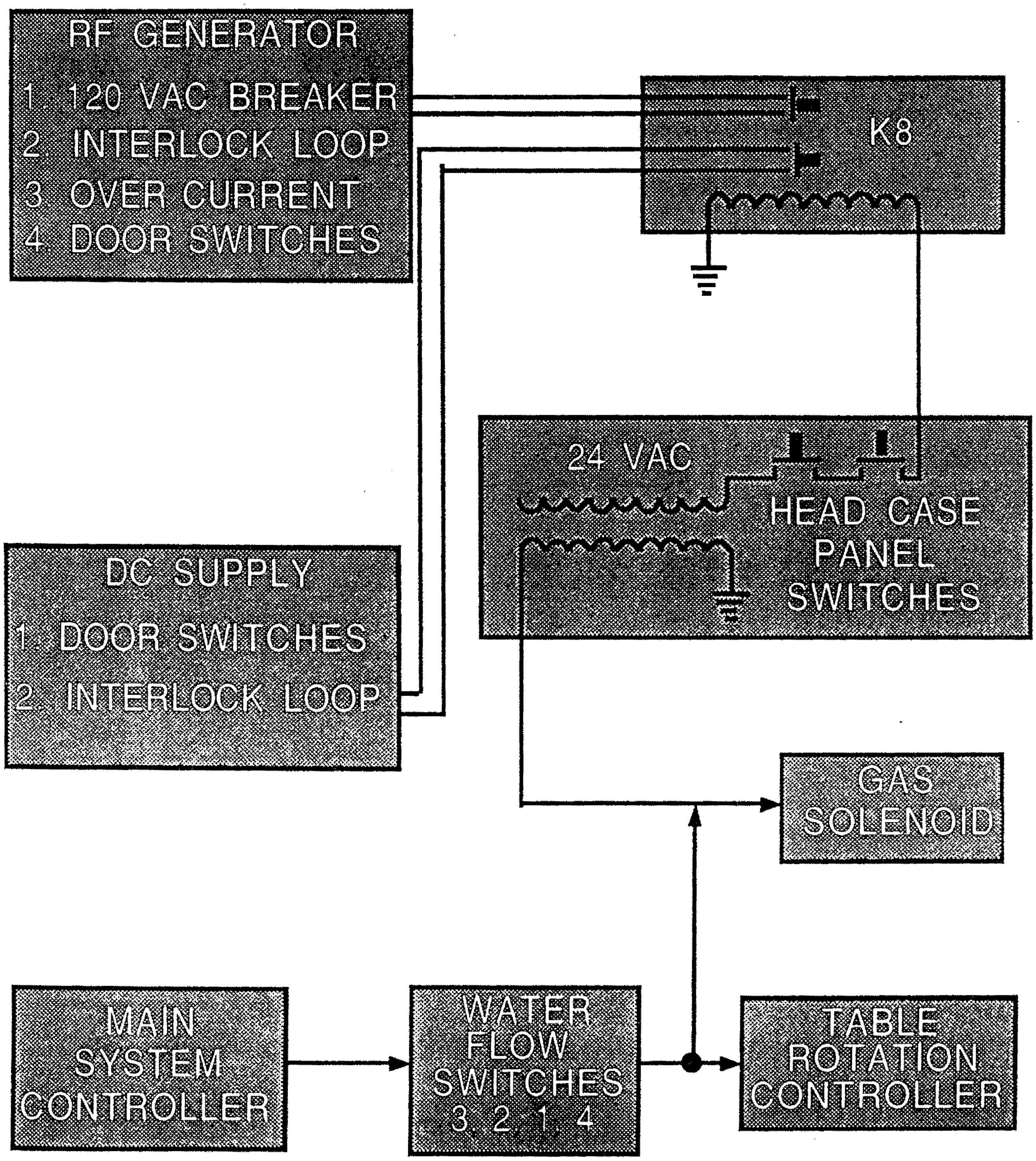
FAULT ISOLATION

Power Distribution Box Fuse Identification



F901.....2A.....SPARE
F902.....2A.....SPARE
F903.....3A.....SPARE
F904.....3A.....SPARE
F905.....5A.....LOADLOCK LID MOTOR UP
F906.....5A.....LOADLOCK LID MOTOR DOWN
F907.....5A.....CARRIER MOTORS
F908.....2A.....TABLE MOTOR UP/DOWN
F909.....5A.....TRANSFORMER-24VAC
F910.....2A.....MSC
F911.....2A.....WATER FLOW SWITCHES
F912.....5A.....PRECISION TABLE DRIVE
F913.....3A.....DGC-III
F914.....3A.....HEAD
F915.....5A.....CRYO REGENERATION HEATER
F916.....3A.....GAS SYSTEM
F917.....2A.....RF POWER/VOLTAGE STABLIZER
F918.....5A.....MEISSNER TRAP HEATER
F919.....2A.....2A23P1-1 SERVO MATCH
F920.....5A.....2A20P1-1
F921.....5A.....5A10P915 DUAL OUTLETS

INTERLOCKS


RF GENERATOR
1. 120 VAC BREAKER
2. INTERLOCK LOOP
3. OVER CURRENT
4. DOOR SWITCHES
K8
24 VAC
HEAD CASE
PANEL
SWITCHES
DC SUPPLY
1. DOOR SWITCHES
2. INTERLOCK LOOP
GAS
SOLENOID
MAIN
SYSTEM
CONTROLLER
WATER
FLOW
SWITCHES
3, 2, 1, 4
TABLE
ROTATION
CONTROLLER

PROCESS CHAMBER ELECTRONICS

DIGITAL GAUGE CONTROL III

The DGC III is a fourth generation, solid state, microprocessor controlled, digital, ionization gauge controller. The basic unit, Model 605-0600, can control two standard Bayard-Alpert, wide range or UHF (nude), tubes. The gauge automatically operates over the pressure range of 2 X 10^{-11} torr to 9.9 x 10^{-2} torr while adjusting the emission current. A display of torr or pascal units may be selected as well as gas correction constants for several common gases. The DGC III contains safety circuits that shut off the tube filament if emission current is lost or if the upper pressure limit of the gauge is exceeded. Degas is automatically turned off by the gauge to prevent damage to the tube. A leak detector function is included to assist the technician in locating vacuum leaks. An audible alarm is used to warn the operator of error conditions, signal keystrokes and indicate leaks in the leak detector mode. The DGC III operates on 100,120, 200, 240 volts with either 50 or 60 Hz power.

The DGCIII can be customized to the user's own requirements through the addition of several option kits. These option kits allow the gauge to control two thermistor tubes,operate four digital setpoints, interface to a computer, output a log report on a printer, control the vacuum system pressure via a piezoelectric valve, automatically cross between the thermistor and ion gaube tubes as the pressure changes, protect the UHV pump from backing pump failures by monitoring the foreline pressure and out-put BCD and analog pressure information.

TYPICAL SETPOINTS

MSC Loadlock Trip......Opens loadlock gate valve or the lock isolation valve (75-150 mt.).

DGC-III, Set Point #1....W/Turbo......... Lock to chamber transfer ($5.0 \cdot 10^{-5}$).
W/O Turbo..Lock to chamber transfer (75-100 mt).

DGC-III, Set Point #2....Processing setpoint ($5.0 \cdot 10^{-7}$).

DGC-III, Set Point #3....NOT USED

DGC-III, Set Point #4....Crossover from thermocouple to ion tube ($1.1 \cdot 10^{-3}$).

CONTROLS AND INDICATORS

CONTROL	FUNCTION
POWER KNOB	Turns on the gauge. NOTE: The pressure is measured in torr (nitrogen). The emission current multiplier is selected by the gauge automatically. The emission will either be x 1, x 0.1 or x 0.01 of the maximum emission.
ZERO	Zero's the thermistor gauges. The Ion Gauges are zeroed automatically.
KEYPAD	Used to command the gauge. **KEYPAD** functions are shown below.
SET POINT	Commands the gauge to set a SET POINT or the pressure control. The **SET POINT** Key is followed by **"1","2","3", "4"**, **"PRES CNTL"**, or **"LEAK DET"** Key, to determine which function will be set.

CONTROLS AND INDICATORS (Continued)

CONTROL	FUNCTION
UP & DOWN	These keys are used for setting a setpoint or the pressure control. After the second key in a set setpoint operation has been pressed, the current value of the setpoint (1, 2, 3, 4, PC, Emission) will be displayed. Pressing the **UP Key** will increase the value while pressing the **DOWN Key** will decrease the value. Presing the **UP** or **DOWN Key** momentairly ***will change* the reading by 0.I unit.** A larger change may be accomplished by holding the key down, longer. After the 10th change, while holding the key down, the increment will change to 1.0 units. Pressing any key, other than the **UP** or **DOWN Key**, will lock in the change and return the DGC to normal operation. These keys are also used for adjusting the gas correction constant. **NOTE: When locking the setpoint, the function normally assigned to the key that is pressed will not be executed. The manual emission selection works in this same manner.**
I/T	**ION/THERMISTOR.** This key alternates beteween the **ION Gauge Tubes** (*either 1 or 2*), to the appropriate **THERMISTOR Tube.** If the gauge is monitoring **ION Gauge 2,** when **I/T** is pressed, the gauge ***will switch*** to **THERMISTOR Gauge 2.** This key also has a second function. It is used to select Setpoint #3 when the gauge is in the Setpoint Set Mode.
1 & 2	These keys are used to select which gauge tube (Thermistor or Ion) the gauge is to monitor. *For example:* If the DGC is monitoring **Thermistor Gauge #1** when **"2"** is pressed, the DGC will switch to **Thermistor Gauge #2.** These keys are also used to select Setpoints 1 and 2 while in the Setpoint Set Mode.