Vacuum Pumps and Components

Vacuum Pumping Systems

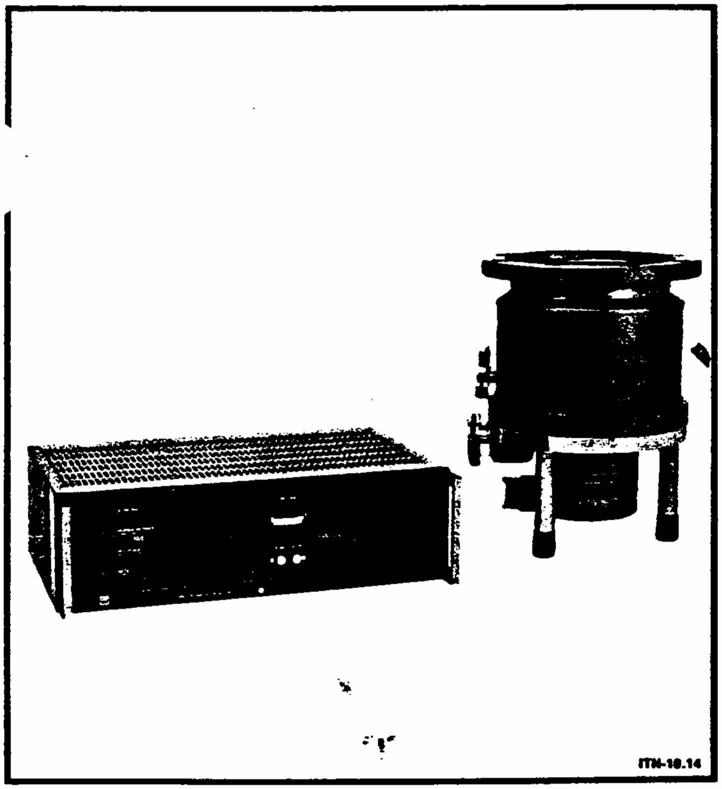
Analytical Systems

LEYBOLD-HERAEUS

LEYBOLD-HERAEUS VACUUM PRODUCTS INC.

Part Number 722-78-018 ■ Edition C

TMP/NT 1000
Turbomolecular Pump & Frequency Converter
MANUAL



LIMITED WARRANTY

Seller warrants to the original purchaser that the equipment to be delivered pursuant to this Agreement will be as described herein and will be free from defects in material or workmanship. Minor deviations which do not affect the performance of the equipment shall not be deemed to constitute either a failure to conform to the specifications or a defect in material or workmanship.

This warranty shall extend for a period of twelve (12) months from the initial date of shipment. Should any failure of conformity to this warranty appear within twelve (12) months from the initial date of shipment, Seller shall, upon immediate notification of such alleged failure and substantiation that the equipment has been operated and maintained in accordance with Seller's recommendations and standard industry practices, correct such defects by suitable repair or replacement at its own expense.

Seller's liability under this warranty shall cease if any major repairs to or any replacement or modification of the equipment is made by any person other than Seller's personnel or persons working under the supervision of Seller's personnel, unless authorized by Seller in writing. Further, the warranty shall cease unless the Buyer has operated the equipment in strict compliance with operating instructions and manuals, if any, provided for the equipment, and unless Buyer operates the equipment in normal use and with proper maintenance.

If the equipment contains components from another manufacturer and are subject to the manufacturer's warranty, then Seller's liability shall be limited to the extent of the warranty which Seller received from the manufacturer or supplier of the equipment component parts. Seller's liability shall be no greater than the liability of the manufacturer or supplier as determined by a final judgment by the Buyer against the manufacturer or supplier of such components. Seller will cooperate with Buyer in such legal action but at Buyer's expense.

THIS WARRANTY IS EXPRESSLY IN LIEU OF ANY AND ALL REPRESENTATIONS AND WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, EXCEPT THE WARRANTY OF TITLE. THIS WARRANTY CONSTITUTES THE EXCLUSIVE REMEDY, and shall not be deemed to have failed of its essential purpose so long as Seller is willing and able to correct defects covered by the warranty in the manner prescribed. The sole purpose of the exclusive remedy shall be to provide Buyer with free repair and/or replacement in the manner and for the time period provided herein.

The entire agreement between the parties is embodied in this writing, which constitutes the final expression of the parties, and it is the complete and exclusive statement of the terms of the agreement. No other warranties are given beyond those set out in this writing.

LIMITATION OF LIABILITY. SELLER SHALL NOT, UNDER ANY CIRCUMSTANCES, BE LIABLE FOR DIRECT OR INDIRECT, SPECIAL DAMAGES, INCIDENTAL OR CONSEQUENTIAL, such as but not limited to, loss of profits, damage to or loss of other property, downtime costs of the equipment, delay expenses, overhead or capital costs, claims of Buyer's customers or activities dependent upon the equipment.

Except to the extent provided in the LIMITED WARRANTY, Seller shall not be liable for any claim or loss arising out of or related to this agreement or the equipment provided pursuant thereto, whether such claim allegedly arises or is based on contract, warranty, tort (including negligence), strict liability in tort or otherwise. Liability shall not in any event exceed the cost of the equipment upon which such liability is based.

SEVERABILITY. If any portion or clause of this agreement is held invalid or unenforceable as to any person or under any circumstances, the invalidity or lack of application shall not impair or affect the other provisions and the application of those provisions which can be given effect without the invalid or unenforceable provision or application. With this intention, the provisions of this agreement are declared to be severable.

CONTENTS

Section	Title	Page
TURBOVAC TMP-1000 Specifications		vii
TURBOTRONIC NT-1000/1500 Specifications		viii
Ordering Information		ix
Dimensional Data		x
SECTION 1 - INTRODUCTION		1-1
1.1	SCOPE OF MANUAL	1-1
1.2	WARNINGS, CAUTIONS, AND NOTES	1-1
1.3	GENERAL DESCRIPTION	1-2
1.4	TMP-1000 ACCESSORIES	1-3
1.4.1	Air Cooling Assembly	1-4
1.4.2	Cooling Unit	1-4
1.4.3	Water Flow Switch	1-5
1.4.4	Bake-Out Jacket	1-6
1.4.5	Automatic Venting Valve	1-6
1.4.6	Vibration Damping Bellows	1-7
1.4.7	Metering/Venting Valve	1-8
1.5	NT-1000/1500 OPTIONAL EQUIPMENT	1-8
SECTION 2 - UNPACKING AND INSPECTION		2-1
2.1	GENERAL INFORMATION	2-1
2.2	UNPACKING AND INSPECTION	2-1
2.3	NT-1000/1500 ADDITIONAL MATERIAL	2-2
SECTION 3 - INSTALLATION		3-1
3.1	GENERAL INFORMATION	3-1
3.2	NT-1000/1500 INSTALLATION	3-1
3.2.1	AC Voltage and Fuse Selection	3-1
3.2.2	Converter Cooling	3-3
3.2.3	Converter Mounting	3-3

CONTENTS (Continued)

Section	Title	Page
SECTION 3 - INSTALLATION (Continued)		
3.2.4	Converter Rear Panel Control Terminal Strip Wiring	3-4
3.2.4.1	Initial Wiring	3-4
3.2.4.2	Remote Starting and Stopping	3-4
3.2.4.3	Remote Normal Operation Sensing	3-6
3.2.4.4	External Converter Frequency Indication	3-6
3.2.4.5	External Pump Speed Control	3-7
3.2.4.6	External Elapsed Time Meter	3-7
3.2.5	Grounding	3-7
3.2.6	Pump and Converter Interconnection	3-8
3.2.7	Checking Pump Motor Direction of Rotation	3-9
3.3	TMP-1000 INSTALLATION	3-11
3.3.1	Preliminary Installation Considerations	3-12
3.3.2	Intake Port Connection	3-13
3.3.3	Exhaust Port Connection	3-14
3.3.4	Turbopump Cooling	3-15
3.3.4.1	Water Cooling Connection	3-15
3.3.4.2	Air Cooling Assembly	3-15
3.3.4.3	Cooling Unit	3-16
3.3.5	Venting Port Connection	3-16
3.3.6	Purge Gas and Venting Port Connection	3-17
3.3.7	Bake-Out Jacket Installation	3-19
3.3.8	Water Flow Switch Installation	3-19
SECTION 4 - OPERATION		4-1
4.1	GENERAL INFORMATION	4-1
4.2	NT-1000/1500 FRONT PANEL CONTROLS AND INDICATORS	4-1
4.3	STARTING AND OPERATING	4-3
4.4	STOPPING	4-5
4.5	VENTING	4-6
4.6	BAKE-OUT	4-7
SECTION 5 - MAINTENANCE AND ADJUSTMENTS		5-1
5.1	GENERAL INFORMATION	5-1
5.2	PREVENTIVE MAINTENANCE	5-1
5.3	TMP-1000 CLEANING	5-2

CONTENTS (Continued)

Section	Title	Page
SECTION 5 - MAINTENANCE AND ADJUSTMENTS (Continued)		
5.4	TMP-1000 DISASSEMBLY/REASSEMBLY	5-5
5.4.1	Tools Required	5-6
5.4.2	Pump Housing and Stator Package Disassembly	5-6
5.4.3	Motor Housing Removal and Motor Stator Check	5-10
5.4.4	Rotor/Spindle Assembly Replacement	5-12
5.4.4.1	Rotor/Spindle Assembly Spare Parts and Accessories	5-13
5.4.4.2	Rotor/Spindle Assembly Removal	5-14
5.4.4.3	Rotor/Spindle Assembly Installation	5-16
5.4.4.4	Rotor/Spindle Assembly Alignment	5-18
5.4.5	Pump Housing and Stator Package Reassembly	5-19
5.4.6	Motor Housing Remounting	5-22
5.4.7	Turbopump Running Tests	5-23
5.4.7.1	Run-Up Test	5-23
5.4.7.2	Leak Test	5-23
5.4.7.3	Venting Test	5-24
5.5	NT-1000/1500 ADJUSTMENTS	5-25
5.5.1	R52 - Minimum Pump Speed Adjustment	5-26
5.5.2	R64 - Pump Cable Length Compensation Adjustment	5-27
5.5.3	R74 - VCO Frequency Adjustment and R92 - NT-1500 VCO Frequency Trimmer Adjustment	5-28
5.5.4	R94 - Frequency Meter Calibration	5-29
SECTION 6 - DETAILED DESCRIPTION		6-1
6.1	TMP-1000 OPERATING PRINCIPLE	6-1
6.2	TMP-1000 CONSTRUCTION	6-2
6.3	TMP-1000C (CORROSIVE) CONSTRUCTION	6-4
6.4	NT-1000/1500 FUNCTIONAL DESCRIPTION	6-6
6.5	NT-1000/1500 BLOCK DIAGRAM	6-8
6.6	NT-1000/1500 CIRCUIT DESCRIPTION	6-12
6.6.1	Low Voltage Power Supply	6-12
6.6.2	Start/Stop Control	6-13
6.6.3	Acceleration Timer	6-15
6.6.4	Status and Control	6-16
6.6.5	DC Link Power Supply	6-18
6.6.6	SCR Triggering Control	6-20
6.6.7	Six-Step Inverter	6-21
6.6.8	Three-Phase Logic	6-23
6.6.9	VCO (Voltage Controlled Oscillator)	6-24

LEYBOLD-HERAEUS

CONTENTS (Continued)

Section	Title	Page

SECTION 6 - DETAILED DESCRIPTION (Continued)

6.6.10 Short Circuit Protection 6-25
6.6.11 Failure Detector 6-26
6.6.12 Failure Detector Latch 6-28
6.6.13 Voltage and Current Limiters 6-28
6.6.14 Pump Select/Overtemperature 6-31

SECTION 7 - TROUBLESHOOTING 7-1

SECTION 8 - PARTS LISTS AND DIAGRAMS 8-1

8.1 GENERAL INFORMATION 8-1

8.2 PART ORDERING INFORMATION 8-1

8.3 TMP-1000 PARTS LIST 8-1

8.4 NT-1000/1500 PARTS LIST AND SCHEMATIC 8-1

LIST OF FIGURES

Figure	Title	Page

SECTION 1 - INTRODUCTION

1-1 Air Cooling Assembly shown mounted below Pump 1-4
1-2 Cooling Unit 1-4
1-3 Water Flow Switch 1-5
1-4 Bake-Out Jacket 1-6
1-5 Automatic Venting Valve 1-6
1-6 Vibration Damping Bellows 1-7
1-7 Metering/Venting Valve for the TMP-1000C 1-8

SECTION 3 - INSTALLATION

3-1 Power Transformer T1 Primary Connections 3-2
3-2 Rear Panel Control Terminal Strip Wiring 3-5
3-3 Motor Rotation Reversal Wiring 3-10
3-4 Typical Pumping System Diagram 3-11

LIST OF FIGURES (Continued)

Figure	Title	Page
SECTION 4 - OPERATION		
4-1	NT-1000/1500 Front Panel Controls	4-1
4-2	Safe High Vacuum Side Venting - Pressure Rise vs. Venting Time	4-6
SECTION 5 - MAINTENANCE AND ADJUSTMENT		
5-1	TMP-1000 Exploded View	5-3
5-2	TMP-1000 Cleaning without Disassembly	5-4
5-3	Pump Housing Removal	5-7
5-4	Stator Package Disassembly	5-9
5-5	Motor Housing Removal	5-11
5-6	Rotor/Spindle Assembly Removal	5-15
5-7	Rotor/Spindle Assembly Installation	5-17
5-8	Rotor/Spindle Assembly Alignment	5-18
5-9	Stator Package and Pump Housing Reassembly	5-21
5-10	Motor Housing Remounting	5-22
5-11	NT-1000/1500 Internal Controls	5-25
SECTION 6 - DETAILED DESCRIPTION		
6-1	Side View of Three Rotor/Stator Stages	6-1
6-2	TMP-1000 Cutaway View	6-3
6-3	TMP-1000C Sectional View showing Inert Gas Seal	6-5
6-4	Typical Turbomolecular Pump Start Up Voltage/Current/ Frequency Relationships	6-7
6-5	NT-1000/1500 Block Diagram	6-11
6-6	Output Voltage Control through SCR Timing	6-19
6-7	Six-Step Induction Motor Drive, Simplified Schematic with Voltage and Current Waveforms	6-22
SECTION 8 - PARTS LISTS AND DIAGRAMS		
8-1	TMP-1000 Part Locations	8-2
8-2	NT-1000/1500 Chassis Part Locations	8-4
8-3	NT-1000/1500, A1 - Control and Regulator Board	8-6
8-4	NT-1000/1500, A2 - Six-Step Inverter Board	8-8
8-5	NT-1000/1500 Electrical Schematic	8-11

LIST OF TABLES

Table	Title	Page
I	TURBOVAC TMP-1000 Specifications	vii
II	TURBOTRONIC NT-1000/1500 Specifications	viii
III	Ordering Information	ix
IV	Dimensional Data	x

SECTION 3 - INSTALLATION

3-1	NT-1000/1500 Power Transformer Connections and Fuse Selection	3-2
3-2	Purge Gas Flow Rates for the TMP-1000C	3-18

SECTION 7 - TROUBLESHOOTING

7-1	Troubleshooting Chart	7-4

SECTION 8 - PARTS LISTS AND DIAGRAMS

8-1	TMP-1000 Parts List	8-3
8-2	NT-1000/1500 Chassis Parts List	8-5
8-3	A1 - Control and Regulator Board Parts List	8-7
8-4	A2 - Six-Step Inverter Board Parts List	8-9

TABLE I. TURBOVAC® TMP-1000 SPECIFICATIONS

	Intake Flange DN*		
	LF150/CF150	CF200/ 6-inch ASA	LF250
Pumping Speed (volume flow rate ltr/sec):			
for N_2	850	1100	1150
for He	880	975	1000
for H_2	900	970	1000

Compression Ratio:
- for N_2 . . . . . $>10^9$
- for He . . . . . 5×10^4
- for H_2 . . . . . 2×10^3

Ultimate Pressure . . . . . $<10^{-10}$ mbar

Rotational Speed . . . . . 36,000 r.p.m.

Start-Up Time . . . . . 4 min.

Cooling . . . . . Water/Air

Cooling Water Temperature . . . . . 59 to 77°F (15 to 25°C)

Cooling Water Consumption (minimum) . . . . . 8 gal/hr (30 ltr/hr)

Ambient Air Cooling Temperature (maximum):
- During Bakeout . . . . . 86°F (30°C)
- Unheated Pump . . . . . 113°F (45°C)

Cooling Water Connection, Hose Nozzle . . . . . 7/16 in. (11 mm)

Fore-Vacuum Port Fitting . . . . . KF®40

Venting Port Fitting KF10

Bake-Out Temperature (pump neck) . . . . . 248°F (120°C)

Mounting Position . . . . . In Any Desired Position

Weight . . . . . 55 lb (25 kg)

Dimensions . . . . . See TABLE IV DIMENSIONAL DATA

Recommended Backing Pump . . . . . TRIVAC® D30B/65B

Lubrication . . . . . Grease (Lifetime Lubricated)

*ISO size DN = nominal width NW
®TURBOVAC, KF, and TRIVAC are registered trademarks of Leybold-Heraeus

LEYBOLD-HERAEUS

TABLE II. TURBOTRONIC NT-1000/1500 SPECIFICATIONS

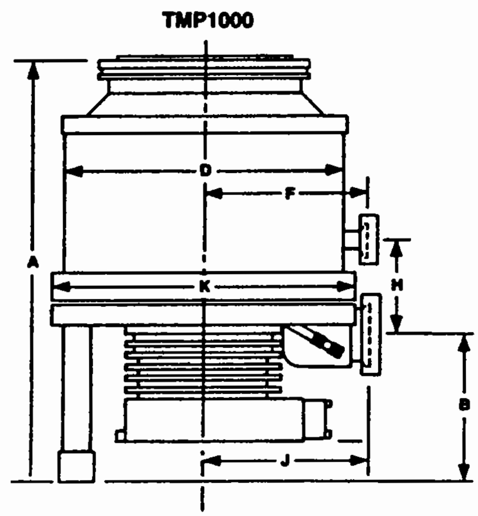
Input Voltage, selectable	110, 115/120, 240 (+/-10%) V AC 50/60 Hz Single Phase
Input Power (max.):	
for TMP-1000	0.9 kVA
for TMP-1500	1.2 kVA
Output Voltage (max.)	3 X 42 V
Rated Output Frequency:	
for TMP-1000	605 Hz
for TMP-1500	355 Hz
Motor Start Up Current:	
for TMP-1000	8.5 A
for TMP-1500	11.5 A
Motor Overload Current Limitation:	
for TMP-1000	6 A
for TMP-1500	8 A
Maximum Allowable Acceleration Time	15 min.
Admissible Ambient Temperature	32 to 113°F (0 to 45°C)
Voltage at Remote Control START/STOP Terminals	+24 V
Normal Operation Relay Contact Ratings	4 A at 250 V AC 120 W at 30 V DC
External Frequency Counter Output	+24 V, Square Wave
Voltage at External Speed Control Terminals	+10 V
External Elapsed Hour Meter Source Voltage (Applied only during normal operation)	18 V AC
Fuse, Chassis:	
for 200 to 240 V AC	T 6.3A/250 D
for 110 to 120 V AC	T 10A/250 D
Fuse, Inverter Board	F 16A/250 G
Weight	55 lb (25 kg)
Dimensions	See TABLE IV DIMENSIONAL DATA

TABLE III. ORDERING INFORMATION

PUMP AND CONVERTER	Catalog Number
TMP-1000 Turbomolecular Pump (order according to inlet flange):	
LF150	85490
CF150	85491
CF200	85496
LF250	85497
6-inch ASA	89589
TMP-1000C Corrosive Series Turbomolecular Pump	
LF150	85535-1
6-inch ASA	89489-1
NT-1000/1500 Frequency Converter	85492-1

ACCESSORIES	
Air Cooler Assembly:	
115 V AC	89445
220 V AC	85498
Cooling Unit	99-239-003
Water Flow Switch	99-287-022
Bake-Out Jacket:	
115 V AC	85494
220 V AC	85493
Flange Adapter, 10-inch ASA (Adapts LF250 flange to 10-inch ASA bolt pattern)	98-278-0703
Automatic Venting Valve:	
Normally Closed	98-273-011
Normally Open	98-273-012
Metering/Venting Valve (for TMP-1000C Corrosive Series Pump)	
115 V AC	85548
220 V AC	85549
Vibration Damping Bellows (for LF150 Inlet Flange)	85344

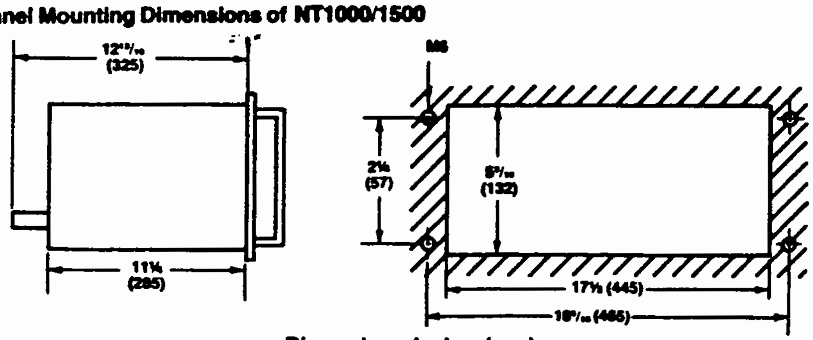
TABLE IV. DIMENSIONAL DATA



Dimensions, Inches (mm)

TMP-1000 Flanges	A	B	D	F	H	J	K
LF150	14 39/64 (371)	4 9/32 (134)	9 3/8 (238)	5 25/64 (137)	3 15/64 (82)	5 33/64 (140)	10 5/32 (258)
CF150	15 5/64 (383)	4 9/32 (134)	9 3/8 (238)	5 25/64 (137)	3 15/64 (82)	5 33/64 (140)	10 5/32 (258)
CF200	14 39/64 (371)	4 9/32 (134)	9 3/8 (238)	5 25/64 (137)	3 15/64 (82)	5 33/64 (140)	10 5/32 (258)
LF250	13 1/2 (343)	4 9/32 (134)	9 3/8 (238)	5 25/64 (137)	3 15/64 (82)	5 33/64 (140)	10 5/32 (258)
6-in. ASA	14 39/64 (371)	4 9/32 (134)	9 3/8 (238)	5 25/64 (137)	3 15/64 (82)	5 33/64 (140)	10 5/32 (258)

Panel Mounting Dimensions of NT1000/1500



Dimensions, Inches (mm)

SECTION 1
INTRODUCTION

1.1 SCOPE OF MANUAL

This manual contains installation, operation, description, and service information for the TURBOVAC® Model TMP-1000 Turbomolecular Pump, and the TURBOTRONIK Model NT-1000/1500 Frequency Converter. These two units are designed to function together for the production of ultra-clean, hydrocarbon-free high vacuum.

Specifications and ordering information for the TMP-1000 and NT-1000/1500 are contained in the front of this manual.

Before unpacking, installing, and operating the TMP-1000 and NT-1000/1500, read Sections 2, 3, and 4 of this manual carefully.. This will ensure that you understand what needs to be done prior to placing the turbopump and its converter into operation.

1.2 WARNINGS, CAUTIONS, AND NOTES

"WARNING" statements call attention to conditions, practices, or procedures which must be observed to avoid personal injury.

"CAUTION" statements contain information which must be followed to prevent damage to equipment.

"NOTES" contain information of special importance or interest.

1.3 GENERAL DESCRIPTION

WARNING

DO NOT use the TMP-1000 for pumping oxidizers or higher than atmospheric concentrations of oxygen.

The Leybold-Heraeus TURBOVAC model TMP-1000 Turbomolecular Pump and TMP-1000C Corrosive Series Pump can produce an ultra-clean, hydrocarbon-free vacuum at an ultimate pressure of $<10^{-10}$ mbar. Other features of both the TMP-1000 and TMP-1000C include:

o Grease lubricated bearings permit the pump to operate in any desired angular position, while retaining the advantages of single axial flow construction.

o Dynamic balancing of the pump's replaceable rotor/spindle assembly produces silent running with minimal vibration.

o The turbine and drive assembly with internal motor are mounted in a stainless steel housing.

o Water cooling is standard while air cooling is offered as an option.

o The pump motor is protected from overheating by a thermal switch, which turns off the pump's frequency converter if the pump motor exceeds its safe operating temperature limit.

o The top rotor blade of the turbine is located just below the high vacuum connection flange to minimize the loss of conductance due to the impedance of the intake port.

o A heat treated aluminum alloy is used for the rotor assembly.

o The complete drive assembly including bearings and motor is located in the fore-vacuum space.

The TMP-1000C Corrosive Series Pump is capable of pumping corrosive or abrasive reaction products. The construction of the TMP-1000C is similar to a standard TMP-1000 with the exception that a special gas purge and venting port is added. An inert gas (e.g., nitrogen, argon) is allowed to enter this port where it forms a protective gas seal around the motor/bearing cavity, thus protecting the metal parts and lubricant contained in this cavity from corrosive attack by reactive gases.

The NT-1000/1500 Frequency Converter is designed to drive either the TMP-1000, TMP-1000C, or TMP-1500 Turbomolecular Pump. The converter automatically compensates for the characteristic differences between these pumps. Basically, the NT-1000/1500 converts single-phase, 110-240 V AC, 50/60 Hz power into three-phase, variable voltage, variable frequency power as required by the turbopump's induction motor. The turbopump is turned "on" and "off" by the converter's front panel START and STOP pushbuttons. A front panel frequency meter indicates the motor's drive frequency as a percentage of its maximum value (100% corresponds to maximum pump speed). Front panel POWER, ACCELERATION, NORMAL OPERATION, and FAILURE indicators show the status of the converter. A rear panel terminal block provides the means of connecting optional control and monitoring devices (e.g., hours meter, frequency counter, speed control).

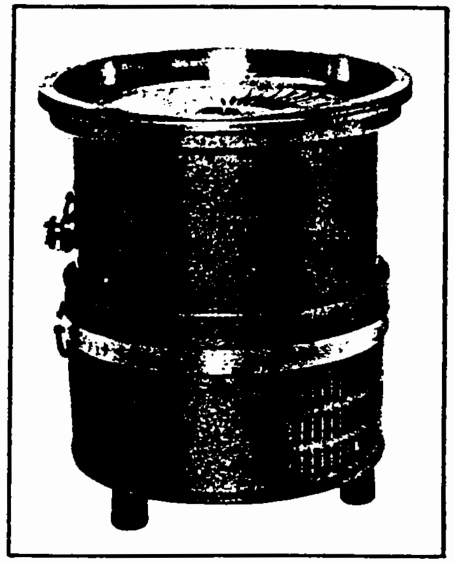
Detailed descriptions of the TMP-1000, TMP-1000C, and NT-1000/1500 are contained in Section 6 of this manual.

1.4 TMP-1000 ACCESSORIES

The following are accessory items available for the TMP-1000. Catalog numbers for these items are contained in Table III Ordering Information, located in the front of this manual.

1.4.1 AIR COOLING ASSEMBLY

The optional Air Cooling assembly (Fig. 1-1) consists of two fans mounted on vibration dampers. This unit is mounted around the motor housing, and is secured in place from below the pump using the supplied hardware. Either a 115 or 220 V AC model can be ordered.



1TN-7.1

Figure 1-1. Air Cooling Assembly shown mounted below Pump

Note that the maximum permissible ambient temperature for a pump being baked-out with air-cooling is 86°F (30°C), while the ambient temperature for unheated pumps at operating pressures lower than 10^{-4} mbar is 113°F (45°C).

Air Cooling Assembly installation information is contained in Section 3.3.4.2.

1.4.2 COOLING UNIT

The optional Cooling Unit (Fig. 1-2) is used wherever air-cooling of the pump is not permissible (i.e., ambient temperature too high), or where normal tap water is not available for water-cooling, or where water is contaminated.

1TN-7.2

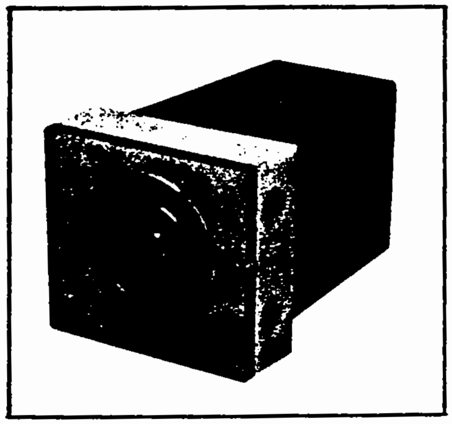
Figure 1-2. Cooling Unit

The water in this device is contained in a separate reservoir, where it is kept at the required temperature by a refrigerator unit. The cooling water is circulated through the turbopump by the Cooling Unit's internal water pumping system.

Cooling Unit installation information is contained in Section 3.3.4.3.

1.4.3 WATER FLOW SWITCH

The optional Water Flow Switch (Fig. 1-3) is used to check that the required quantity of cooling water is flowing through the pump.



1TN-7.3

Figure 1-3. Water Flow Switch

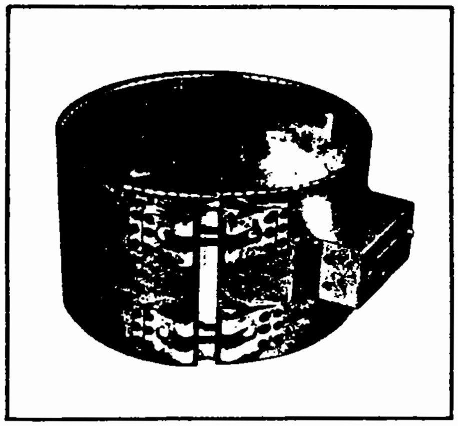
This switch's normally open contacts are connected to the remote STOP input of the pump's frequency converter. As long as there is sufficient water flowing through the pump, these contacts will close and allow the pump to operate normally. However, if the water flow should decrease to an insufficient level, these contacts will open and turn off the pump.

Water Flow Switch installation and adjustment information is contained in Section 3.3.8.

LEYBOLD-HERAEUS

1.4.4 BAKE-OUT JACKET

The optional Bake-Out Jacket (Fig. 1-4) allows automatic controlled bake-out of the turbopump at 248°F (120°C). This device is easily fitted to the upper part of the pump housing, just below the pump's high-vacuum flange. Either a 115 or 220 V AC model can be ordered.



1TN-7.4

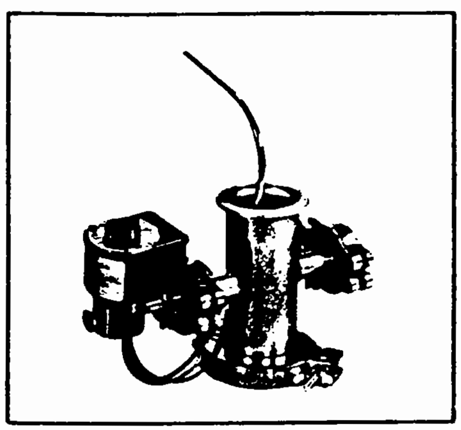
Figure 1-4. Bake-Out Jacket

Bake-out of the pump and vacuum chamber is only necessary when operational pressures of $<10^{-8}$ are required. Normally a bake-out time of 6 hours is sufficient for the pump. Longer baking times will, as a rule, not significantly improve the ultimate operational pressure.

Bake-Out Jacket installation information is contained in Section 3.3.7, while operating information is located in Section 4.6.

1.4.5 AUTOMATIC VENTING VALVE

An Automatic Venting Valve (Fig. 1-5) should be used when the pump is vented through its lateral venting port. This device is an electromagnetic actuated valve which mounts on the pump's KF10 lateral venting port. Normally-open and normally-closed valves are available. Normally-open valves close when energized, and open when deenergized. Normally-closed valves open when energized, and close when deenergized.



1TN-7.5

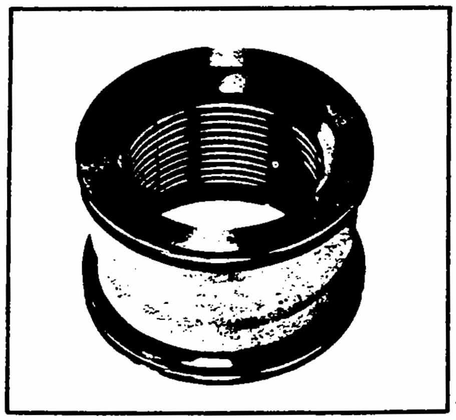
Figure 1-5. Automatic Venting Valve

The Automatic Venting Valve is connected into the pumping system such that when the pump is shut down, this valve will open and allow the venting gas to enter the pump at its lower rotor/stator stages while the pump is still rapidly rotating. This ensures very clean venting of the pump, eliminating entrainment of any residual hydrocarbons to the high-vacuum side.

Automatic Venting Valve installation information is contained in Section 3.3.5, while operating information is located in Section 4.5.

1.4.6 VIBRATION DAMPING BELLOWS

The optional Vibration Damping Bellows assembly (Fig. 1-6) is a flexible duct which is connected between the turbopump's vacuum inlet and the outlet of the system vacuum chamber. We recommend that bellows be used for connecting the TMP-1000 to instruments highly sensitive to vibration, or to prevent external vibrations from being transmitted to the pump. Note that the TMP-1000 is normally used without bellows because of its precision dynamic balance which produces a total vibration velocity of not more than 0.15 mm/second.



1TN-7.6

Figure 1-6. Vibration Damping Bellows

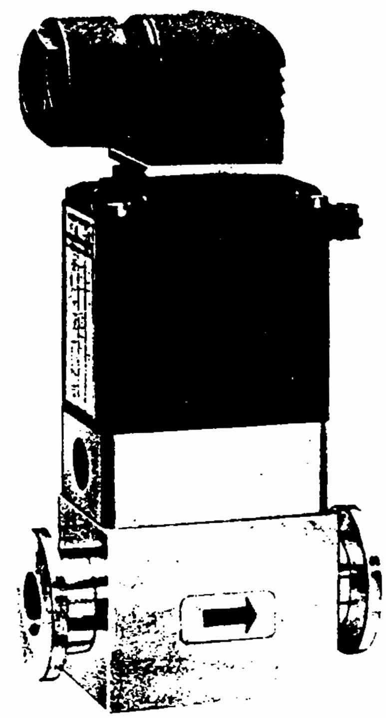
LEYBOLD-HERAEUS

1.4.7 METERING/VENTING VALVE

The Metering/Venting Valve (Fig. 1-7) is required on a TMP-1000C Corrosive Series Pump. This device is mounted on the pump's KF10 purge gas and venting port.

A dosage of inert gas flows from the Metering/Venting Valve into the pump's motor/bearing cavity, where a protective gas seal is formed around the motor and its ball bearing lubricant. Then upon pump shut-down, this valve automatically increases the flow of inert gas, thus venting the pump to atmospheric pressure through the pump's purge gas and venting port.

Metering/Venting Valve installation information is contained in Section 3.3.6.



1TN-7.7

Figure 1-7. Metering/Venting Valve for the TMP-1000C

1.5 NT-1000/1500 OPTIONAL EQUIPMENT

The following optional equipment can be added to the frequency converter. Wiring information is contained in Section 3.2.4.

- Remote START/STOP Switches -- Normally open and normally closed momentary pushbuttons or a single toggle switch can be used for the purpose of remotely starting and stopping the turbopump. Refer to Section 3.2.4.2.

- <u>Remote Normal Operation Device</u> -- An indicating or control device (e.g., LED, lamp, or valve) can be turned on or off when the converter achieves normal operation. Refer to Section 3.2.4.3.

- <u>External Frequency Counter</u> -- A digital frequency counter can be used to obtain a quantitative indication of the converter's output frequency. Refer to Section 3.2.4.4.

- <u>External Pump Speed Control</u> -- A 5 k ohm potentiometer is used to externally vary pump speed from 50 to 100% of its rated rotational speed. Refer to Section 3.2.4.5.

- <u>External Elapsed Time Meter</u> -- An 18 V AC external elapsed time meter can be used to indicate total normal operation time of the turbopump. Refer to Section 3.2.4.6.

NOTES

SECTION 2
UNPACKING AND INSPECTION

2.1 GENERAL INFORMATION

This section includes instructions for unpacking the TMP-1000 Turbomolecular Pump and the NT-1000/1500 Frequency Converter, and inspecting these items for shipping damage.

2.2 UNPACKING AND INSPECTION

Proceed as follows to unpack and check the TMP-1000 and NT-1000/1500 for shipping damages as soon as you receive it, even though the equipment may not be needed right away.

1. Inspect the outside of each shipping container for visible damage. If damage is apparent, keep the shipping container and packing materials if internal damage is later found.

CAUTION

In the following step, do not remove the protective covers from the TMP-1000 inlet and outlet ports until the pump is ready for connection to the vacuum system. This ensures that the pump will not be damaged or become dirty.

2. Carefully unpack the TMP-1000 and NT-1000/1500 and inspect for damage.

3. Remove the NT-1000/1500 top cover and inspect for internal damage. Ensure that all circuit boards are secured in place and that all connectors are tight.

4. If you find any evidence of damage, proceed as follows:

a. Save the shipping container, packing material, and damaged part for inspection.

b. Notify the carrier that made the delivery within 15 days of delivery, in accordance with Interstate Commerce Commission regulations, and file a claim with the carrier for the damage.

NOTE: All equipment is shipped F.O.B. from the factory; therefore, any damage in transit is the responsibility of the carrier.

c. Contact the Order Services Department of Leybold-Heraeus in Export, PA or your nearest Leybold-Heraeus representative to order replacement parts.

2.3 NT-1000/1500 ADDITIONAL MATERIAL

The following quantities of additional material is included with the NT-1000/1500:

Qty.

1 - Chassis Fuse, Type T 10A/250 D, for 110-120 V AC;
1 - Chassis Fuse, Type T 6.3A/250 D, for 200-240 V AC;
1 - 7 Conductor Pump Cable with Connectors, 16.5 ft. (5 m), cable is marked on both ends with heat-shrink tubing;
2 - Fitting Brackets for mounting the converter into a 19-inch rack;
1 - Instruction Manual.

SECTION 3
INSTALLATION

3.1 GENERAL INFORMATION

This section contains information on how to install both the NT-1000/1500 Frequency Converter and the TMP-1000 Turbomolecular Pump. Also included is a procedure which checks that the pump will be rotating in the correct direction, before the pump is installed.

3.2 NT-1000/1500 INSTALLATION

The following procedures describe how to wire and install the NT-1000/1500 Frequency Converter.

3.2.1 AC VOLTAGE AND FUSE SELECTION

Connect the primary wiring of power transformer T1 to correspond to the AC line voltage that will be applied to the converter, and also install the proper AC line fuse as follows:

WARNING

To avoid personal injury due to electrical shock, DO NOT plug the converter into an AC service outlet with its top cover removed during the following procedure.

1. Remove the converter's top cover by unscrewing its seven countersunk screws and one fillister-head screw.

2. Connect the AC line and make the necessary jumper connection(s) to the primary side of transformer T1 as listed in Table 3-1 and shown in Fig. 3-1. Also see the NT-1000/1500 schematic in Fig. 8-5.

3. Install the proper AC line fuse (F1) at the converter's rear panel per Table 3-1.

4. Replace the top cover.

TABLE 3-1. NT-1000/1500 POWER TRANSFORMER CONNECTIONS AND FUSE SELECTION

AC Line Voltage	110	115/120	200/220	240
AC Line Connection to Terminals	2&6	1&3	2&6	1&6
Jumper Connection(s) to Terminals	2-5 3-6	1-4 3-6	3-5	3-4
Fuse	10 A	10 A	6.3 A	6.3 A

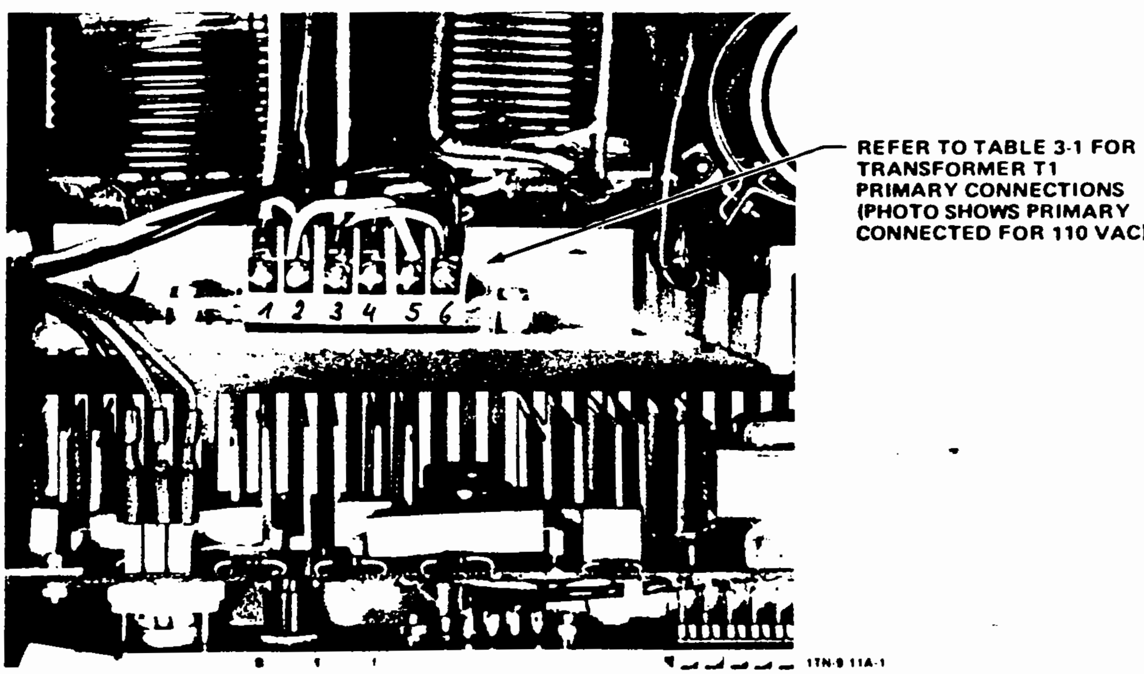


Figure 3-1. Power Transformer T1 Primary Connections

3.2.2 CONVERTER COOLING

The NT-1000/1500 Frequency Converter depends primarily on convection cooling to maintain an acceptable internal operating temperature. This temperature is easily achieved if air flow through the bottom and top of the converter is not restricted and if ambient air temperatures do not exceed 113°F (45°C).

Excessive operating temperatures will void the converter's warranty, may result in premature failure of the converter, and will definitely degrade its reliability.

3.2.3 CONVERTER MOUNTING

The converter is shipped with four rubber feet, allowing it to be placed on any hard surface up to 16.4 feet (5 m) away from the pump. For greater distances, additional pump cable must be ordered; also, the converter's pump cable length compensation control must be readjusted as described in Section 5.5.2.

For 19 inch rack-mount installations, Extender Ears (P/N 721-75-000) are included with the converter. These items consist of two rectangular metal plates, each having two slotted screw holes and two round screw holes. To install these Extender Ears, proceed as follows:

1. Pry out the plastic cover in front of each handle.

2. Loosen the two screws that secure the handles to the front panel, and then remove the spacer plate behind each handle.

3. Insert the Extender Ears in place of the spacer plates with their slotted screw holes positioned behind the handle screws, and then tighten the handle screws.

4. Reinstall the plastic handle covers.

3.2.4 CONVERTER REAR PANEL CONTROL TERMINAL STRIP WIRING

Figure 3-2 illustrates the converter's rear panel wiring. Additional wiring information in contained in Sections 3.2.4.1 thru 3.2.4.6.

3.2.4.1 Initial Wiring

If you DO NOT wish to use the remote start-stop features, connect a jumper to rear panel terminals X1-2 and -3. See Fig. 3-2(a).

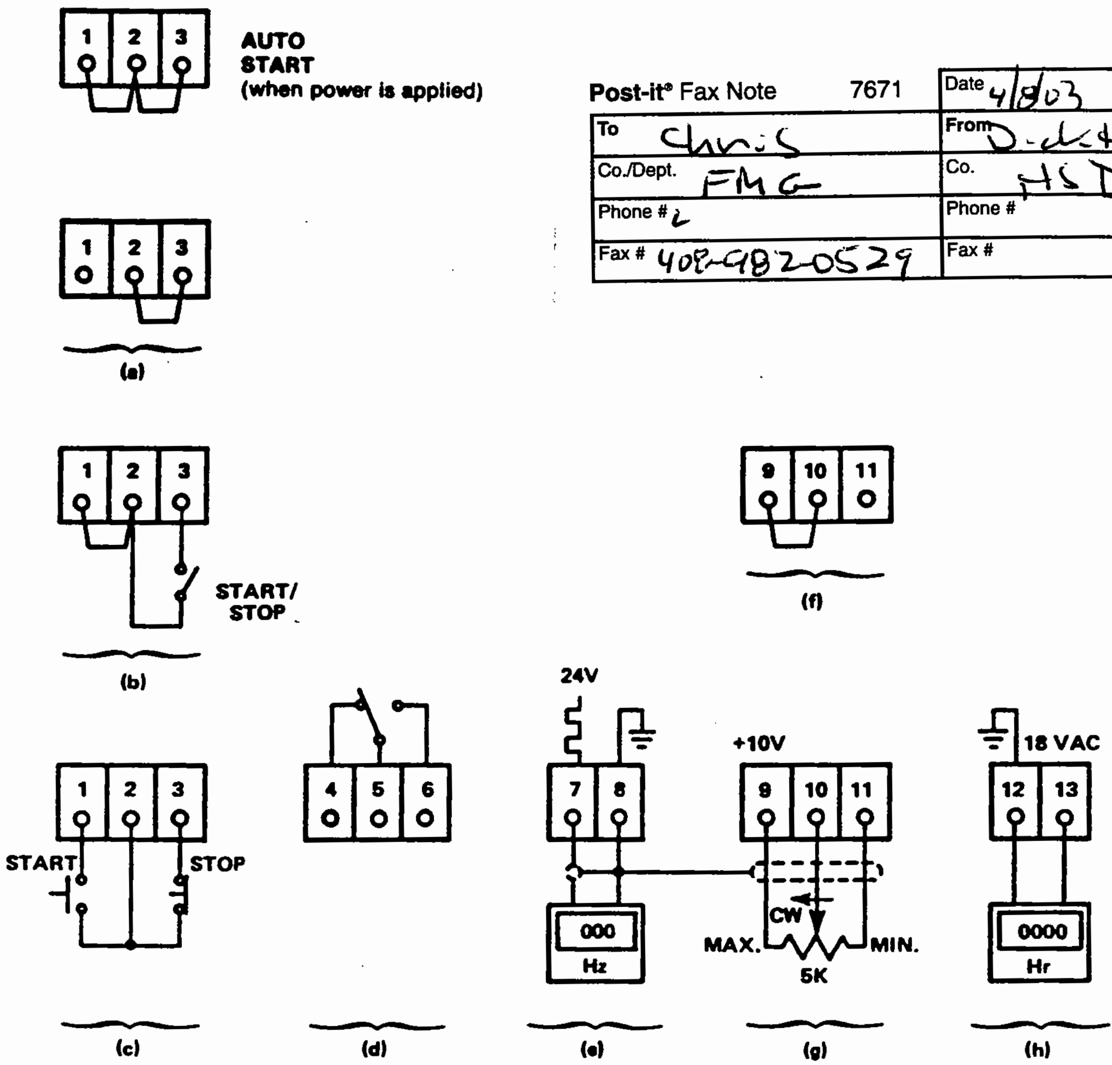
If you DO NOT wish to use the external speed control feature, connect a jumper to rear panel terminals X1-9 and -10. See Fig. 3-2(f).

3.2.4.2 Remote Starting and Stopping

Terminals X1-1, -2, -3 are inputs to be used for starting and stopping the pump from a remote location. The following are two methods that the converter may be wired for remote starting and stopping:

1. The first method uses two momentary pushbutton switches which function the same way as the converter's front panel START/STOP controls. This wiring arrangement uses a momentary switch closure to start the pump, and a momentary switch open to stop the pump. Note that a short term power failure will reset the converter and stop the pump. Wire according to Fig. 3-2(c).

Post-it® Fax Note 7671	Date 4/8/03	# of pages ▶ 1
To Chris	From D. [illegible]	
Co./Dept. FMG	Co. HSD	
Phone # 2	Phone #	
Fax # 408-982-0529	Fax #	



(a) INSTALL JUMPER WHEN REMOTE STOP/START IS NOT USED.
(b) REMOTE START/STOP USING A SINGLE TOGGLE SWITCH.
(c) REMOTE START/STOP USING TWO MOMENTARY PUSHBUTTONS.
(d) NORMAL OPERATION RELAY OUTPUTS.
(e) FREQUENCY COUNTER
(f) INSTALL JUMPER WHEN EXTERNAL SPEED CONTROL IS NOT USED.
(g) PUMP SPEED CONTROL.
(h) ELAPSED TIME METER.

1TN-6.1

Figure 3-2 Rear Panel Control Terminal Strip Wiring

2. The second method uses a single toggle switch. With this wiring configuration, the pump will start when the switch is closed, and will stop when the switch is open. An advantage of wiring your system in this fashion is that following a short term power failure, the pump will automatically restart without operator involvement. Wire according to Fig. 3-2(b).

If the remote start-stop feature is not used, a jumper must be installed between terminals X1-2 & -3, see Fig. 3-2(a).

3.2.4.3 Remote Normal Operation Sensing

Relay contact outputs X1-4 (N.C.), X1-5 (Com), and X1-6 (N.O.) are provided to indicate when normal operation is achieved by the converter. External indicating or control devices can be activated by these relay contact outputs which are rated 4 A at 250 V AC and 120 W at 30 V DC. See Fig. 3-2(d).

For example, a remote normal operation lamp and its power source can be connected in series with relay contact output X1-5 & -6. This output will close and light the remote lamp when the front panel NORMAL OPERATION indicator lights.

3.2.4.4 External Converter Frequency Indication

Terminals X1-7 & -8 can be connected to a frequency counter for the purpose of obtaining a quantitative indication of the converter's output frequency. The output signal at these terminals is a +24 volt square wave. See Fig. 3-2(e).

Note that an output frequency of 605 Hz corresponds to the TMP-1000's rated rotational speed of 36,000 r.p.m.

3.2.4.5 External Pump Speed Control

A 5 K ohm, linear-taper potentiometer when connected to terminals X1-9, -10, -11 is used to vary pump speed from 50 to 100% of its rated rotational speed. Connect this potentiometer as shown in Fig. 3-2(g).

Note that 100% rated rotational speed corresponds to +10 volts and 50% rated rotational speed corresponds to +5 volts at terminal X1-10 referenced to ground.

If the external pump speed control is not used, a jumper must be installed between terminals X1-9 & -10, see Fig 3-2(f).

3.2.4.6 External Elapsed Time Meter

Terminals X1-12 & -13 provide an output of 18 V AC whenever the converter achieves normal operation. An elapsed time meter can be connected to these terminals for the purpose of indicating total normal operation time of the pump. See Fig. 3-2(h).

3.2.5 GROUNDING

In order to reduce any possibility of electrical shock, and to prevent a malfunction of the converter due to electrical noise, ground the converter chassis to the enclosure in which it is installed or to a nearby earth ground using the grounding screw at the rear, lower right-hand corner of the unit. Note that this ground connection is in addition to the ground wire contained in the converter's AC power cord.

Keep the inductance of the ground connection as low as practicable by using a short lead made of copper braid or heavy wire.

3.2.6 PUMP AND CONVERTER INTERCONNECTION

The pump and converter are interconnected by a standard 16.4 ft. (5 m), 7-conductor pump cable which is supplied with the converter. Note that this pump cable is marked at both ends by heat-shrink tubing. If the older 6-conductor unmarked pump cable is mistakenly used with the TMP-1000, the pump will run for safety reasons at the slower rotational speed of the TMP-1500 (21,000 r.p.m.).

CAUTION

When plugging the octal pump cable connector into the pump's electrical connector, ensure that the key and keyway of these connectors properly mate. Otherwise, the converter may be damaged due to improper connections.

Note that if you use a pump cable that is longer than the standard cable, you must readjust the pump cable length compensation control as described in Section 5.5.2.

3.2.7 CHECKING PUMP MOTOR DIRECTION OF ROTATION

Before installing the pump, check that the pump will be rotating in the correct direction when power is applied as follows:

WARNING

This equipment employs voltages which are dangerous and may be fatal if contacted. Extreme caution should be exercised when working with the equipment with any of its protective covers removed. To prevent electrical shock, always connect the chassis of the unit to a low impedance ground.

CAUTION

Before plugging the converter into an AC service outlet, ensure that its power transformer, T1, is wired for the correct AC line voltage, and that the correct chassis fuse, F1, is installed. Refer to Section 3.2.1.

1. Install the pump cable between the pump and converter as described in Section 3.2.6.

2. Plug the converter into an AC service outlet. Observe that the front panel POWER indicator should be on.

3. Press START; observe rotor rotation through the high-vacuum inlet port; then press STOP.

4. The rotor should be turning clockwise (as observed through high-vacuum inlet). If not, proceed as follows:

   a. Unplug the converter from the AC service outlet.

   b. Remove the top cover from the converter.

c. Interchange any two of the three-phase output wires connected to the inverter board, see Fig. 3-3.

d. Repeat steps 2 thru 4 to ensure that the pump is rotating in the correct direction. Then replace the top cover.

5. After completing this procedure, unplug the converter. If the pump is not going to be installed at this time, remove the pump cable and place the pump back into its protective shipping material and store in a dry location.

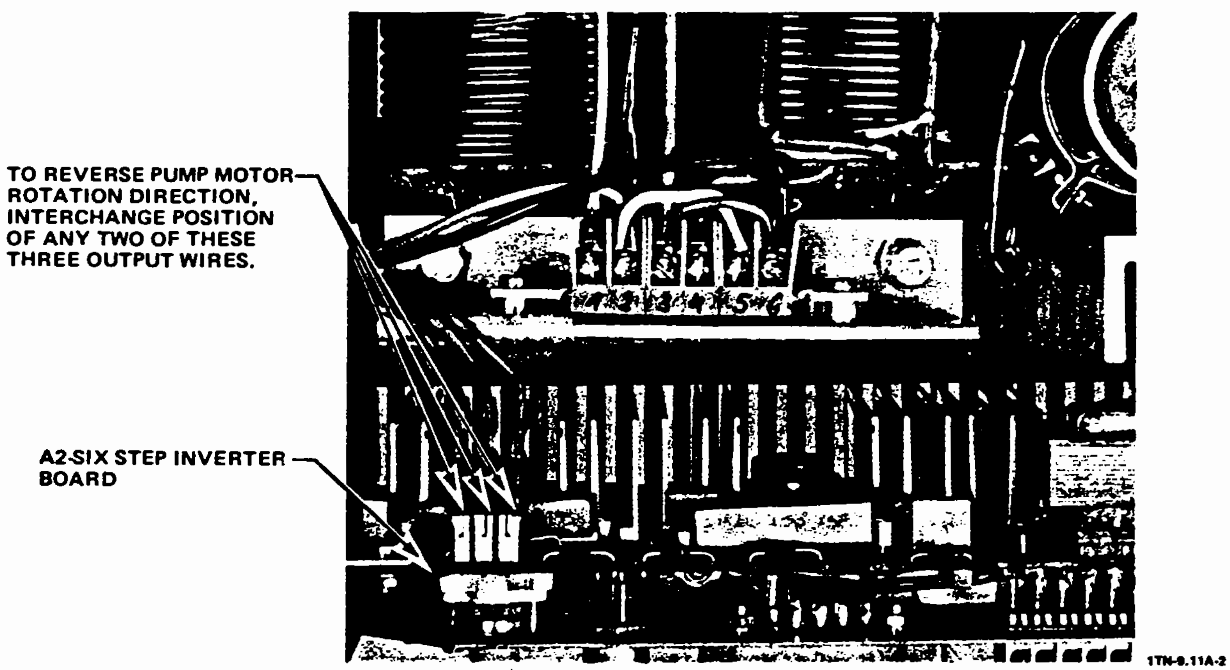


Figure 3-3. Motor Rotation Reversal Wiring

3.3 TMP-1000 INSTALLATION

The following procedures describe how to install the TMP-1000 Turbomolecular Pump. A typical installation schematic is shown in Fig. 3-4.

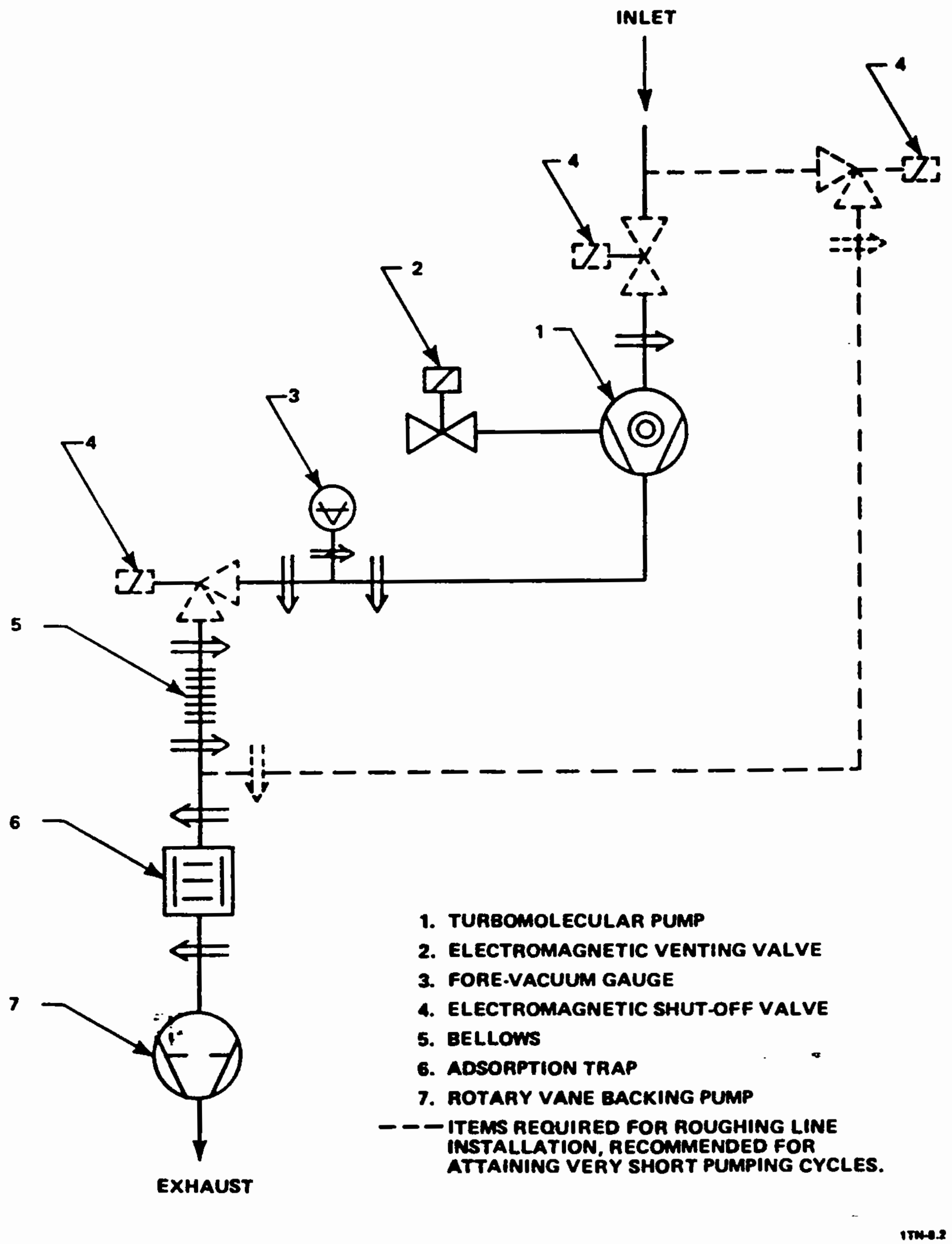


Figure 3-4. Typical Pumping System Diagram

3.3.1 PRELIMINARY INSTALLATION CONSIDERATIONS

1. The pump is shipped in a sealed PVC bag with moisture absorbent. Also, protective covers are installed on the pump's intake and exhaust ports. Remove this material just before mounting the pump to the system.

2. Ensure that the pump motor's direction of rotation is correct before installing the pump. Refer to Section 3.2.7.

3. When installing the pump within a magnetic field, ensure that the magnetic induction measured at the surface of the pump housing does not exceed 50 gauss [5 mT (militesla)] in a radial field and 150 gauss (15 mT) in an axial field. If these values are exceeded, the resulting eddy currents might heat up the rotor; therefore, suitable magnetic shielding of the pump will be necessary.

4. If pumping corrosive or abrasive media, the TMP-1000C Corrosive Series Pump should be used.

5. The standard TMP-1000 is radiation resistant up to 10^5 rad. If higher radiation resistance is required, please contact Leybold-Heraeus.

6. The pump must be protected from heavy external shocks or vibration. Bellows are recommended if the pump is connected to any vibrating components (i.e., backing pump).

7. The pump can be mounted in any angular position directly by its intake flange to the vacuum system. However, if Vibration Damping Bellows is installed between the vacuum system and the pump, then additional bracing or supporting of the pump at its feet or at the base plate is recommended.

8. A source of clean tap water should located near the pump for cooling purposes. If no tap water source is available, use the Air Cooling Assembly or Cooling Unit option. Refer to Sections 1.4.1 and 1.4.2.

9. If the TMP-1000 will be continuously operated between 1.3×10^{-3} mbar and its maximum rated pressure of 0.13 mbar, the rating of the backing pump or pump system needs to be increased to accommodate the exceptionally high throughput of the turbopump. Contact Leybold-Heraeus for recommendations.

3.3.2 INTAKE PORT CONNECTION

In most cases the TMP-1000 can be mounted directly by its intake flange (Fig. 6-2, Item 1) to the vacuum system. And due to its grease lubricating system, the turbopump can be mounted and operated in any position. The turbopump is secured to the vacuum system using any one of the following five types of flanges: LF150, CF150, CF200, CF250, and 6-inch ASA. The type of flange used depends on such factors as compatibility with other system flanges, the vacuum system's nominal operating pressure, and the maximum pumping speed required. Note that CF flanges use metal seals and are used in ultra-high vacuum applications.

LF flanged turbopumps are supplied with half of the required number of LF Flange Clamps; whereas, no mounting hardware is supplied with the ASA and CF flanged turbopumps. Type ASA and LF flange assembly information can be found in the Vacuum Fittings section of the Leybold-Heraeus Catalog ("Product and Vacuum Technology Reference Book").

If the turbopump is connected to instruments highly sensitive to vibration, or to prevent external vibrations from being transmitted to the turbopump, Vibration Damping Bellows should be installed on the turbopump's intake port (refer to Section 1.4.6).

Before making the high vacuum connection, ensure that the wire-mesh splinter guard (see Fig. 6-2, Item 2) is inserted into the turbopump's intake port.

3.3.3 EXHAUST PORT CONNECTION

The pump exhaust port is supplied with a type KF40 fitting. Assembly information for this and other types of vacuum fittings is located in the Leybold-Heraeus Catalog ("Product and Vacuum Technology Reference Book").

In order to achieve fast pump down times and low operating pressures, it is essential to install an adequate backing pump at the turbopump's exhaust port. We recommend using the Leybold-Heraeus TRIVAC D30B/D65B Rotary Vane Pump as the backing pump.

To prevent backstreaming of oil from the backing pump toward the TMP-1000 upon shut-down or in the event of a power failure, a TRIVAC pump incorporates an internal anti-suckback device which automatically closes the TRIVAC's intake port when the pump is switched off. If another type of backing pump is used, an airing/isolating valve that seals off the backing pump's intake port should be installed. We recommend using the Leybold-Heraeus SECUVAC valve (KF reducer fittings may also be required).

To ensure that the fore-vacuum space of the TMP-1000 remains free from oil vapors, an adsorption trap should be installed into the fore-vacuum line. Consult Leybold-Heraeus for the trap best suited to your particular application.

To prevent vibrations from being transmitted from the backing pump to the TMP-1000, use bellows or flexible tubing to connect these two pumps.

3.3.4 TURBOPUMP COOLING

The TMP-1000 is normally water cooled using a clean source of tap water. However, if tap water is not available or if the water is contaminated, then cooling is accomplished by using either the Air Cooling Assembly or the Cooling Unit. Refer to the following sections on cooling.

3.3.4.1 Water Cooling Connection

Connect a source of clean tap water to either of the pump's water nozzles (see Fig. 6-2, Item 7a). The water should be between 59 to 77°F (15 to 25°C) at a pressure of between 40 and 90 psig. Use 7/16 in. (11 mm) I.D. hose to make the water connection. Connect a second hose from the nearest water drain to the pump's other water nozzle. Use hose clamps to secure both hoses to the pump.

To ensure that clean water is being fed through the pump, install a fine mesh strainer or automotive fuel filter in the cooling water supply line.

Although the pump is overtemperature protected by its internal thermal switch, we recommend installing a Water Flow Switch (refer to Section 1.4.3) in the cooling water drain line as described in Section 3.3.8.

3.3.4.2 Air Cooling Assembly

Where water cooling is not possible, the Air Cooling Assembly (refer to Section 1.4.1) can be used to cool the pump. This unit is mounted around the motor housing, and is secured to the pump base using the three screws supplied with the Air Cooling Assembly.

When installing the Air Cooling Assembly, ensure that its intake air ports are not obstructed.

Connect the Air Cooling Assembly to a source of either 115 or 220 V AC (depending on model ordered), single phase power that is switched on and off simultaneously with the pump. See the Air Cooling Assembly's electrical specification label for specific voltage required. The Air Cooling Assembly requires 24 watts.

Note that the maximum permissible ambient temperature for a pump being baked out with air cooling is 86°F (30°C), while the ambient temperature for unheated air-cooled pumps at operating pressures lower than 10^{-4} mbar is 113°F (45°C).

3.3.4.3 Cooling Unit

Where neither water cooling nor air cooling is possible, the Cooling Unit (refer to Section 1.4.2) can be used to cool the pump.

Install the Cooling Unit as described in its instruction manual.

Connect the water lines of the Cooling Unit to the water nozzles of the pump using 7/16 in. (11 mm) I.D. hose. Use hose clamps to secure both hoses to the pump.

3.3.5 VENTING PORT CONNECTION

The TMP-1000 should be vented to atmospheric pressure immediately when switched off to prevent back diffusion of the process gas and/or oil vapors from the backing pump into the high vacuum side of the turbopump. Venting is normally accomplished through the pump's lateral venting port (see Fig. 6-2, Item 5) which is supplied with a KF10 fitting. Venting gas should enter the lateral venting port through an Automatic Venting Valve (refer to Section 1.4.5).

Connect the lateral venting port to an Automatic Venting Valve using a KF10 clamp. Ensure that the supplied centering ring with sintered metal filter is fitted to the lateral venting port.

The venting valve should be wired to a source 115 V AC, single phase power such that the valve will be closed when the pump is running. Then when the pump is switched off, the venting valve should immediately open and allow the venting gas to enter the pump.

Either leave the input side of the Automatic Venting Valve open to the atmosphere, or connect it to a bottled source of venting gas (i.e., dry nitrogen) using whatever fittings are necessary. When using a pressurized venting line, DO NOT exceed a venting pressure of 7 psig.

When venting from the high-vacuum side, the lateral venting port must be blanked off.

3.3.6 PURGE GAS AND VENTING PORT CONNECTION (for corrosive series pumps only)

The TMP-1000C Corrosive Series Pump must be connected to a continuous supply of inert purge gas (e.g., nitrogen, argon) at its purge gas and venting port (see Fig. 6-3) which is supplied with a KF10 fitting. The purge gas should enter the pump through a Metering/Venting Valve (refer to Section 1.4.7).

Connect the purge gas and venting port to a Metering/Venting Valve using a KF10 clamp. Ensure that the Metering/Venting Valve is mounted such that the arrow forged into its valve housing points toward the centerline of the pump.

Connect the Metering/Venting Valve to a source of 115 V AC, single phase power such that while the pump is switched on, its solenoid bypass is energized and therefore closed, thus, allowing a metered amount of inert gas to enter the pump. Then when the pump is switched off, the solenoid bypass should deenergize and open, thus, venting the pump to atmospheric pressure by allowing a much greater volume of inert gas to flow into the pump.

Connect the input side of the Metering/Venting Valve directly to the inert gas supply line via whatever fittings are necessary. Note that the Metering/Venting Valve has been sized to allow an inert gas flow rate of 36 standard cubic centimeters per minute (sccm) at atmospheric pressure. This flow rate maintains the motor cavity at a pressure that is approximately ten times higher than the normal foreline pressure. Other flow rates at elevated purge gas inlet pressures are listed in Table 3-2. Be certain that the backing pump(s) or pumping systems(s) are capable of handling this purge gas flow, in addition to the normal throughput of the turbopump and any expected process gas inflow.

TABLE 3-2. PURGE GAS FLOW RATES FOR THE TMP-1000C

Purge Gas Inlet Pressure (psig)	Purge Gas Flow Rate (sccm)
0	36.0
2	40.9
5	48.2
7 (max. recommended)	54.4
10	60.5
15	72.7

3.3.7 BAKE-OUT JACKET INSTALLATION

The Bake-Out Jacket is used when operational pressures of $<10^{-8}$ mbar are required (refer to Section 1.4.4).

Install the Bake-Out Jacket on the upper part of the pump housing as close as possible to the intake flange. This unit is secured around the pump using the supplied hardware.

The Bake-Out Jacket is powered by a source of either 115 or 220 V AC (depending on model ordered), single phase power. See the unit's electrical specification label for specific voltage required. The Bake-Out Jacket requires 500 watts.

3.3.8 WATER FLOW SWITCH INSTALLATION

Following the instructions supplied with the optional Water Flow Switch, perform the following:

1. Install the Water Flow Switch in the turbopump's water drain line using the switch's Low Flow Range "In" and "Out" connections [0.1 to 1.0 gal/min (0.4 to 3.8 ltr/min)]. These connections are 1/4 inch NPT female. The unused connections should be sealed using the plugs supplied with the switch. Observe that the water switch rotor will always spin in a clockwise direction when the water lines are correctly connected.

2. Adjust the potentiometer inside the Water Flow Switch to shut down the pump at a minimum water flow rate 0.13 gal/min (0.5 ltr/min).

NOTE: There is hysteresis in the switching process, causing the trip point to be slightly different for rising and falling flow rates. For a precise measurement of the trip point, make the measurement while reducing the flow rate so that it falls through the trip point.

Electrically connect the Water Flow Switch to the Frequency Converter's rear panel remote stop terminals as follows:

o If a jumper is installed between remote stop terminals X1-2 and X1-3, remove this jumper and connect the normally open (N.O.) relay contacts of the Water Flow Switch between these two terminals.

o If a remote stop switch is connected to terminals X1-2 and X1-3, connect the normally open (N.O.) relay contacts of the Water Flow Switch in series with the remote stop switch.

In operation, as long as there is sufficient water flowing through the pump, the Water Flow Switch will be closed and allow the pump to operate normally. However, if the water flow should fall below 0.13 gal/min (0.5 ltr/min), this switch will open and shut down the pump.

SECTION 4
OPERATION

4.1 GENERAL INFORMATION

This section contains information on how to start, operate, and stop the TMP/NT-1000 vacuum pumping system. Information on turbopump venting and bake-out is also presented.

WARNING

DO NOT use the TMP-1000 or TMP-1000C for pumping oxidizers or higher than atmospheric concentrations of oxygen.

4.2 NT-1000/1500 FRONT PANEL CONTROLS AND INDICATORS

The following functions are performed by the NT-1000/1500 Frequency Converter's front panel controls and indicators, see Fig. 4-1:

START - Starts the pump.

STOP - Stops the pump or resets the converter's fault circuit.

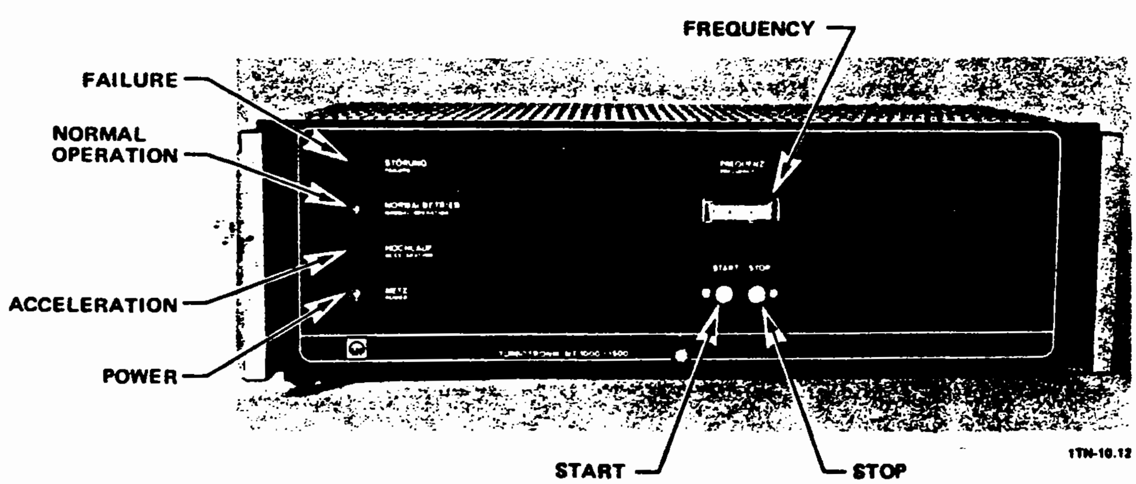


Figure 4-1. NT-1000/1500 Front Panel Controls

FREQUENCY - This meter indicates the pump's drive frequency as a percentage of its maximum value (100% corresponds to maximum pump speed).

POWER (Yellow) - Indicates when power is applied to the converter.

ACCELERATION (Green) - Indicates when the pump is accelerating at a pump motor current level that is approximately 30% higher than is normally permissible during normal operation.

NORMAL OPERATION (Yellow) - Lights as soon as the turbopump accelerates to the desired rotational speed (adjustable between 50 and 100% of the pump's rated rotational speed of 36,000 r.p.m., when the optional external pump speed control is installed). Note that this indicator remains on as long as the pump's rotational speed does not drop below approximately 12,000 r.p.m.

FAILURE (Red) - Indicates the pump has been stopped due to:

a. The pump's failure to accelerate to at least one-third of its rated rotational speed within an acceleration time period of 15 minutes.

b. An overload which caused the pump's rotational speed to drop below approximately 12,000 r.p.m. (corresponds to a frequency meter indication of approximately 33%).

c. A pump overtemperature condition.

d. A defective or misadjusted converter.

4.3 STARTING AND OPERATING

To start and operate the NT-1000/1500 Frequency Converter and TMP-1000 Turbomolecular Pump, proceed as follows:

1. Before starting the vacuum pumping system, ensure that the NT-1000/1500 and TMP-1000 have been correctly installed as described in Sections 3.2 and 3.3.

2. Plug the converter into an AC service outlet and observe that its POWER indicator should light.

3. Turn on the pump's cooling-water flow or its air-cooling fans.

4. If starting a TMP-1000C Corrosive Series Pump, open the purge-gas line and ensure that the Metering/Venting valve is energized (refer to Sections 1.4.7 and 3.3.6).

5. If the converter's FAILURE indicator turns on during this procedure, refer to Section 7 Troubleshooting.

6. Start the backing pump and then start the turbopump by pressing the START pushbutton on the converter. Observe that the converter's ACCELERATION indicator should light. Also observe that the FREQUENCY meter indication should first swing to 100%, then drop to approximately 5%, and then slowly rise as the pump accelerates. (The turbopump can also be remotely started. Refer to Section 3.2.4.2.)

   NOTE: When pumping out small chambers (i.e., where a pressure below 1 mbar is attained within 10 minutes) the backing pump and turbopump can be switched on at the same time. Larger chambers, however, must first be roughed down to approximately 5×10^{-1} mbar by the backing pump before the turbopump is switched on; otherwise, the turbopump will not accelerate fast enough to avoid an overload failure. Roughing can be accomplished either through the turbopump while it is at a standstill, or through a separate roughing line.

7. As soon as the turbopump accelerates to the desired operating speed, the NORMAL OPERATION indicator will light and the ACCELERATION indicator will turn off. (Remote normal operation sensing is possible by using the relay outputs at the rear of the converter. Refer to Section 3.2.4.3.). Note that if the turbopump is then slowed down because of an overloaded, the NORMAL OPERATION indicator will remain on as long as the pump's rotational speed does not drop below approximately 12,000 r.p.m. (corresponds to a FREQUENCY meter indication of approximately 33%). A further reduction in rotational speed will cause the converter to automatically shut off and light its FAILURE indicator.

NOTE: The NORMAL OPERATION indicator will also light if the turbopump has achieved a rotational speed of at least 12,000 r.p.m. at the end of the maximum allowable acceleration time period of 15 minutes. Otherwise, at the end of this time period, the converter will shut down the pump and light the FAILURE indicator.

8. Observe that the FREQUENCY meter is now indicating the pump's drive frequency as a percentage of its maximum value (100% indicates maximum pump speed). (An actual drive frequency indication is obtained by connecting a frequency counter at the rear of the converter. Refer to Section 3.2.4.4.)

9. Pump speed can be varied between 50 and 100% of its rated rotational speed of 36,000 r.p.m. by adjusting the optional external pump speed control. Refer to Section 3.2.4.5.

10. If operational pressures of $<10^{-8}$ are required, bake-out the turbopump as described in Section 4.6.

11. Total normal operation time can be recorded by an optional Elapsed Time Meter connected at the rear of the converter. Refer to Section 3.2.4.6.

12. In the event of a momentary power failure, the converter will automatically shut off. When power is restored, the converter must be restarted by pressing its START pushbutton. Note that the converter can be restarted even while the turbopump is still rotating. (Automatic restart is possible by connecting an external start switch at the rear of the converter as described in Section 3.2.4.2.)

4.4 STOPPING

To stop the TMP-1000 and to shut down the vacuum pumping system, proceed as follows:

1. Stop the turbopump by pressing the converter's STOP pushbutton.

2. Immediately vent a TMP-1000 through its lateral venting port with dry air or nitrogen. A TMP-1000C Corrosive Series Pump is automatically vented through its purge gas and venting port by the Metering/Venting Valve immediately after the turbopump is switched off. For additional venting information, refer to Section 4.5.

3. Turn off the cooling-water flow or air-cooling fans as soon as possible to avoid condensation of vapors in the turbopump.

4. Switch off the TRIVAC backing pump. Its anti-suckback device should automatically close the foreline to prevent backstreaming of oil vapor into the turbopump. If another type of backing pump is used, close the external airing/isolation valve before switching off the backing pump (note that a Leybold-Heraeus SECUVAC valve automatically closes when the backing pump is switched off).

5. If the turbopump is removed from the vacuum system after venting with dry gas, seal off its intake and exhaust ports with blank flanges. Also, when storing the turbopump for prolonged periods of time, place the pump into its PVC shipping bag with moisture adsorbent and store in a dry location.

4.5 VENTING

The TURBOVAC TMP-1000 is normally vented to atmospheric pressure through its lateral venting port by an Automatic Venting Valve (refer to section 3.3.5). Dry air or nitrogen is recommended for venting because it will prevent condensation of water vapor in the pumping system. If a pressurized venting line is used, DO NOT exceed a vent port inlet pressure of 7 psig.

The TURBOVAC TMP-1000C Corrosive Series Pump must be vented through its purge gas and venting port by a Metering/Venting Valve (refer to Section 3.3.6). Venting is accomplished by increasing the purge gas flow rate through the Metering/Venting Valve when the turbopump is switched off. Thus, the motor/bearing cavity is vented before the rest of the pump in order to prevent any corrosive gases or abrasive reaction products from being sucked into the cavity. If a pressurized purge/venting line is used, DO NOT exceed a venting port inlet pressure of 7 psig.

Venting from the high vacuum inlet is possible; however, it is advisable to proceed in accordance with the pressure rise graph shown in Fig. 4.2. Shock venting should be avoided, but it can be done in emergency situations without damaging the pump.

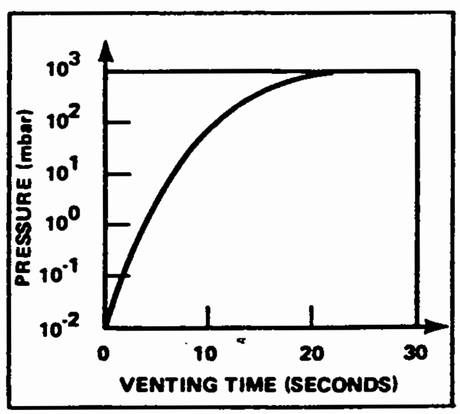


Figure 4-2. Safe High Vacuum Side Venting - Pressure Rise vs. Venting Time

4.6 BAKE-OUT

In order to attain operational pressures of $<10^{-8}$ mbar, the TMP-1000 and the connected vacuum system should be baked out at the same time. Normally a bake-out time of 6 hours for the turbopump using its Bake-Out Jacket (refer to Section 3.3.7) is sufficient. Longer baking times will, as a rule, not significantly improve the ultimate operational pressure.

During bake-out the turbopump intake flange temperature must not exceed 248°F (120°C), and its rotor temperature must not exceed 212°F (100°C). Therefore, precautions must be made to protect against direct heat radiation from the vacuum system's heater.

When baking out components at the fore-vacuum side (e.g., adsorption trap), make sure that the temperature of turbopump's exhaust flange does not exceed 176°F (80°C).

The turbopump can be continuously baked-out while running; however, note that the ambient air temperature for an air-cooled turbopump during bake-out must not be higher than 86°F (30°C).

NOTES

SECTION 5
MAINTENANCE AND ADJUSTMENTS

5.1 GENERAL INFORMATION

This section contains information on vacuum system preventive maintenance, TMP-1000 cleaning, TMP-1000 disassembly/reassembly, and NT-1000/1500 adjustment.

Figure 5-1 shows an exploded view of the TMP-1000. Refer to this figure as necessary in the following sections.

5.2 PREVENTIVE MAINTENANCE

The TMP-1000 is maintenance free. This turbopump contains life-time lubricated bearings which do not require regreasing. The only time service may be required is if the pump becomes contaminated, or if its replaceable rotor/spindle assembly becomes defective.

The NT-1000/1500 is also maintenance free. This converter is an all solid-state unit which does not require any further attention once it has been adjusted for proper operation.

WARNING

Poisonous or explosive gas can collect in filters and traps when pumping hazardous process gases. Use proper precautions to protect personnel when maintaining filters and traps.

Filters and Traps mounted in the vacuum and fore-vacuum lines must be maintained to be effective. A filter element that is saturated with contaminants can not protect your vacuum system. A dirty inlet filter or foreline trap also has poor conductance which reduces the pumping speed. A dirty exhaust filter on the backing pump results in backpressure which reduces pumping speed and makes it difficult to maintain the required pressure in the system. Backpressure can also result in damage to the backing pump. It is therefore essential that you set up a maintenance schedule which keeps the system's filters and traps clean. The frequency of maintenance depends on contaminant load generated by your process.

5.3 TMP-1000 CLEANING

Slight contamination (e.g., by an oil film) can be cleaned without disassembling the turbopump. In case of heavy contamination, however, it will be necessary to first disassemble the pump as described in Section 5.4, and then apply cleaning solvent to the rotor blades, stator rings, and stator disk halves using a brush (see Fig. 5-1).

WARNING

If the pump has been exposed to corrosive or toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions to prevent inhaling or coming in physical contact with these chemicals when disassembling the pump.

CAUTION

DO NOT apply cleaning solvent to any of the O-rings. Some solvents could dissolve or cause swelling and cracking of the O-ring material. Also, DO NOT allow the cleaning solvent to enter the spindle assembly which contains the greased ball bearings.

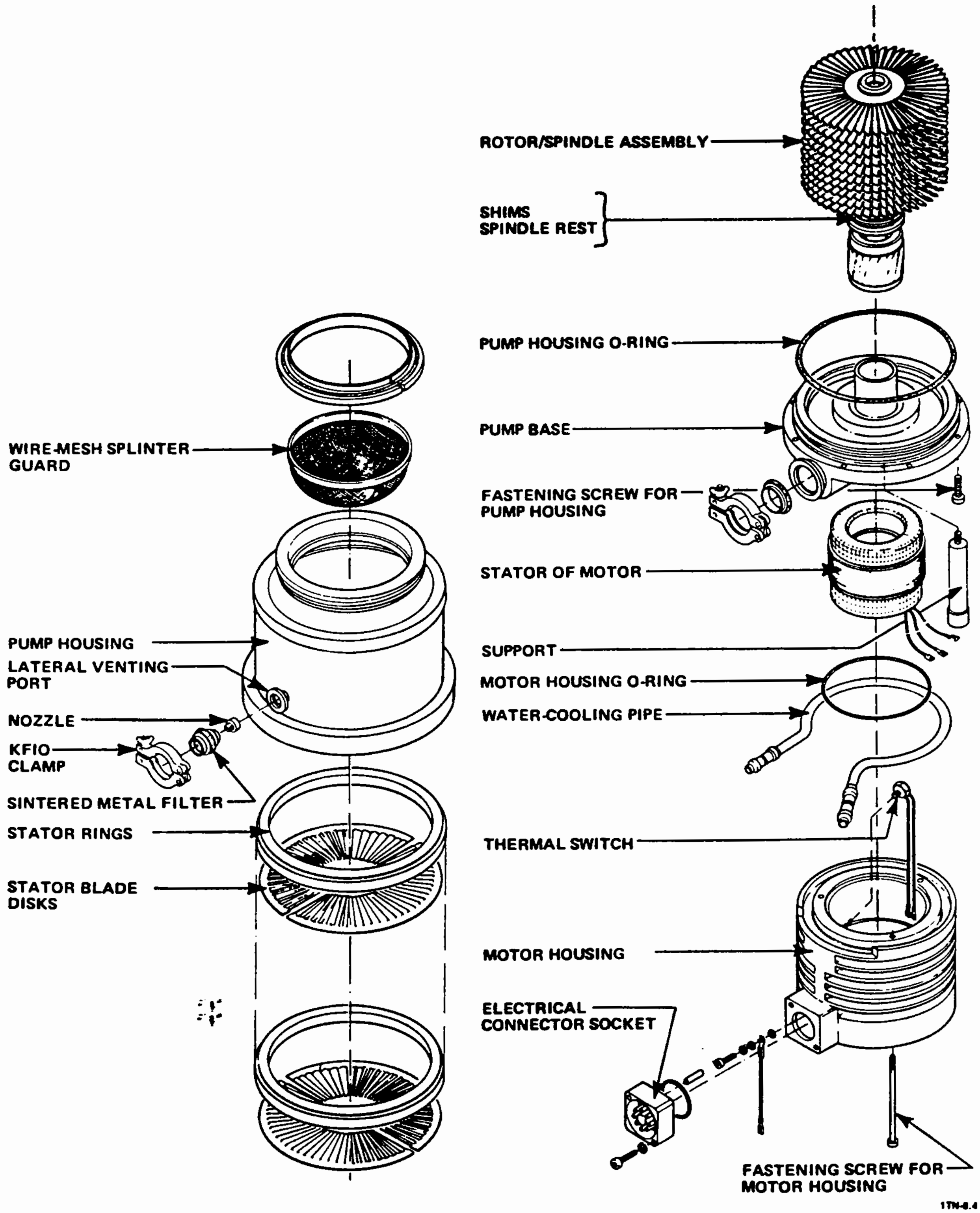


Figure 5-1. TMP-1000 Exploded View

To clean the pump without disassembly, proceed as follows:

1. Disconnect the turbopump from the system, then remove its wire-mesh splinter guard and inlet O-ring.

CAUTION

In the following step, DO NOT allow the cleaning solvent level to be higher than the rim of the lateral venting port, see Fig. 5-2. This prevents cleaning solvent from entering the spindle assembly which contains the greased ball bearings.

2. Slowly lower the turbopump upside down into a container filled with a suitable cleaning solvent (e.g., Trichlorethylene, Acetone, Freon).

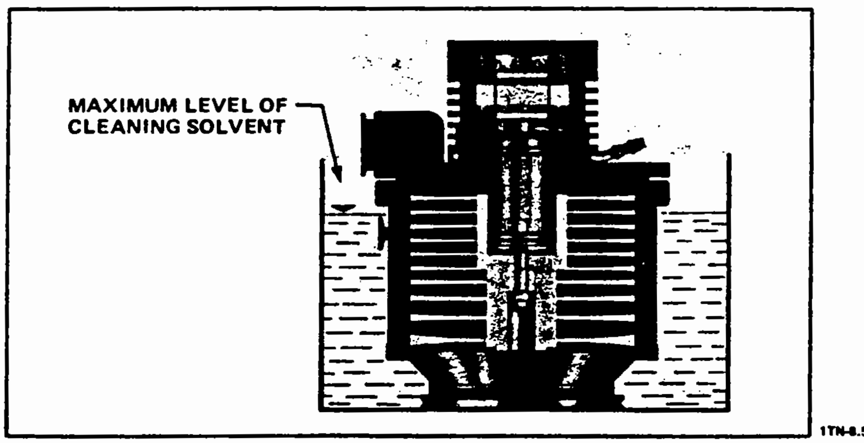


Figure 5-2. TMP-1000 Cleaning without Disassembly

3. Allow the cleaning solvent to react for about 10 to 15 minutes. During this period, GENTLY lift and lower the turbopump several times in order to flush the rotor and stator components.

4. Repeat steps 2 and 3 at least once using fresh solvent.

5. After cleaning, place the turbopump, with its high-vacuum port facing down, on a piece of cardboard for at least 2 hours to allow the solvent to drain and completely evaporate. During this period, turn the turbopump for a short time on its side with the lateral venting port facing downwards; this allows the solvent between the stator rings and pump housing to drain off.

6. Replace the wire-mesh splinter guard and inlet O-ring, then remount the pump to the system.

5.4 TMP-1000 DISASSEMBLY/REASSEMBLY

WARNING

If the pump has been exposed to corrosive or toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions to prevent inhaling or coming in physical contact with these chemicals when disassembling the pump.

The TMP-1000 should only need to be completely disassembled when it is heavily contaminated and requires cleaning, or when replacing a defective rotor/spindle assembly.

The following sections describe how to disassemble and then reassemble the TMP-1000. Please read all of these instructions before starting to disassemble the pump.

5.4.1 TOOLS REQUIRED

The following tools are required to disassemble/reassemble the TMP-1000:

- o 3-mm Allen Wrench
- o 4-mm Allen Wrench
- o 5-mm Allen Wrench
- o Allen Torque Wrench, 1 to 15 Nm (0.7 to 11 ft-lb)
- o 4-mm (1/8-inch) Flat Blade Screwdriver
- o 4-mm (1/8-inch) Phillips Head Screwdriver
- o Flat Pliers
- o Feeler gauges 0.1 to 1 mm (0.004 to 0.040 in.)
- o Try Square, max. blade lengths 200 mm (8 inches)
- o Ohmmeter (ohm and megohm range)
- o Felt-Tip Pen (eraseable)
- o Emery Cloth, 120 grain

5.4.2 PUMP HOUSING AND STATOR PACKAGE DISASSEMBLY

This procedure describes how to remove the pump housing and stator package from the TMP-1000.

1. Prepare a clean work area. Use a plastic or rubber pad as a support for the turbopump.

2. Remove all connections from the turbopump (i.e., power supply leads and cooling water lines).

3. Disconnect the turbopump from the vacuum system and remove its wire-mesh splinter guard. Then place turbopump on its support legs in the work area.

4. If the turbopump uses an Air Cooler Assembly, remove the air cooler as follows; otherwise, proceed to step 5:

   a. Set the turbopump upside down on its inlet flange.

   b. Using a phillips head screwdriver, remove the three screws which secure the Air Cooler Assembly to the turbopump.

   c. Pull the Air Cooler Assembly up from the pump base (note that it may be necessary to remove turbopump's rubber feet).

   d. Place the turbopump back on its support legs.

5. Using a 5-mm Allen wrench, remove the eight pump housing screws from the pump base (Fig. 5-3A).

6. Insert two of the pump housing screws removed in step 5 into the two jack screw holes (Fig. 5-3B). Tighten these two screws uniformly until the pump housing lifts off the pump base by approximately 1/8 inch (5 mm). Then remove these jack screws.

7. Grasp the pump housing with both hands and pull it straight up from the pump base.

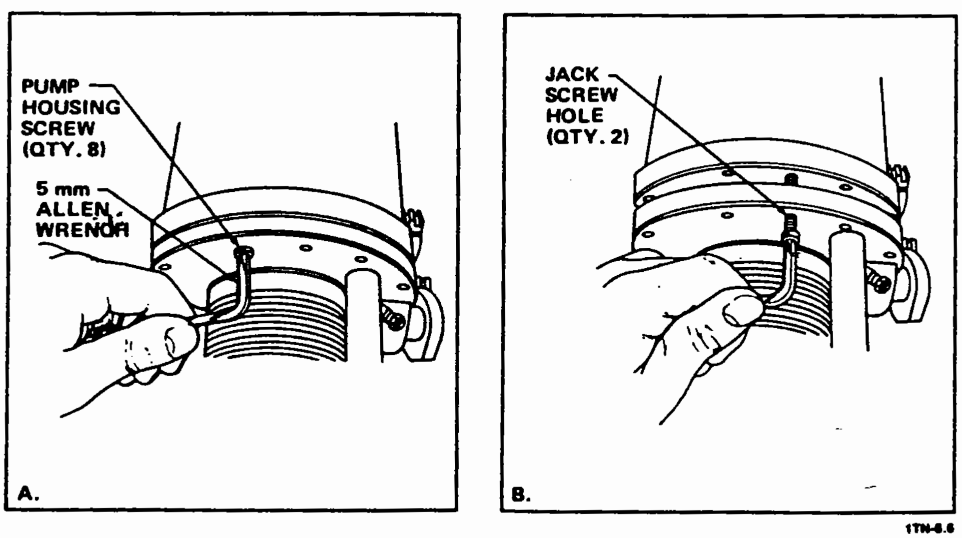


Figure 5-3. Pump Housing Removal

8. Using a felt-tip pen, number the stator rings from top to bottom (Fig. 5-4A).

9. Lift off the first stator ring (Fig. 5-4B) and place it upside down next to the turbopump (Fig. 5-4D). Note that if the stator rings cling together, use a flat blade screwdriver and CAREFULLY pry the rings apart.

10. Pull out the first two stator disk halves (Fig. 5-4C) and place them also upside down in the first stator ring (Fig. 5-4D).

> NOTE: During disassembly of the stator package, check for damaged stator rings and stator disk halves. Look for friction marks, cold welds, and deformed parts. Repair or replace any damaged part(s) before reassembling the turbopump.

11. Continue to lift off the stator rings and pull out the stator disk halves, until the complete stator package is stacked upside down next to the turbopump (Fig. 5-4D).

12. This completes the pump housing and stator package disassembly procedure.

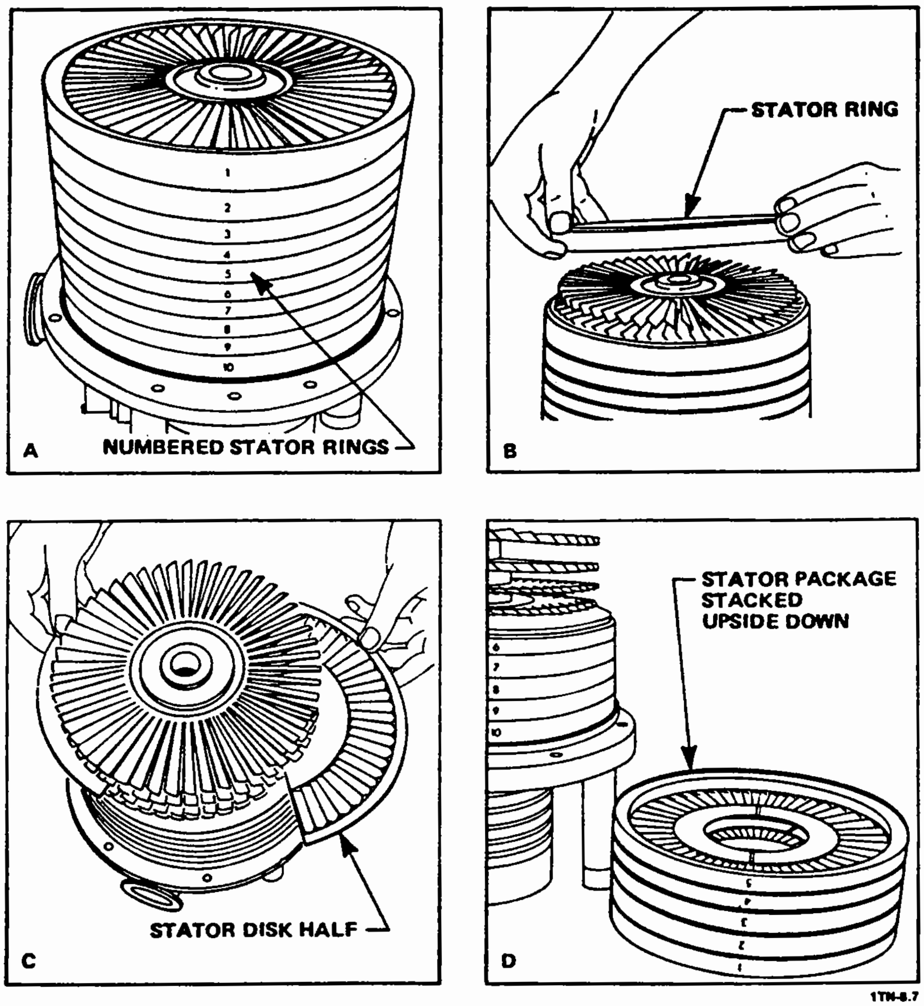


Figure 5-4. Stator Package Disassembly

5.4.3 MOTOR HOUSING REMOVAL AND MOTOR STATOR CHECK

This procedure describes how to remove the turbopump's motor housing, and then describes how to check the motor stator for signs of friction and overheating.

1. Place the pump housing upside down on its intake flange. If the pump assembly has been removed from its housing as described in Section 5.4.2, CAREFULLY reinsert the pump assembly into the pump housing (Fig. 5-5A).

2. Using a 4-mm Allen wrench, remove the three motor housing screws from the pump base (Fig. 5-5B).

3. Grasp the motor housing with both hands and pull it straight up from the pump base (Fig. 5-5C). If necessary, CAREFULLY pry the motor housing up passed its O-ring using a flat blade screwdriver.

4. Check the motor stator (see Fig. 5-1) for any possible friction marks. Remove any marks, which indicate insufficient radial play, by slightly polishing them with Emery cloth (120 grain).

5. Check for any indication that the motor stator has become too hot (stator shows discoloration). Using an ohmmeter, check the stator's inter-phase resistance at pump connector terminals 6+7, 7+8, and 6+8 (Fig. 5-5D). The resistance measured between any two phases should be 0.62 ±0.05 ohm.

7. This completes the motor housing removal and motor stator check procedure.

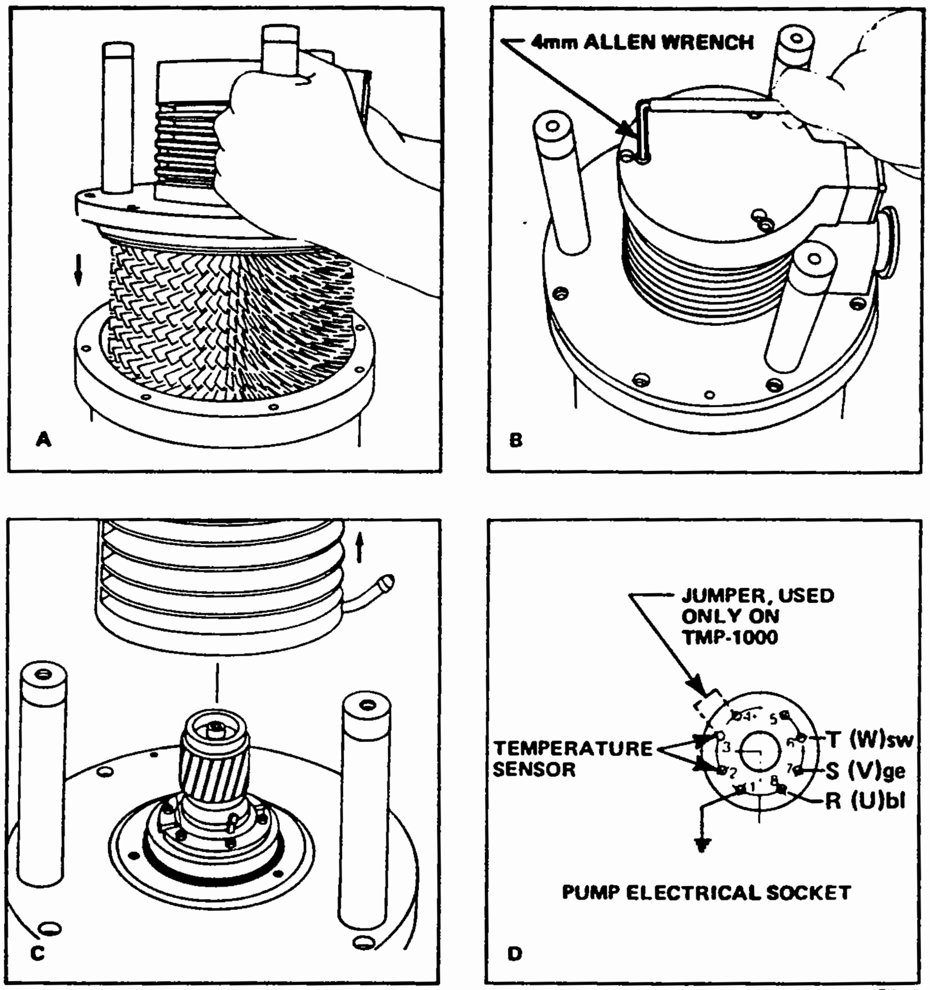


Figure 5-5. Motor Housing Removal

5.4.4 ROTOR/SPINDLE ASSEMBLY REPLACEMENT

The procedures contained in Sections 5.4.4.1 thru 5.4.4.4 describe how to replace a defective TMP-1000 rotor/spindle assembly.

The following instructions assume that the pump housing has been removed, the stator package has been disassembled, and the motor housing has been removed, as described in Sections 5.4.2 and 5.4.3.

5.4.4.1 Rotor/Spindle Assembly Spare Parts and Accessories

The following spare parts and accessories are supplied with each new rotor/spindle assembly (see Fig. 5-1).

Item	Part Number
Spindle Rest, 2 halves	221-02-262
Shims	221-02-258
Pump Housing O-Ring	239-50-735
Motor Housing O-Ring	239-50-179
High Vacuum Grease	--
Moisture Absorbent, 2 bags	--
Rotor Blade Clearance Gauge	--

When ready to unpack the new rotor/spindle assembly, carefully remove the assembly with its packing material from the cardboard shipping container. Save all shipping material if you intend on shipping the replaced rotor/spindle assembly back to Leybold-Heraeus for servicing.

To pack the replaced rotor/spindle assembly, reuse the original packing material and include one bag of moisture absorbent.

5.4.4.2 Rotor/Spindle Assembly Removal

The following instructions describe how to remove the rotor/spindle assembly from the pump base.

1. Using a 3-mm Allen wrench, remove the six spindle rest screws from the pump base (Fig. 5-6A).

2. Pull out the two halves of the spindle rest and remove any shims (Fig. 5-6A). Count and record the number of shims that were removed. The same number of shims will be used when the new rotor/spindle assembly is installed.

3. Unscrew and remove the three pump support legs from the pump base.

4. Grasp the pump base with both hands and lift the pump from its housing (Fig. 5-6B).

5. Turn the pump rightside up and place the motor rotor on the work pad. Then press down on the outer edges of the pump base until the rotor/spindle assembly pops free of the base (Fig. 5-6C).

6. Grasp the rotor/spindle assembly by its spindle and lift the assembly from the pump base (Fig. 5-6D). Then place the rotor/spindle assembly on the work pad with its motor rotor facing upwards.

7. Reinstall the three pump support legs on the pump base and set the base upright on its support legs.

8. This completes the rotor/spindle assembly removal procedure.

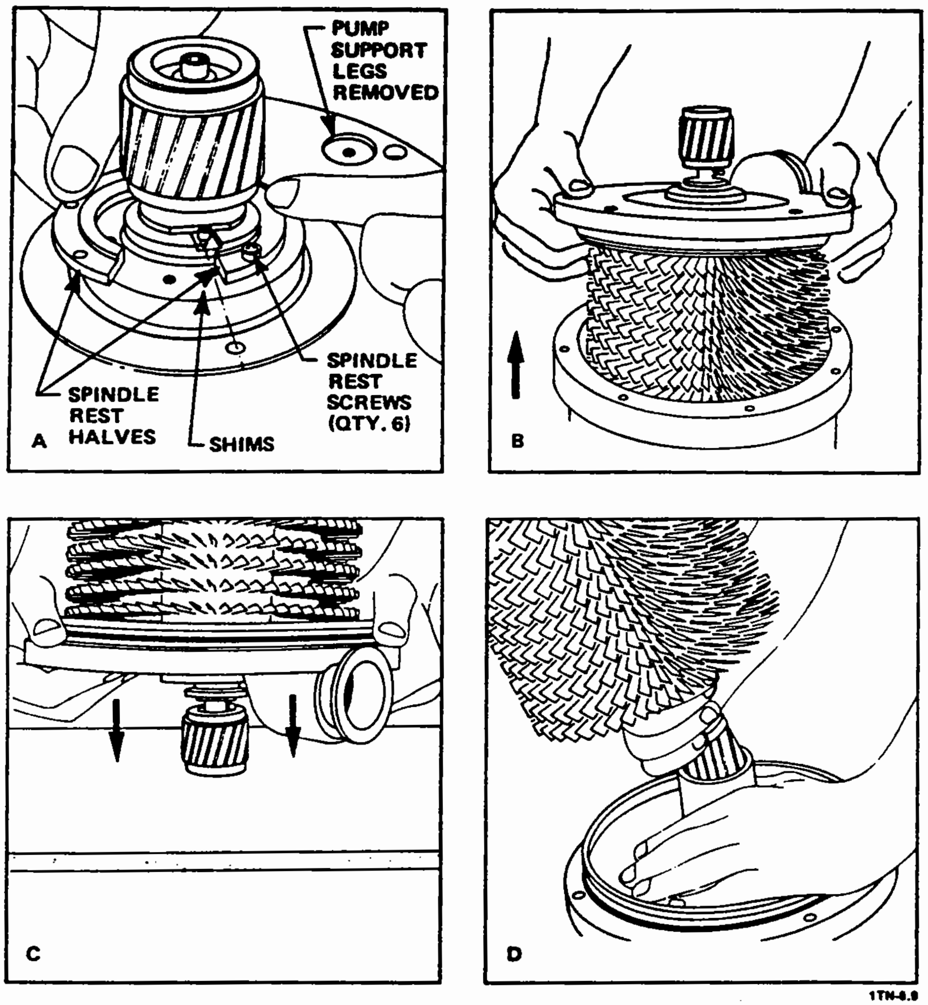


Figure 5-6. Rotor/Spindle Assembly Removal

LEYBOLD-HERAEUS

5.4.4.3 Rotor/Spindle Assembly Installation

The following procedure describes how to install a new rotor/spindle assembly.

Note that the new spindle rest halves, which are supplied with the rotor/spindle assembly, should be used in place of the old parts.

1. Remove all O-rings, and then clean all pump parts except the new rotor/spindle assembly with a suitable cleaning solvent (e.g., Trichlorethylene, Acetone, Freon).

2. Make a thorough visual inspection of the pump, and replace any defective parts at this time.

3. Unpack the new rotor/spindle assembly.

4. Apply a thin film of high-vacuum grease (supplied with the new rotor/spindle assembly) to the inside of the upper one third of the pump base pipe socket (Fig. 5-7A).

5. Grasp the new rotor/spindle assembly by its cooling jacket, and then CAREFULLY insert the motor rotor into the pump base pipe socket down to the tension wire which surrounds the cooling jacket (Fig. 5-7A). Then remove the tension wire.

6. Using your hand, slowly press down on the top rotor hub until the groove for the spindle rest becomes fully visible below the pump base.

7. Place the pump housing upside down on its intake flange, and then CAREFULLY insert the pump assembly into the pump housing (Fig. 5-7B).

8. Install the same number of shims which were removed in Section 5.4.4.2 step 2 over the motor rotor, and then insert the two spindle rest halves into the spindle groove (Fig. 5-7C). Make sure the pump base vent hole IS NOT covered. Note that if installed correctly, one of the spindle rest parting joints will be positioned opposite the pump exhaust port.

9. Using a 3-mm Allen socket torque wrench, replace the six spindle rest screws into the pump base and tighten to 1.8 ft-lb (1.5 Nm).

10. Remove the pump from its housing and place upright on its support legs.

11. This completes the rotor/spindle assembly installation procedure. Proceed to Section 5.4.4.4 to check the vertical alignment of the rotor blades.

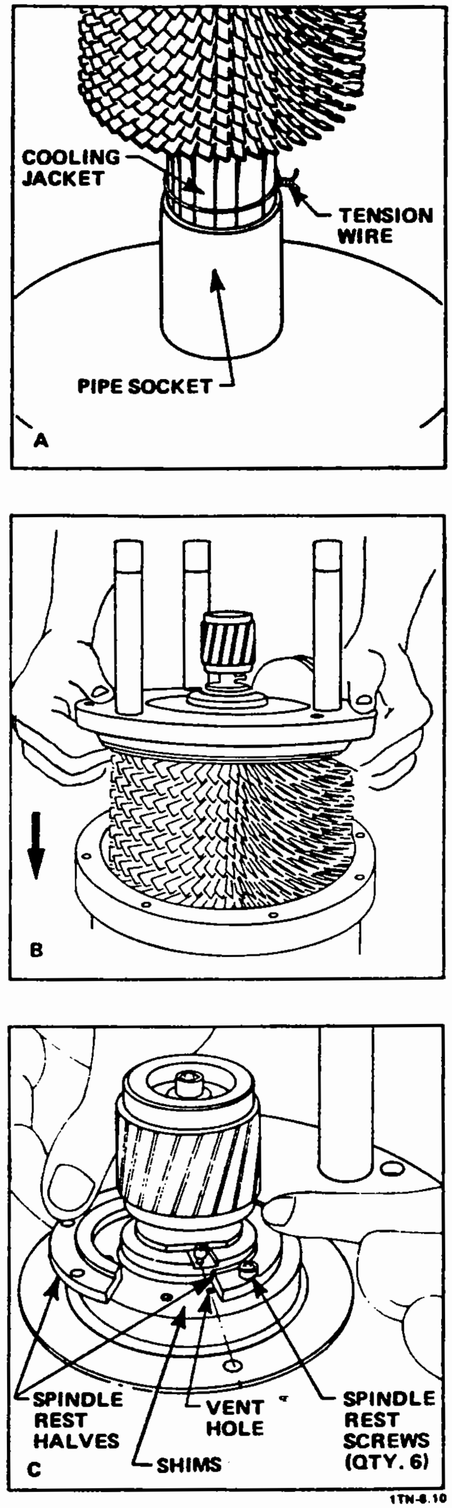


Figure 5-7. Rotor/Spindle Assembly Installation

5.4.4.4 Rotor/Spindle Assembly Alignment

This procedure checks the vertical alignment of the rotor/spindle assembly, using the rotor-blade clearance gauge supplied with each new assembly.

1. Set rotor-blade clearance gauge on the edge of the pump base, and align vertically by means of a try-square (Fig. 5-8A).

2. Using your hand, turn the rotor slowly and observe the rotor blades as they move through the teeth of the clearance gauge. The rotor blades MUST NOT touch the clearance gauge. If they do touch, proceed to step 3; otherwise, this completes the rotor/spindle assembly alignment procedure.

3. If several blade rows touch the clearance gauge, the rotor/spindle assembly must be raised or lowered by adding or removing shims (Fig. 5-7C). If, however, only single blades touch the gauge, they can be re-aligned using flat pliers. Grip the out-of-line rotor blade with flat pliers as shown in Fig. 5-8B, and bend as necessary [DO NOT bend the blade tip more than 0.04 in. (1 mm)]. Repeat steps 2 and 3 until all rotor blades move freely through the clearance gauge.

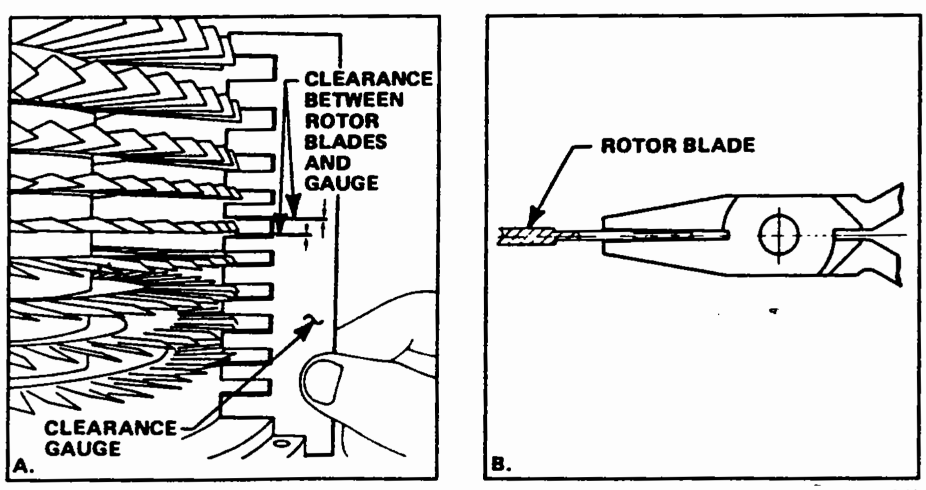


Figure 5-8. Rotor/Spindle Assembly Alignment

5.4.5 PUMP HOUSING AND STATOR PACKAGE REASSEMBLY

This procedure describes how to reassemble the stator package and replace the pump housing.

A new pump housing O-ring should be installed whenever the pump housing is removed for servicing purposes (Pump Housing O-ring Part No. 239-50-735). Note that a new O-ring is supplied with each new rotor/spindle assembly.

1. Apply a thin film of high-vacuum grease to a new pump housing O-ring and install the O-ring on the pump base (Fig. 5-9A). Ensure that the O-ring IS NOT twisted.

2. Remove the top two stator disk halves from the upside down stacked stator package, and then reinsert them below the last rotor blade row. Be very careful to ensure that the abutting joints of the stator disk halves DO NOT overlap.

3. Remove the top stator ring from the upside down compiled stator package and install it over the rotor. Make sure that the gap between all the stator rings are uniform over their entire outer circumference.

4. Alternately place stator rings and stator disks one above the other by repeating steps 2 and 3, until the entire stator package is reassembled onto the turbopump (Fig. 5-9A).

NOTE: It is normal that after the stator package has been installed, some blade contact and pinging may be noticeable when the rotor is slowly turned. This is because the spacer rings are not yet sufficiently compressed downward to form the intended clearances between the stator and rotor blades. No pinging should be heard, however, after the pump housing has been installed and tightened down.

CAUTION

To prevent the stator package from becoming dislocated, DO NOT invert or turn the turbopump on its side before the pump housing is replaced and its screws are replaced and tightened.

5. Slowly lower the pump housing directly over the stator package, being careful not to bump the stator rings which may knock them out of place. Then set the pump housing on the pump base such that the lateral venting port is positioned directly above the exhaust port. Also ensure that the housing's eight screw holes are aligned with the screw holes in the pump base. This hole alignment is essential since the pump base O-ring prohibits the alignment of these holes by rotating the pump housing once the housing has been seated.

6. Replace and hand tighten the eight pump housing screws with the turbopump setting on its three support legs.

7. Using a 5-mm Allen socket torque wrench, uniformly cross tighten the pump housing screws to 6.6 ft-lb (9 Nm) (Fig. 5-9B). While tightening these screws, make sure that the top of the pump housing joins properly with the top stator ring. There must not be a gap around the circumference of this joint, and the joint surfaces must be flush (Fig. 5-9C).

8. Using a feeler gauge, check the uniformity of the annular gap between the pump base and pump housing. There must be a gap, and this gap should not vary by more than 0.02 in. (0.5 mm) (Fig. 5-9D). If the gap variations are greater than specified, perform step 9; otherwise, proceed to step 10.

9. Loosen the pump housing screws and retighten them again uniformly; then repeat step 8. If still unsuccessful, remove the pump housing and check whether any stator rings have

slipped off from their position or whether any stator disk halves are overlapped; then repeat steps 6, 7, and 8.

10. After installation of the pump housing, check for smooth running of the rotor/spindle assembly by slightly pushing at the rotor hub. There should be no pinging noises and no perceptible resistance in the motor bearings.

11. This completes the stator package and pump housing reassembly procedure.

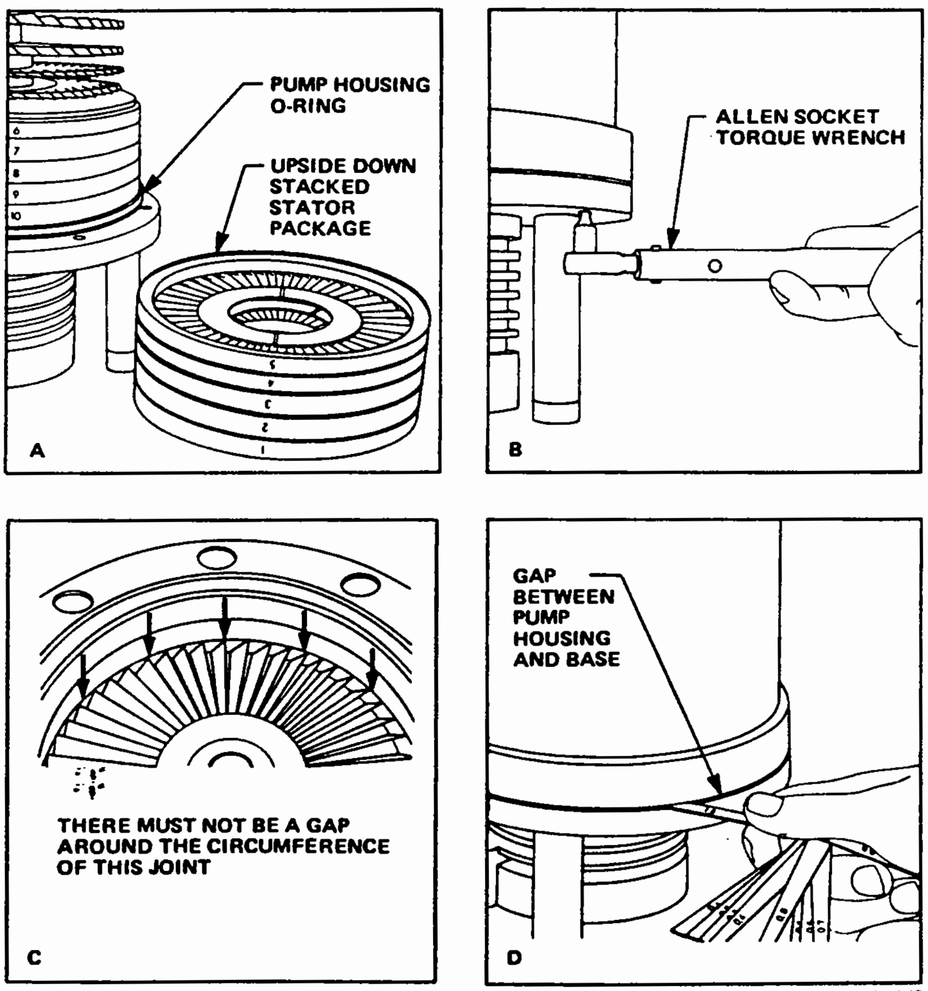


Figure 5-9. Stator Package and Pump Housing Reassembly

5.4.6 MOTOR HOUSING REMOUNTING

This procedure describes how to remount the motor housing.

A new motor housing O-ring should be installed whenever the motor housing is removed for servicing purposes (Motor Housing O-ring Part No. 239-50-179). Note that a new O-ring is supplied with each new rotor/spindle assembly.

1. Place the pump upside down on its intake flange.

2. Apply a thin film of high-vacuum grease to a new motor housing O-ring and install the O-ring on the pump base (Fig. 5-10A). Ensure that the O-ring IS NOT twisted.

3. Set the motor housing on the pump base such that the electrical connector is directly above the exhaust port (Fig. 5-10B).

4. Replace and hand tighten the three motor housing screws.

5. Using a 4-mm Allen socket torque wrench, uniformly tighten the motor housing screws to 4 ft-lb (5.5 Nm) (Fig. 5-10B).

6. This completes the motor housing remounting procedure.

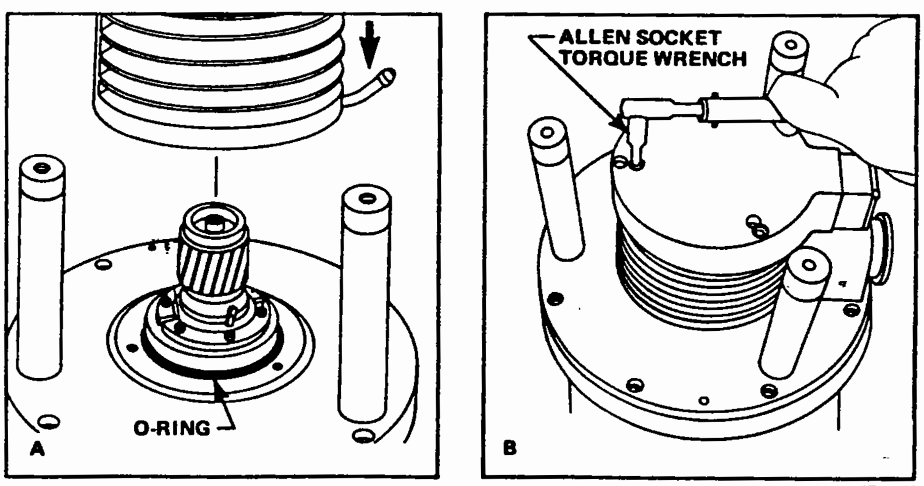


Figure 5-10. Motor Housing Remounting

5.4.7 TURBOPUMP RUNNING TESTS

After reassembling the turbopump, the following Run-Up Test, Leak Test, and Venting Test procedures should be performed.

5.4.7.1 Run-Up Test

1. Install blank flanges on both the high-vacuum intake port and lateral venting port.

2. Connect a suitable backing pump to the exhaust port.

3. Connect the turbopump to its frequency converter and start the turbopump.

4. Observe that within 5 minutes, the converter should change from ACCELERATION to NORMAL OPERATION. A longer run-up time indicates improper assembly or a leak.

5. This completes the run-up test.

5.4.7.2 Leak Test

1. Install blank flanges on both the high-vacuum intake port and lateral venting port.

2. Connect the turbopump to an ULTRATEST Leak Detector.

NOTE: If an ULTRATEST Leak Detector is not available, the working pressure of the turbopump can be measured as an indication of any leaks. A blanked off turbopump should attain a working pressure of $<1 \times 10^{-6}$ mbar.

3. Start the leak detector and turbopump.

4. Leak check the turbopump; the leak rate should be $<1 \times 10^{-6}$ mbar ltr/sec.

5. This completes the Leak Test.

5.4.7.3 Venting Test

1. Switch off the turbopump.

2. Vent the turbopump by removing the blank flange from its lateral venting port. While detaching the blank flange, listen for any pinging noises. If no pinging noises are heard, this completes the venting test; otherwise, proceed to step 3.

3. If pinging noises are heard, you will need to disassemble/ reassemble the turbopump as described in section 5.4. Check for proper assembly of the stator rings and stator disks, and also check the vertical alignment of the rotor/stator assembly.

4. After reassembling the turbopump, repeat all of the turbopump running test procedures under Section 5.4.7.

5.5 NT-1000/1500 ADJUSTMENTS

WARNING

This equipment employs voltages which are dangerous and may be fatal if contacted. Extreme caution should be exercised when working with the equipment with any of its protective covers removed. To reduce the possibility of electrical shock, always connect the chassis of the unit to a low impedance ground.

This section contains information of how to adjust the following five controls located inside the NT-1000/1500 Frequency Converter (Fig. 5-11):

- o R52 Minimum Pump Speed
- o R64 Pump Cable Length Compensation
- o R74 VCO Frequency
- o R92 NT-1500 VCO Frequency Trimmer
- o R94 Frequency Meter Calibration

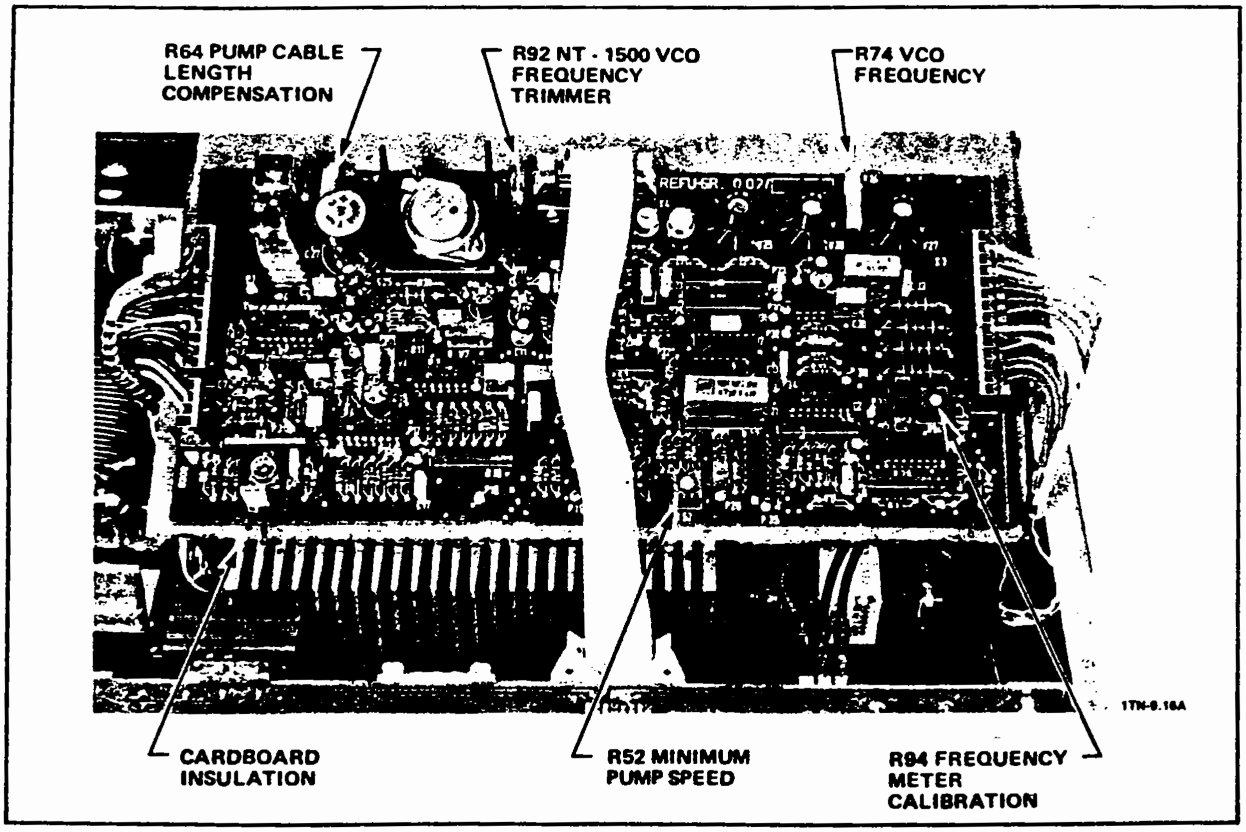


Figure 5-11. NT-1000/1500 Internal Controls

LEYBOLD-HERAEUS

5.5.1 R52 - MINIMUM PUMP SPEED ADJUSTMENT

Minimum Pump Speed control R52 is adjusted to limit the slowest pump speed to 50% of the turbopump's rated rotational speed, as set by the optional external pump speed control. Adjust this control as follows:

> NOTE: If the optional external pump speed control is not used, you do not need to adjust R52. The turbopump will automatically operate at its rated rotational speed when started.

1. Install the optional external pump speed control at the rear of the frequency converter as described in Section 3.2.4.5.

2. Turn external pump speed control to its full clockwise (CW) position.

3. Start the pumping system and allow the turbopump to reach its rated rotational speed. The front panel FREQUENCY meter should indicate 100% before proceeding.

4. Turn external pump speed control to its full counterclockwise (CCW) position, and observe that the FREQUENCY meter should fall very slowly to an indication of 50%. If not, perform steps 5; otherwise, proceed to step 6.

5. With the external pump speed control set to minimum, adjust potentiometer R52 (Fig. 5-11) for a FREQUENCY meter indication of 50%.

6. This completes the minimum pump speed adjustment procedure.

5.5.2 R64 - PUMP CABLE LENGTH COMPENSATION ADJUSTMENT

Pump Cable Length Compensation control R64 compensates for the voltage drop in the pump cable (voltage at the turbopump will be less than the converter's output voltage).

If this control is misadjusted, the voltage/frequency ratio for startup at the turbopump will be incorrect. A good indication that this control needs readjustment is when the FAILURE indicator turns on shortly after the turbopump is started.

To adjust potentiometer R64, proceed as follows:

1. Disconnect the turbopump from the vacuum system.

2. Connect the turbopump to its frequency converter. A backing pump and water cooling connections are not needed.

3. Using your hand, prevent the turbopump from rotating by blocking its rotor through the high vacuum inlet port; then, press the converter's START pushbutton. In a few seconds after start-up, you should feel the motor torque increasing as the drive frequency decreases.

4. With the rotor blocked, turn potentiometer R64 (Fig. 5-11) counterclockwise (CCW) until the FAILURE indicator turns on; then, turn R64 clockwise (CW) until the FAILURE indicator just turns off.

5. Observe that the FREQUENCY meter should indicate approximately 5% (corresponds to a start-up frequency of between 15 to 20 Hz for the TMP-1000).

6. Press STOP.

7. This completes the pump cable length compensation adjustment procedure.

5.5.3 R74 - VCO FREQUENCY ADJUSTMENT and R92 - NT-1500 VCO FREQUENCY TRIMMER ADJUSTMENT

The VCO Frequency control, R74, and the NT-1500 VCO Frequency Trimmer control, R92, are adjusted to produce maximum converter output frequencies of 605 Hz for the TMP-1000 and 355 Hz for the TMP-1500. To adjust these controls, proceed as follows:

1. Connect a frequency counter to the rear of the converter at terminals X1-7 and -8 as described in Section 3.2.4.4.

2. Disconnect the turbopump from the converter and connect a jumper to converter output connector terminals X0-4b and -5b, located at the converter's rear panel (this jumper simulates the connection of a TMP-1000). Also connect a jumper to terminals X0-5a and -5b (this jumper closes the overtemperature circuit).

3. With power applied to the converter and with the pump stopped, the frequency counter should indicate 605 ±10 Hz. Remove the jumper connected at terminals X0-4b and -5b (leave X0-5a and -5b connected) and observe that the frequency counter should now indicate 355 ±5 Hz. If either frequency indication was out of tolerance, perform steps 4 and 5; otherwise, proceed to step 6.

4. Reconnect the jumper to terminals X0-4b and -5b, then adjust potentiometer R74 (Fig. 5-11) for a frequency counter indication of 605 Hz.

5. Remove the jumper connected in step 4 and adjust potentiometer R92 (Fig. 5-11) for a frequency counter indication of 355 Hz.

6. This completes the VCO frequency and NT-1500 VCO frequency trimmer adjustment procedure.

5.5.4 R94 - FREQUENCY METER CALIBRATION

Frequency Meter Calibration control R94 is adjusted to make the FREQUENCY meter indicate 100% when the turbopump is running at its rated rotational speed. To adjust this control, proceed as follows:

1. Connect a frequency counter to the rear of the converter at terminals X1-7 and -8 as described in Section 3.2.4.4.

2. Start the pumping system and allow the turbopump to reach its rated rotational speed. Observe that the frequency counter should indicate 605 ±10 Hz for the TMP-1000 (355 ±5 Hz for the TMP-1500).

3. The front panel FREQUENCY meter should now be indicating 100%. If not, perform step 4; otherwise, proceed to step 5.

4. With the turbopump operating at its rated rotational speed, adjust potentiometer R94 (Fig. 5-11) for a FREQUENCY meter indication of 100%.

5. This completes the frequency meter calibration procedure.

LEYBOLD-HERAEUS

NOTES

SECTION 6
DETAILED DESCRIPTION

6.1 TMP-1000 OPERATING PRINCIPLE

The TURBOVAC TMP-1000 is a turbomolecular pump designed to operate in the region of molecular flow. The operating principle of such a pump is as follows:

Gas molecules enter the pump's high vacuum inlet by virtue of their thermal motions (Fig. 6-1). Some gas molecules are then struck by the blades of the first rotor stage and tend to rebound in the desired pumping direction (i.e., toward the first stage of stator vanes). Note that the tip velocity of the rotor blades is of the same order of magnitude as the mean thermal velocity of the gas molecules. The molecules then rebound off the vanes of the first stator stage in such a direction as to increase the probability of their being favorably impelled by the blades of the second rotor stage. This process is repeated through all rotor/stator stages. The series of impacts statistically favors motion toward the exhaust port where the gas molecules are pumped and exhausted to atmosphere by a backing pump.

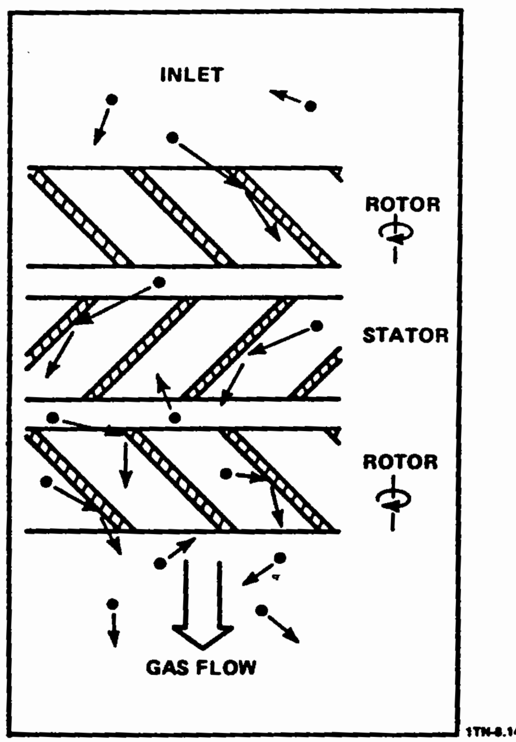


Figure 6-1. Side View of Three Rotor/Stator Stages

The ultimate pressure of turbomolecular pumps is influenced by the partial pressures of the different gases at the pump's exhaust port, and by the pump's compression ratio for the individual gas components. In the ultra-high vacuum range at pressures of $<10^{-9}$ mbar, the ultimate total pressure is mainly determined by the amount of hydrogen present. Note that the TMP-1000 is specified to have a compression ratio for hydrogen of 2 X 10^3. Therefore, in order for the TMP-1000 to attain its specified ultimate pressure of <10^{-10} mbar, it is necessary to use a backing pump which is capable of maintaining a very low hydrogen partial pressure at the turbomolecular pump's exhaust port. A two-stage rotary vane pump is recommended for this purpose.

6.2 TMP-1000 CONSTRUCTION

Figure 6-2 shows the TMP-1000 as a single axial flow turbomolecular pump of vertical design.

The high vacuum intake port (1) is secured directly to the vacuum chamber by any one of five different flanges (LF150, CF150, CF200, LF250, and 6-inch ASA). The type of intake flange supplied is identified by the pump's catalog number (refer to Ordering Information at the front of this manual).

The gas to be pumped enters the intake port and passes through a wire-mesh splinter guard (2), which protects the pump from mechanical damage by small foreign objects down to approximately 1.5 mm in size.

Gas molecules then encounter the pump's rotor (4) and stator (3) assembly. The rotor and stator have turbine blades around their circumference with each rotor/stator pair forming a pumping stage, so that the whole assembly is composed of a multitude of pumping stages mounted in series. The first four rotor/stator pairs form the pump's vacuum stages. These stages are characterized by blades of large radial span with large blade angles. This design configuration provides a large annular inlet area and ensures maximum particle capture for pumping. The gas captured by the upper vacuum stages is then transferred to the lower compression stages where the gas is compressed to fore-vacuum pressure. These

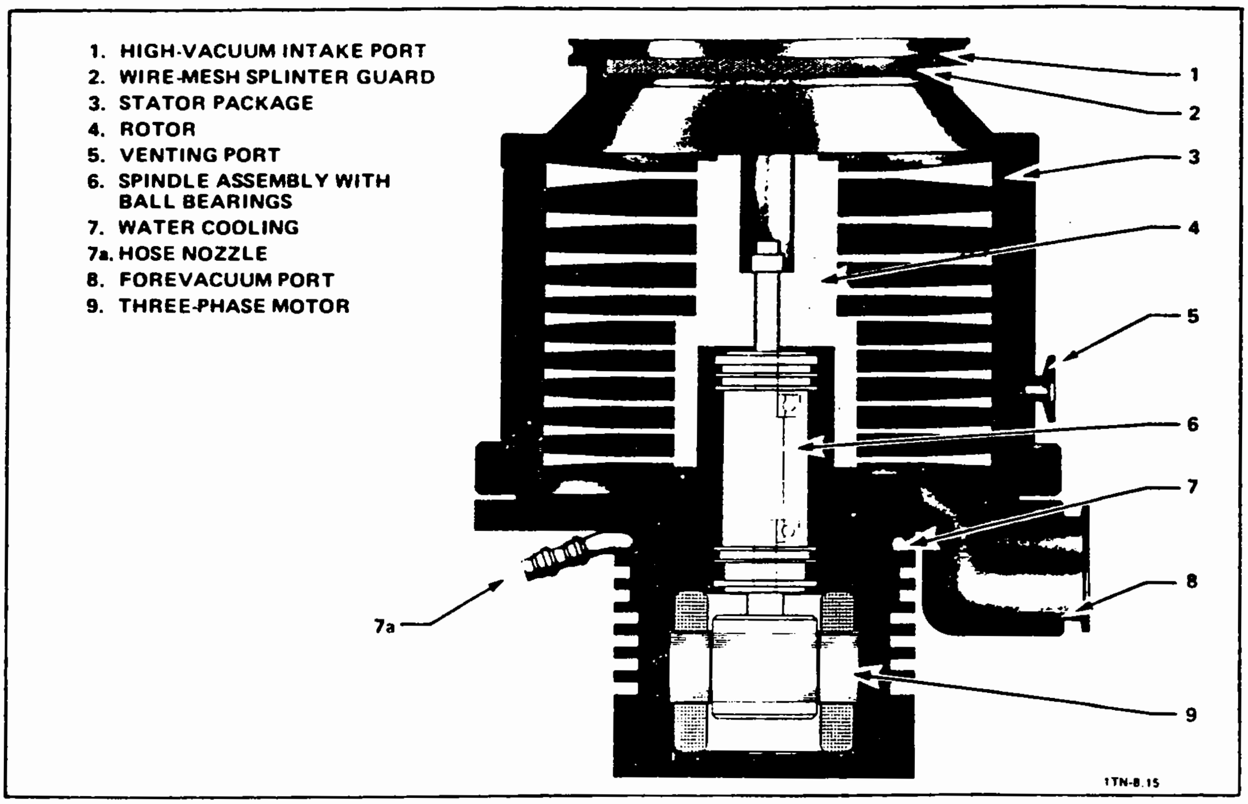


Figure 6-2. TMP-1000 Cutaway View

compression stages are characterized by blades of short radial span with narrow blade angles, thus maximizing both average blade speed and compression.

The rotor is directly driven by a three-phase, squirrel-cage induction motor (9). The motor and its spindle assembly with ball bearings (6) are mounted in the fore-vacuum space, thus keeping the high-vacuum space free of any grease contaminants.

The rotor shaft in the spindle assembly (6) is supported by two precision ball bearings lubricated with a special grease. Note that the bearings are lifetime lubricated, within the sealed spindle assembly, with a mean time between failure (MTBF) of approximately 20,000 hours. This unique lubricating system allows the pump to be mounted in any desired angular position.

The motor is normally water cooled (7 & 7a); however, an air cooling option is also available.

A bi-metal thermal switch mounted in the motor housing prevents the motor from overheating. This switch will open and cause the NT-1000/1500 Frequency Converter to turn off the pump if the motor temperature exceeds its safe operating limit of 133°F (56°C). Note that the pump cannot be restarted until the thermal switch closes.

A lateral venting port (5) provides the means of venting the pump to atmospheric pressure.

Gas exits the pump via the exhaust port (8) which is supplied with a type KF40 fitting.

6.3 TMP-1000C (CORROSIVE) CONSTRUCTION

The TMP-1000C is a corrosive series type pump capable of pumping corrosive or abrasive reaction products. The construction of the TMP-1000C is similar to a standard TMP-1000 with the exception that a special gas purge inlet port is added. This inlet port is supplied with a type KF10 fitting. The gas purge inlet port allows the turbobpump's motor chamber to be flooded with inert gas (e.g., nitrogen, argon), thus protecting the non-corrosion-resistant constituents of lubricant and ball bearings from corrosive attack by reactive gases. This protective gas seal also prevents metallic dust, when contributed by a process, from penetrating into the lubricated drive section and hence from intermixing with the lubricant.

The protective gas seal in a TMP-1000C is illustrated in Fig. 6-3. Since the motor chamber in TURBOVAC pumps forms an enclosed space joined with the fore-vacuum space by only a narrow gap above the upper ball bearing, the pressure generated by inert gas flooding in the motor chamber is higher than that in the fore-vacuum space. The resulting permanent gas stream flowing in the direction of the fore-vacuum space safely prevents reactive or abrasive media from

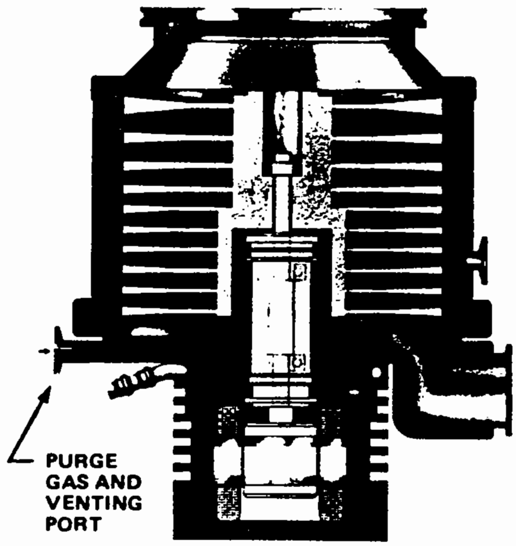


Figure 6-3. TMP-1000C Sectional View showing Inert Gas Seal

penetrating into the motor chamber, so that even standard lubricants, such as mineral oils and greases, can be used without risk.

Venting the TMP-1000C is accomplished by a specially designed metering/venting valve attached to the purge gas inlet port. This valve automatically allows a greater volume of purge gas to enter the pump upon shutdown. Venting via the purge gas inlet offers the advantage that during venting, no residual abrasive or corrosive media can be sucked from the fore-vacuum space into the motor chamber.

6.4 NT-1000/1500 FUNCTIONAL DESCRIPTION

The TURBOTRONIC NT-1000/1500 Frequency Converter provides for the conversion of single-phase, 110-240 V AC, 50/60 Hz power into three-phase, variable voltage, variable frequency power as required by the TMP-1000 and TMP-1500 Turbomolecular Pumps. This power conversion is necessary for the induction motors which provide the drive power for these pumps.

Induction motors require that the motor drive frequency be closely related to the rotational frequency. At normal operating speed, the TMP-1000 pump motor requires a drive frequency of 605 Hz while the TMP-1500 requires a drive frequency of 355 Hz. A major function of the frequency converter is to provide the high frequency power necessary to drive the pump at its rated speed.

In order to achieve minimum pump acceleration time, it is desirable to operate the pump motor at its maximum torque. Torque is a function of the difference between the drive frequency and the actual motor rotational frequency, called the "slip" frequency. Up to a point induction motor torque increases as the slip frequency increases. As the slip frequency continues to increase, however, the torque ceases to increase and for a "low slip", high efficiency motor, the torque actually begins to decrease.

Consequently, a second function of the frequency converter is to start the pump from rest with a low drive frequency, and then slowly increase the frequency so that the pump motor is always operating at maximum torque during acceleration.

Induction motors also require that the drive voltage be proportional to, and closely related to the drive frequency. A drive voltage which is too high or too low with respect to the drive frequency will result in reduced torque and increased motor heating.

Therefore, a third function of the frequency converter is to maintain the proper relationship between drive voltage and drive frequency.

The torque required to accelerate the pump is generally more than that required to maintain normal operating speed. Therefore, in order to reduce heating in both the pump motor and in the frequency converter package, the converter automatically lowers the maximum current allowed to flow through the pump motor once normal operating speed has been achieved.

To aid in the understanding of the frequency converter's operating principles, a typical start up profile of a turbomolecular pump is shown in Fig. 6-4. This figure illustrates the relationship between rotational speed, drive frequency, motor current, and drive voltage of a turbomolecular pump as it accelerates from rest.

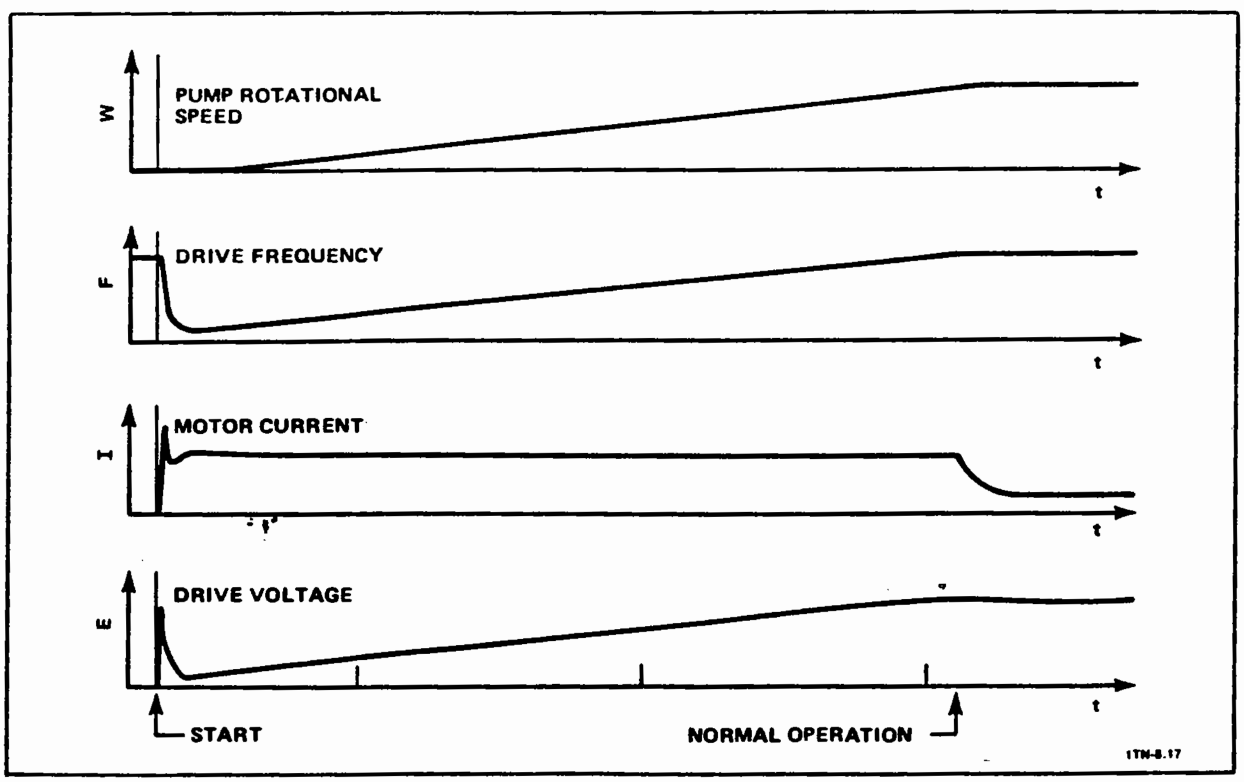


Figure 6-4. Typical Turbomolecular Pump Start Up Voltage/Current/Frequency Relationships

6.5 NT-1000/1500 BLOCK DIAGRAM

A block diagram of the NT-1000/1500 Frequency Converter in shown in Fig. 6-5. A more detailed schematic of the converter is included in Section 8, see Fig. 8-5.

The NT-1000/1500 Frequency Converter uses the variable frequency, variable voltage technique to control the motor speed of a turbomolecular pump. This technique is based on the principle that the speed of an induction motor is determined by the synchronous speed and slip of the rotor. The synchronous speed is related to the motor's drive frequency while slip is proportional to the load or torque demand on the motor.

To convert the 110-240 V AC, 50/60 Hz power line into a variable frequency, variable voltage controlled three-phase power source, the NT-1000/1500 Frequency Converter uses the DC Link method. This method basically converts AC into a variable DC voltage, and then inverts this DC voltage between the converter's three output lines in a sequence which synthesizes an AC output signal. This type of converter is called a DC Link converter because of the DC link between the input and output of the power inverter.

The turbopump is started by pressing the converter's START button. At this time an inhibit signal is removed from the SCR triggering control circuit which allows the SCR controlled bridge rectifier to begin converting AC to DC.

The resultant DC voltage level (hereafter called the DC link voltage) is varied by controlling the ratio of each SCR's "on-time" to its "off-time" during each rectified AC half cycle. The SCRs are turned on by the application of a positive trigger pulse to their gate inputs from the SCR triggering control circuit. The timing of these trigger pulses is controlled by a DC control voltage produced by the voltage and current limiter circuit, and are synchronized with the AC line.

The DC link voltage is then applied to a six-step inverter which switches the DC link voltage onto the three output lines in a sequence and at a frequency which synthesizes a three-phase AC output. Thus the amplitude of the AC output can be changed by varying the DC link voltage, and the frequency of the AC output can be changed by varying the switching frequency.

The switching frequency is made proportional to the DC link voltage by having the DC link voltage (E_{link}) control the frequency of a VCO (voltage controlled oscillator). The output of the VCO is then used to trigger the converter's three-phase logic circuit which provides properly-timed, turn-on pulses to the six-step inverter. Drive frequency is indicated as a percentage of its maximum value (100% corresponds to maximum pump speed) by the front panel FREQUENCY meter.

The DC link voltage is regulated so as to keep the converter in either current or voltage limiting. At start up the converter immediately goes into current limiting due to the motor's low rotor impedance, thus causing the converter to apply a very low drive voltage to the motor. As the motor accelerates, however, its back emf causes the converter to increase drive voltage by an amount necessary to keep itself in acceleration current limiting. Once the DC link voltage reaches a preset maximum level (corresponds to maximum pump speed), the converter then goes into voltage limiting and allows the motor current to decrease and seek its normal operating level (dependent upon pump loading).

Speed adjustment of the pump motor, between 50 and 100% of its rated rotational value, can be accomplished by varying the voltage level at which the voltage limiter circuit goes into voltage limiting. An external speed control is connected to the rear of the converter for this purpose.

During acceleration the status and control circuit lights the ACCELERATION indicator. Also during acceleration, an acceleration timer allows the pump motor to operate at a current level that is 30% higher than is normally permissible for a period of approximately 15 minutes. This increased current level shortens the pump's acceleration time. As soon as the pump reaches the desired rotational speed during the acceleration time period, the status and control circuit will turn off the ACCELERATION indicator, light the NORMAL OPERATION indicator, and reduce the current limit level.

The acceleration timer gives the TMP-1000 15 minutes to accelerate to at least its minimum rotational speed of 12,000 r.p.m. If the turbopump is not above its minimum speed at the end of the acceleration time period, the failure detector will stop the pump and light the FAILURE indicator. However, if the pump is above its minimum speed when the acceleration time period expires, the status and control circuit will light the NORMAL OPERATION indicator and allow the pump to continue to operate at a reduced current limit level.

In the event of a pump overload (i.e., heavy process gas load) the pump motor current level will increase due to the higher torque demand of the pump. However, if the increasing current level causes the converter to go back into current limiting, the DC link voltage and drive frequency are then reduced. If the DC link voltage drops to a level that causes the pump motor to slow down to approximately one-third of the pump's rated rotational speed, the failure detector will then stop the pump and light the FAILURE indicator.

The pump select circuit determines whether a TMP-1000 or TMP-1500 turbopump is connected to the converter, and then automatically changes the circuits of the VCO and current limiter to correspond to the requirements of the pump in use. Note that the TMP-1000 requires an output frequency of 605 Hz with an overload current limitation of 6 amperes, while the TMP-1500 requires a frequency of 355 Hz with a current limitation of 8 amperes.

If a short circuit occurs at the output of the converter, the short circuit protection circuit reacts immediately by disabling the three-phase logic circuit, in turn, protecting the transistors in the six-step inverter. Note that this protection circuit acts independently of the current limiter circuit.

The pump motor is overtemperature protected by a bi-metal thermal switch contained in the motor housing. This normally closed switch will open if the motor temperature exceeds its safe operating limit [133°F (56°C) for the TMP-1000, 149°F (65°C) for the TMP-1500], in turn, causing the failure detector to stop the pump and light the FAILURE indicator.

Pressing the STOP button turns off the converter by sending an inhibit signal to the SCR triggering control circuit which, in turn, removes the DC link voltage by turning off the SCR controlled bridge rectifier. Note that pressing the STOP button also clears the failure detector circuit and turns off the FAILURE indicator.

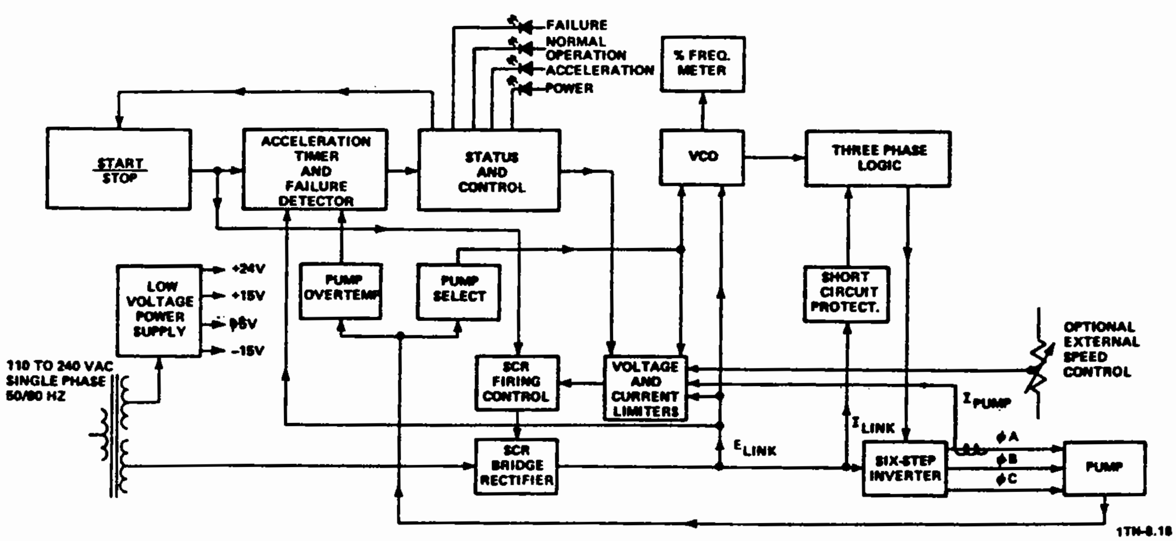


Figure 6-5. NT-1000/1500 Block Diagram

6.6 NT-1000/1500 CIRCUIT DESCRIPTION

The NT-1000/1500 Frequency Converter schematic is shown in Fig. 8-5 of Section 8. In order to ease the job of understanding and fault isolating, the schematic divides the converter electronics into the following fourteen functional blocks:

1. Low Voltage Power Supply
2. Start/Stop Control
3. Acceleration Timer
4. Status and Control
5. DC Link Power Supply
6. SCR Triggering Control
7. Six-Step Inverter
8. Three-Phase Logic
9. Voltage Controlled Oscillator (VCO)
10. Short Circuit Protection
11. Failure Detector
12. Failure Detector Latch
13. Voltage and Current Limiters
14. Pump Select/Overtemperature

6.6.1 LOW VOLTAGE POWER SUPPLY
(See Fig. 8-5)

The low voltage power supply provides an unregulated voltage of +24 and regulated voltages of +15, +5, and -15. Also two AC reference signals are supplied to the zero crossing reference input of SCR triggering control IC D4.

The center-tapped secondary of transformer T1 supplies 18 V AC (referenced to ground), which is then rectified by diode bridge V20, regulated by Zener diode V21 and three-terminal regulators N4 and N5, and filtered by capacitors C25, C26, C27, C31, and C34.

6.6.2 START/STOP CONTROL
(See Fig. 8-5)

NAND gates D1A and D1B are cross connected to form a set-reset flip-flop which performs the converter's start/stop function.

When power is first applied, components R6.4 and C7 ensure that the flip-flop comes up in its reset state (P4 low, P8 high), causing the pump to be turned off. The converter is then prepared to be started as follows:

1) The flip-flop's low set output (P4) performs the following:

   - Inhibits the operation of SCR triggering control IC D4.
   - Turns off FET V29 which disables the front panel FREQUENCY meter.
   - Disables fault detector circuit IC N3D.

2) The flip-flop's high reset output (P8) performs the following:

   - Applies a positive voltage to the non-inverting input of IC N1A in the VCO control circuit, causing the VCO to be at its maximum frequency when the START button is pressed. This allows the converter to restart a pump which is already spinning, thus preventing the inverter transistors from being short circuited and possibly destroyed.
   - Resets acceleration timer D2, causing its output (P37) to go low.
   - Applies a positive voltage to the non-inverting input of IC N3B in the current limiter circuit, causing the converter to be in current limiting when the START button is pressed.
   - Disables motor-speed sense IC N3C of the acceleration timer circuit, causing the output of N3C (P36) to be low when the pump is started.

Pressing the START button starts the converter by applying a low to NAND gate D1A pin 1, which causes the flip-flop to set (P4 high, P8 low). The high and low outputs of the flip-flop then start the converter as follows:

1) The flip-flop's high set output (P4) performs the following:

   - o Enables SCR triggering control IC D4, allowing it to start triggering the SCRs in the DC link power supply.
   - o Turns on the front panel FREQUENCY meter.
   - o Enables fault detector circuit IC N3D, allowing it to turn off the converter in the event of a failure.
   - o Lights the front panel ACCELERATION indicator.

2) The flip-flop's low reset output (P8) performs the following:

   - o Allows acceleration timer D2 to start timing.
   - o Enables motor-speed sense IC N3C, allowing its output (P36) to go high when the pump motor reaches its maximum rotational speed.

Pressing the STOP button stops the converter by causing NAND gate D1C to reset the flip-flop (P4 low, P8 high) by applying a low to NAND gate D1B pin 6. The outputs of the flip-flop then stop the converter and prepare it to be restarted as previously described.

In the event of a failure, the failure detector circuit turns off the converter by applying a low signal to NAND gate D1B pin 6 from inverter V6A of the status and control circuit. The failure detector is then latched in its failure state by the conduction of transistor V5. The failure detector is reset by pressing the STOP button, which causes the output of NAND gate D1C to go low and remove the emitter voltage from transistor V5.

6.6.3 ACCELERATION TIMER

(See Fig. 8-5)

During acceleration, acceleration timer D2 allows the pump motor to operate at a current level that is 30% higher than is normally permissible for a period of up to 15 minutes. This is accomplished by short-circuiting resistor R27 of the current limiter circuit, thereby increasing the current limiting reference voltage applied to the inverting input of IC N3B. Resistor R27 is short-circuited by analog switch D3A, which is turned on by the application of a positive voltage to its control input from inverter V6E of the status and control circuit.

The acceleration timer also prevents the fault detector circuit from faulting during start up, when the DC link voltage is low, by allowing a negative voltage to be applied through resistor R18 to the inverting input of fault detector circuit IC N3D.

When the START button is pressed, a low is applied to acceleration timer reset input D2 pin 2, causing the timer to start timing. The acceleration timer's output (Test Point P37) is low during this time period, allowing the high output of inverter V6E to turn on analog switch D3A which short-circuits resistor R27. Also at this time, fault detector circuit IC N3D disregards the low DC link voltage applied to its inverting input through resistor R11.5, due to the negative voltage applied through resistor R18.

At the end of the 15 minute acceleration time period, the acceleration timer's output (P37) goes high, making the output of inverter V6B go low and perform the following: 1) lights the NORMAL OPERATION indicator; 2) energizes normal operation relay K1; 3) turns off ACCELERATION indicator by causing the output of inverter V6C to go high; 4) lowers pump motor current limit level by opening analog switch D3A of the current limiter circuit.

LEYBOLD-HERAEUS

The high output of the acceleration timer also cancels the negative voltage applied through resistor R18 to the fault detector circuit, thereby allowing the fault detector to turn off the converter if the DC link voltage drops to a level that slows the pump down to approximately one-third of its rated rotational speed.

If the pump motor reaches its maximum rotational speed before the end of the 15 minute acceleration time period, motor-speed sense circuit IC N3C allows a high to be applied to acceleration timer D2 pin 1, causing its output (P37) to go high and initiate a normal operation state. Note that IC N3C monitors the output of the current limiter circuit (P7), which goes negative shortly after the converter goes into voltage limiting.

6.6.4 STATUS AND CONTROL
(See Fig. 8-5)

Status of the frequency converter is displayed by a series of LEDs (POWER, ACCELERATION, NORMAL OPERATION, FAILURE) which are turned on and off by the status and control circuit. This circuit also generates signals which control the operation of the converter.

The POWER indicator is turned on by the +24 volt output of the low-voltage power supply whenever the converter is plugged into an AC outlet.

The ACCELERATION indicator lights as soon as the output of inverter V6C goes low when the START button is pressed.

Normal operation begins whenever the output of acceleration timer IC D2 (Test Point P37) goes high which, in turn, makes the output of inverter V6B go low and perform the following: 1) lights the NORMAL OPERATION indicator; 2) energizes normal operation relay

K1; 3) turns off ACCELERATION indicator by causing the output of inverter V6C to go high; 4) lowers pump motor current limit level to 6 amperes for the TMP-1000 (8 amperes for the TMP-1500) by opening analog switch D3A of the current limiter circuit.

When normal operation relay K1 is energized, it starts the optional external hours meter connected to rear panel terminals X1-12 and -13. This relay also has a set of N.O. and N.C. contacts available at rear panel terminals X1-4, -5, -6 which can be connected to an external monitor or control device. These contacts are rated 4 A at 250 V AC and 120 W at 30 V DC.

When a failure occurs, the failure detector causes the output of inverter V6A to go low and perform the following: 1) lights the FAILURE indicator; 2) turns off the converter by causing the start/stop flip-flop to reset (P4 low, P8 high); 3) latches on the failure detector by turning on transistor V5.

The output of inverter V6D goes low and lights the FAILURE indicator if cable compensation control R64 of the VCO circuit is misadjusted.

The output of inverter V6E goes low if the SCR controlled bridge rectifier heatsink becomes too hot during acceleration. This low signal causes analog switch D3A to open which, in turn, lowers the converter's current limit level to 6 amperes for the TMP-1000 (8 amperes for the TMP-1500). This circuit action is similar to current reduction when the converter goes into normal operation, but does not cause the converter to switch from acceleration to normal operation.

6.6.5 DC LINK POWER SUPPLY
(See Fig. 8-5)

The DC link power supply provides a variable DC output (E_{link}) of up to -56 volts to the six-step inverter circuit, where E_{link} is inverted between the converter's three output lines in a sequence which synthesizes an AC output signal.

Control of E_{link} is accomplished by means of the gate inputs to the SCR controlled bridge rectifier. Positive trigger pulses at the gate inputs turn on the SCRs sometime in each half cycle of the AC line voltage (see Fig. 6-6). The SCRs then turn themselves off at the end of each half cycle. E_{link} is increased by turning on the SCRs early during each half cycle, while E_{link} is lowered by turning on the SCRs late in each half cycle.

Resistor R4 on the six-step inverter board is the link current (I_{link}) sense resistor, providing a voltage of +20 mV per ampere of link current. This I_{link} voltage is used by the short circuit protection circuit.

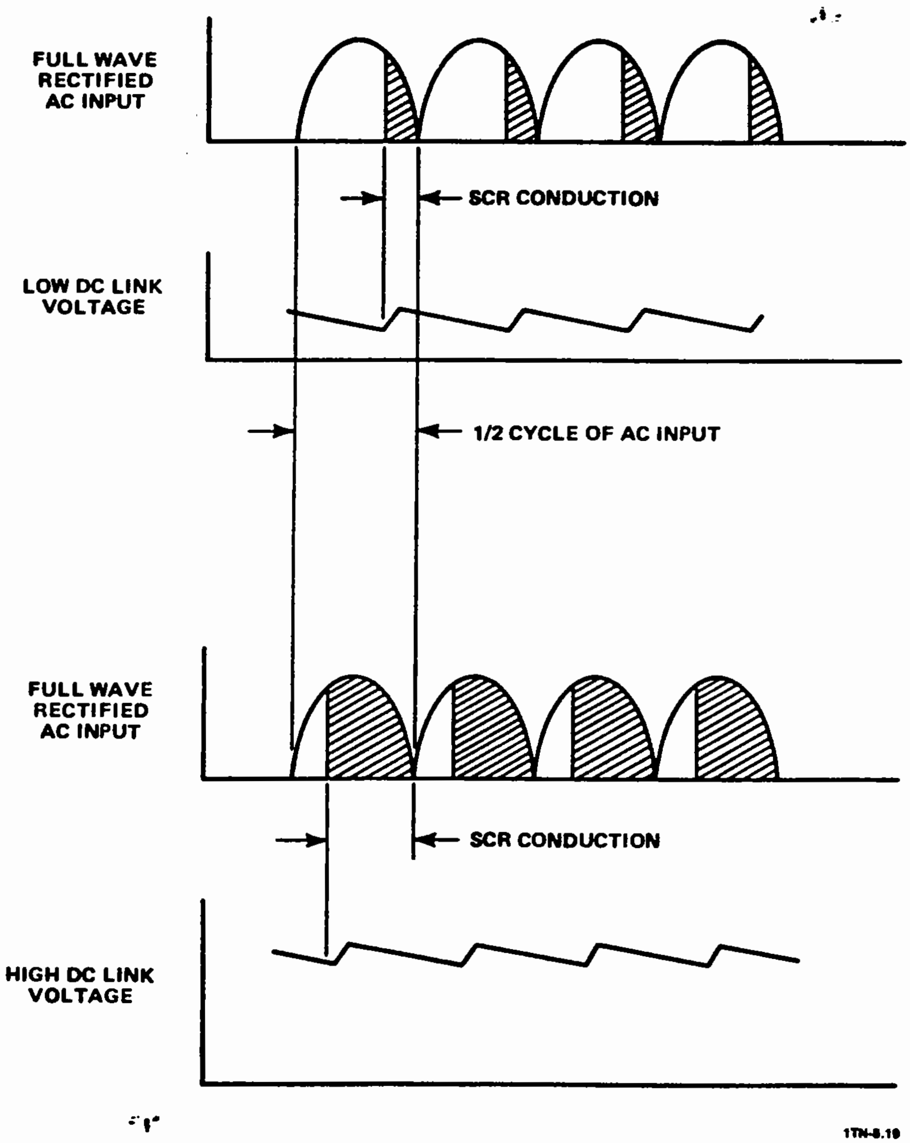


Figure 6-6. Output Voltage Control through SCR Timing

6.6.6 SCR TRIGGERING CONTROL
(See Fig. 8-5)

The SCR controlled bridge rectifier is turned on by positive trigger pulses from IC D4 pin 10 (Test Point P2). The timing of these trigger pulses is determined by a DC control voltage applied to IC D4 pin 5 (P13) from the voltage and current limiter circuits. A zero control voltage causes the SCRs to be turned on all the time, while a control voltage of +7 keeps them turned off. The conduction of the SCRs can thus be changed by varying the DC control voltage between 0 and +7 volts.

The SCR triggering control circuit consists of IC D4, which is a general purpose trigger device composed of a zero-crossing detector, a comparator, a sawtooth generator, and an output stage.

The zero-crossing detector produces a negative-going output pulse at IC D4 pin 2 (P3) whenever the AC power line voltage is crossing through zero. This pulse is used to discharge capacitor C16 at the beginning of each AC half cycle, thus synchronizing the timing of the SCR trigger pulses with the beginning of each half cycle of the AC line voltage. AC input signals to the zero-crossing detector come from the low-voltage power supply and are applied to IC D4 pin 1 (P9).

The comparator produces a positive output signal at IC D4 pin 7 (P10) when its inverting input (pin 6) goes more positive than its non-inverting input (pin 5). This output signal starts the sawtooth generator by applying a positive voltage to IC D4 pin 14. In operation, capacitor C16 which was discharged by the output of the zero-crossing detector is now allowed to charge through resistor R35 during the half cycle, and thus apply a slowing rising positive voltage to IC D4 pin 6. The output of the comparator then goes positive as soon as the voltage across capacitor C16 goes more positive than the DC control voltage applied IC D4 pin 5.

The sawtooth generator is used to produce bursts of trigger pulses by turning on and off the output stage during the time interval the SCRs are to be on. This generator produces sawtooth pulses at IC D4 pin 15 whenever its input (pin 14) goes positive. The pulse repetition time of the sawtooth generator is approximately 0.3 mS.

The output stage provides positive SCR trigger pulses at IC D4 pin 10 (P2) when its inhibiting input (pin 8) is high and its control input (pin 9) is taken low by the output of the sawtooth generator.

The SCRs are turned off when the STOP button is pressed by a low signal applied to IC D4 pin 8 from the start/stop circuit.

6.6.7 SIX-STEP INVERTER
(See Fig. 8-5)

The DC link voltage is switched onto the converter's output lines by the six-step inverter circuit in a sequence which synthesizes a three-phase AC output. The inverter's six pairs of output transistors are switched on and off at the desired frequency and in the correct sequence by the three-phase logic circuit.

Figure 6-7 shows a simplified schematic of a variable frequency, variable voltage six-step induction motor drive, along with its output voltage and current waveforms for a resistive load (connected in place of a motor). Note that the resultant current waveform of each output line resembles an AC signal, with each cycle consisting of six discrete steps - hence, the name six-step.

Pump motor current is measured by current transformer T2, rectifier bridge V17, and load resistor R5. These components produce a negative voltage that is proportional to pump current. This negative voltage is used by the current limiter circuit.

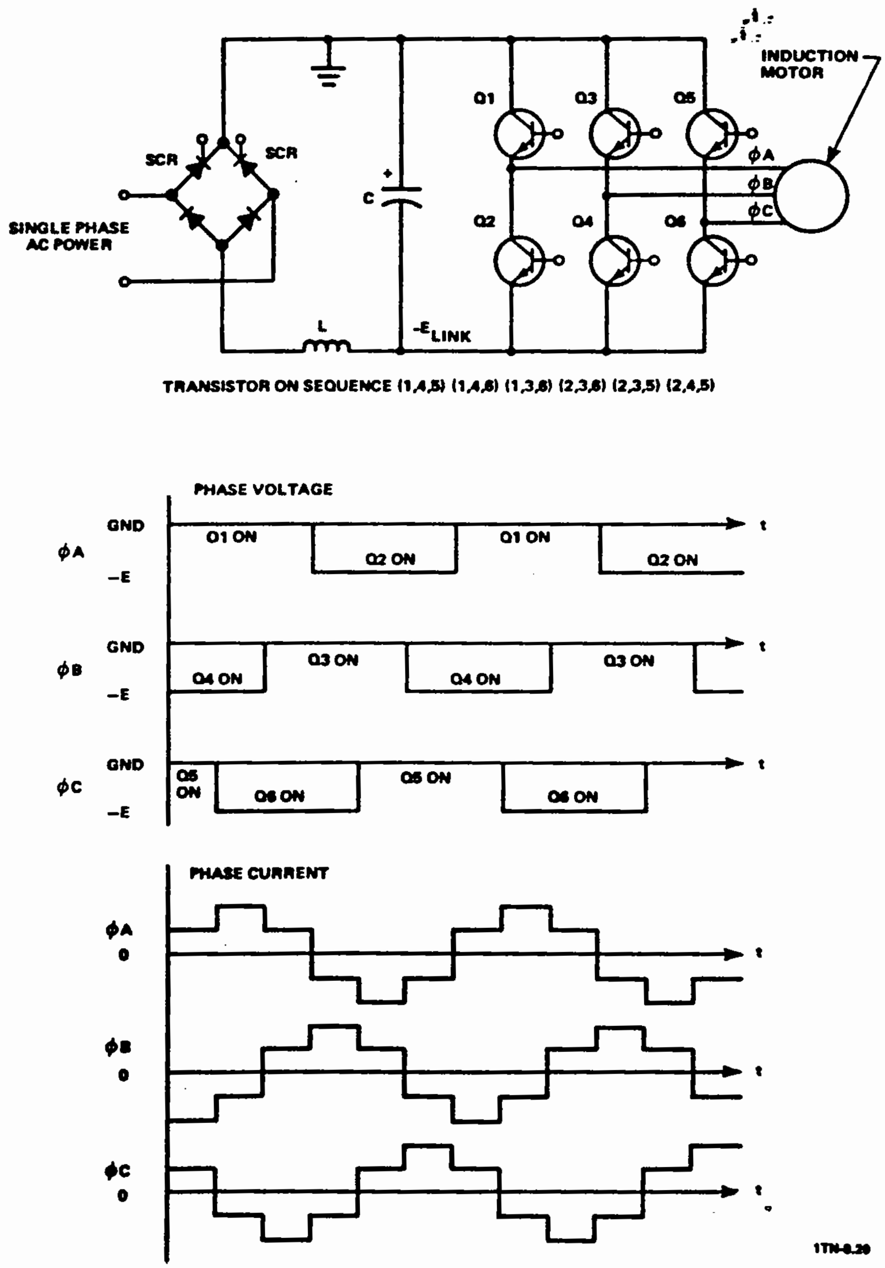


Figure 6-7. Six-Step Induction Motor Drive, Simplified Schematic with Voltage and Current Waveforms

6.6.8 THREE-PHASE LOGIC
(See Fig. 8-5)

The three-phase logic circuit consists of divide-by-six counter IC D6, six-step sequencer IC D7, and drive transistors V22 thru V27. This circuit is driven by the output of the VCO and is responsible for the proper sequencing of the transistors in the six-step inverter.

The output of the VCO (Test Point P32) is applied to divide-by-six counter IC D6 which produces a three-bit binary output (pins 8, 9, 11) that drives six-step sequencer IC D7 at one-sixth the VCO frequency.

The outputs of IC D7 (pins 1 thru 6) go low and turn on their associated drive transistors (V22 thru V27) in a sequence determined by IC D7's internal logic arrangement. IC D7 thus establishes the turn-on sequence of the Six-Step Inverter Board's source and sink transistor pairs.

IC D7 pin 7 provides an output that corresponds to the pump drive frequency. This output is buffered by inverter V6F, which produces at rear-panel terminals X-11 & -12 a square-wave output at an amplitude of +24 volts. A frequency counter can be connected to these terminals for a quantitative readout of the pump drive frequency.

6.6.9 VCO (VOLTAGE CONTROLLED OSCILLATOR)
(See Fig. 8-5)

The switching frequency of the six-step inverter is determined by the VCO (voltage controlled oscillator) circuit consisting of VCO IC D5, comparators N1A and N1D, voltage follower N1B, and analog switches D3C and D3D.

VCO IC D5 operates at a maximum frequency of 3630 Hz for the TMP-1000 and 2130 Hz for the TMP-1500. This frequency can be varied from approximately 5 to 100% of its maximum value by changing the positive control voltage applied to IC D5 pin 7.

The VCO control voltage (Test Point P26) is generated by comparator N1A and voltage follower N1B. This circuit monitors the DC link voltage and then produces a control voltage that causes the VCO frequency to track any changes in link voltage, so as to maintain a constant voltage-to-frequency ratio.

When the converter is stopped, a positive voltage from the start/stop circuit charges capacitor C20 through resistor R90 and diode V30.3. The voltage across C20 makes the output of comparator N1A go to its maximum positive level which, in turn, causes the VCO to run at its maximum frequency. Then when the converter is started, capacitor C20 discharges through resistor R69, causing the VCO frequency to slowly decrease until it reaches the correct voltage-to-frequency ratio, at which time the frequency starts to increase with increasing link voltage. This design feature of starting the converter at its maximum frequency allows the pump to be restarted from any rotational speed.

If during start-up the output of comparator N1A goes negative, the output of comparator N1D will go positive and light the FAILURE indicator. This condition indicates that cable length compensation control R64 is misadjusted and should be readjusted as described in Section 5.5.2.

Analog switches D3C and D3D set up the VCO circuit to automatically operate with either the TMP-1000 or TMP-1500, and are controlled by the pump select circuit. These switches are N.O. devices that close with the application of a positive voltage to their control inputs (pins 6 and 12). Both switches are open when the converter is connected to a TMP-1000 and are closed for a TMP-1500.

The front panel FREQUENCY meter indicates converter frequency as a percentage of the maximum drive frequency at the pump's rated rotational speed. Note that FET V29 turns on the FREQUENCY meter when the pump is started by the application of a positive gate voltage from the start/stop circuit.

6.6.10 SHORT CIRCUIT PROTECTION
(See Fig. 8-5)

The short circuit protection circuit provides a fast response time to link-current overloads greater than 25 amperes by immediately turning off the converter's output transistors.

In operation, link-current-sense resistor R4 applies a positive voltage of 20 mV per ampere of link current to the inverting input (Test Point P20) of comparator N6. At current levels greater than 25 amperes, this positive voltage becomes greater than the reference voltage applied to the comparator's non-inverting input, causing the comparator's output (P21) to go low and trigger pulse stretcher IC D8. Once pulse stretcher IC D8 is triggered, it's output (P22) goes high for approximately 25 mS and disables three-phase logic IC D7. During this time period, drive is removed from inverter transistors V5, V6, V9, V10, V13, and V14.

As soon as the output of pulse stretcher IC D8 (P22) returns low, drive is reapplied to the inverter transistors; however, if the short circuit is still present, drive is again removed for 25 mS. This process continues until either the short circuit is removed, or the converter goes into its failure mode.

6.6.11 FAILURE DETECTOR
(See Fig. 8-5)

The failure detector circuit consists of comparator N3D and NAND gate D1D. The output of failure detector circuit IC N3D (Test Point P11) is high during both acceleration and normal operation, but goes low if a fault occurs which causes the converter to turn itself off.

The failure detector's output is high when the sum of all negative and positive voltages applied to its inverting input is negative enough to turn on diode V7.5, which clamps the comparator's inverting input one diode drop below ground. This negative voltage causes the comparator's output (P11) to be high, the output NAND gate D1D to be low, and the output of inverter V6A of the status and control circuit to be high which, in turn, causes the FAILURE indicator to be off.

In the event of a failure, the output of the failure detector is made to go low by having its inverting input go positive as follows:

- If the pump motor overheats, its thermal switch will open and cause the output of inverter V6G of the pump select/ overtemperature circuit to go high and apply a positive voltage to resistor R6.3, which causes the inverting input of comparator N3D to go positive.

- o If the pump motor slows down to approximately one-third of its rated rotational speed (e.g., leak in vacuum system causing intake side pressure to rise), the negative DC link voltage applied to resistor R11.5 will have decreased to a level that causes the inverting input of comparator N3D to go positive. Note that the fault detector circuit is inhibited from activating during acceleration, when the DC link voltage is low, by acceleration timer D2 (refer to section 6.6.3).

When the sum of all negative and positive voltages at the inverting input of comparator N3D is positive, diode V7.6 turns on and clamps the comparator's inverting input one diode drop above ground. This positive voltage causes the comparator's output to go low, the output of NAND gate D1D to go high, and the output of inverter V6A to go low which, in turn, causes the following to occur:

1) Diode V9.4 conducts and lights the FAILURE indicator.

2) Diode V9.6 conducts and causes the output of inverter V6C to go high during acceleration, which turns off the ACCELERATION indicator.

3) Diode V9.5 conducts and causes transistor V5 of the fault detector latch circuit to turn on and latch the detector in its failure mode.

4) Diode V9.5 by conducting also causes the converter to be turned off by applying a low to start/stop circuit IC D1B pin 6, which causes the start/stop circuit's flip-flop to reset (P4 low, P8 high).

6.6.12 FAILURE DETECTOR LATCH
(See Fig. 8-5)

The failure detector latch circuit consists of transistor V5. This transistor is turned off during acceleration and normal operation, but is turned on in the event of a failure by the status and control circuit.

As soon as a fault is detected, transistor V5 is turned on by a low signal applied to its base from inverter V6A of the status and control circuit. A positive voltage from the collector of V5 is then applied to resistor R4.4 of the failure detector circuit, causing the detector to latch in its failure mode.

Transistor V5 also turns on if fuse F2, on the six-step inverter board, has blown. In this situation, V5 causes the failure detector circuit to turn off the converter.

The failure detector latch circuit is reset by pressing the STOP button, which causes the output of NAND gate D1C to go low and remove the emitter voltage from transistor V5.

6.6.13 VOLTAGE AND CURRENT LIMITERS
(See Fig. 8-5)

The voltage and current limiter circuits regulate the DC link voltage so as to keep the converter in either current or voltage limiting. At start up the converter immediately goes into current limiting due to the motor's low rotor impedance, thus causing the converter to apply both a very low drive voltage and drive frequency to the motor. As the motor accelerates, however, its back e.m.f. causes the rotor impedance to increase which, in turn, causes the converter to increase both drive voltage and drive frequency by an amount necessary to keep itself in acceleration current limiting. Once the DC link voltage reaches a preset level (corresponds to the desired pump speed), the converter then goes into voltage limiting and allows the motor current to decrease to its normal operating level (dependent upon pump loading).

The output of the voltage and current limiter circuits (Test Point P13) regulates the DC link voltage by applying a DC control signal of between 0 and +7 volts to SCR triggering control IC D4 pin 5 which, in turn, controls the conduction of the SCR bridge rectifier (refer to section 6.6.6). Note that 0 volts causes maximum link voltage while +7 volts causes minimum link voltage.

The current limiter circuit consists of high-gain amplifier N3B, which amplifies the difference between a negative feedback voltage that is proportional to pump current (P16) and a positive reference voltage (P19). The current limiter circuit then outputs an SCR DC control signal (P7) which varies the DC link voltage as necessary to limit the motor current of a TMP-1000 pump at 8.5 amperes during acceleration, and 6 amperes during normal operation (11.5 and 8 amperes, respectively for the TMP-1500). For example, during start-up the current level will begin to decrease as the pump motor accelerates, causing the negative feedback voltage applied to the current limiter to decrease (go less negative). This positive going voltage at the inverting input of amplifier N3B causes its output to decrease, thereby raising the DC link voltage by causing the SCR triggering circuit to increase the conduction time of the SCRs in the DC link power supply.

Note that the current limit level can be changed by varying the reference voltage, where a more positive reference voltage increases the current limit level.

Analog switch D3A is used to raise the current limit level during acceleration by short-circuiting resistor R27, thus raising the reference voltage applied to amplifier N3B pin 6. Then after either the acceleration time period has expired, or after the pump reaches its rated rotational speed, analog switch D3A opens and causes the current limit level to be reduced to its normal operating value. Analog switch D3A is closed by the application of a positive voltage to its control input (pin 13) from inverter V6E of the status and control circuit.

Analog switch D3B is used to raise the overall current limit levels for the TMP-1500 pump by short-circuiting resistor R29, thus raising both the acceleration and normal operation reference voltages. Analog switch D3B is closed by the application of a positive voltage to its control input (pin 5) from the pump select circuit.

The voltage limiter circuit consists of voltage follower N1C and amplifier N3A. The operation of this circuit is similiar to the current limiter, in that it amplifies the difference between the negative link voltage (P12) and a positive reference voltage (P35), and then outputs an SCR DC control signal (P15) that varies the DC link voltage as necessary to limit the converter's output at its maximum level of 42 volts. For example, if the DC link voltage increases (becomes more negative) due to AC line fluctuations, this negative going voltage at the inverting input of amplifier N3A causes its output to increase, and thus lowers the DC link voltage by causing the SCR triggering circuit to reduce the conduction time of the SCRs in the DC link power supply.

Pump speed can be varied between 50 and 100% of its rated rotational value by changing the voltage limiter's reference voltage. A fixed reference of +10 volts is produced at the output of voltage follower N1C when a jumper is connected to terminals X1-9 and -10, causing the pump to operate at its rated rotational speed. However, with the jumper removed and an external 5 K ohm, linear-taper potentiometer connected to terminals X1-9, -10, and -11, the reference voltage can be lowered which, in turn, slows down the pump by lowering the DC link voltage. Potentiometer R52 is adjusted to limit the pump's minimum speed to 50% of its rated rotational value when the external speed control is set to its slowest speed position.

6.6.14 PUMP SELECT/OVERTEMPERATURE

(See Fig. 8-5)

The pump select/overtemperature circuit performs the following two functions:

1) Determines whether a TMP-1000 or TMP-1500 pump is connected to the converter, and then automatically changes the VCO and current limiter circuits to correspond to the requirements of the pump in use.

2) Monitors pump motor temperature, and turns off the converter in the event the motor temperature exceeds its safe operating limit [133°F (56°C) for the TMP-1000, 149°F (65°C) for the TMP-1500].

With a TMP-1000 pump connected to the converter, a ground is applied through connector X0-5b to the pump select circuit, causing its output (Test Point P24) to be low. This low signal opens analog switches D3D and D3C of the VCO circuit, and opens analog switch D3B of the current limiter circuit.

A TMP-1500 pump causes the output of the pump select circuit (P24) to be high, causing analog switches D3D, D3C, and D3B to be closed.

The pump motor is overtemperature protected by a normally closed, bi-metal thermal switch contained in the motor housing. During normal operation, this switch is closed and causes the output of inverter V6G to be low. However, if the pump motor temperature exceeds its safe operating limit, the thermal switch will open and cause the output of inverter V6G to go high which, in turn, causes the failure detector to turn off the converter.

SECTION 7

TROUBLESHOOTING

WARNING

The NT-1000/1500 Frequency Converter employs voltages which are dangerous and may be fatal if contacted. Extreme caution should be exercised when working with this equipment when its top cover is removed. To reduce the possibility of electrical shock, always connect the converter's chassis to a low impedance ground.

WARNING

If the TMP-1000 Turbomolecular Pump has been exposed to corrosive or toxic gases, the pump could be contaminated with dangerous chemicals. In such cases, use the proper precautions when working on the pump to prevent inhaling or coming in contact with these chemicals.

The cause of most maintenance problems can be resolved by using the Troubleshooting Chart contained in Table 7-1. To use this chart, first locate the symptom of the problem, isolate the trouble area, then perform the recommended corrective action(s). The "References" column lists Figures and Sections in this manual that are helpful in correcting the problem.

Part locating diagrams and replacement parts for both the TMP-1000 and NT-1000/1500, are contained in Section 8.

The electrical schematic of the NT-1000/1500 is also contained in Section 8 (Fig. 8-5). This schematic contains useful troubleshooting information in the form of voltage levels and waveforms.

TROUBLESHOOTING TABLE OF CONTENTS

Symptom	Page
1. POWER indicator does not light when converter is plugged into an AC outlet	7-4
2. ACCELERATION indicator does not light after pressing START	7-4
3. FAILURE indicator lights immediately after pressing START	7-5
4. Converter switches from ACCELERATION to FAILURE within 15 minutes after pressing START	7-6
5. Converter switches from ACCELERATION to NORMAL OPERATION before pump reaches the desired operating speed	7-6
6. Pump attains only 50% of its rated rotational speed	7-7
7. Pump speed cannot be lowered to 50% of its rated rotational speed using the optional external speed control	7-7
8. Maximum drive frequency 355 Hz instead of 605 Hz	7-7
9. NORMAL OPERATION indicator does not light after pump has achieved desired operating speed	7-7
10. Converter never switches from ACCELERATION to NORMAL OPERATION	7-7
11. FAILURE indicator lights after pump has been operating normally	7-8
12. Converter turns itself off without FAILURE indicator coming on	7-8
13. Fuse F1 blown	7-9
14. Fuse F2 blown	7-10
15. Pump does not start	7-10
16. Pump does not attain desired rotational speed after 15 minutes of acceleration	7-11
17. Pump rotational speed drops from desired level	7-12
18. FREQUENCY meter does not indicate 100% during normal operation	7-13
19. Pump is noisy or vibrates	7-13
20. Pump becomes oily	7-13

TROUBLESHOOTING TABLE OF CONTENTS (Continued)

Symptom	Page
21. Pump fore-vacuum pressure too high (>10^{-2} mbar)	7-14
22. Pumping speed insufficient	7-15
23. Pump does not attain desired working pressure	7-15
24. Pump housing temperature exceeds 131°F (55°C) during continuous operation	7-16
25. Pump emits pinging noises during venting	7-16

TABLE 7-1. TROUBLESHOOTING CHART

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
1. POWER indicator does not light when converter is plugged into an AC outlet.	a. AC power	Converter not receiving AC power.	Check for presence of voltage at AC outlet.	
		Fuse F1 blown.	Refer to Symtom 13.	Fig. 8-2
	b. POWER indicator	POWER LED burned out.	Check for +24 V at POWER LED. If +24 V is present, replace LED.	Figs. 8-2 & 8-5
	c. Power Supply	Power Transformer defective.	Check for secondary voltages at transformer T1. If no secondary voltages are present, replace T1.	Figs. 8-2 & 8-5 Sect. 6.6.1
		Low Voltage Power Supply on A1 board defective.	Check for +24 V on A1 board at test point P5. If no voltage is present, replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.1
2. ACCELERATION indicator does not light after pressing START.	a. Rear panel connections	External start bypass jumper not installed.	Connect a jumper to terminals X1-2 and -3 when external start switch is not used.	Figs. 3-2 & 8-5 Sect. 3.2.4.1 Sect. 3.2.4.2
	b. Optional water flow switch	Insufficient water flow through pump has caused the optional water flow switch to open and prevent the converter from starting.	Ensure that the cooling water supply is turned on. Check for clogged water lines and clean if necessary.	Sect. 3.3.4.1
		Water flow switch mis-adjusted.	Adjust water flow switch for a minimum flow rate of 0.13 gal/min (0.5 ltr/min).	Sect. 3.3.8
		Water flow switch defective.	Replace water flow switch.	
	c. ACCELERATION indicator	ACCELERATION LED burned out.	Check for +24 V at ACCELERATION LED. If +24 V is present, replace LED.	Figs. 8-2 & 8-5
	d. Front panel START switch	START switch defective.	Jumper external start terminals X1-1 and -2. If ACCELERATION indicator turns on, replace front panel START switch.	Figs. 8-2 & 8-5 Sect. 3.2.4.2 Sect. 6.6.2
	e. A1 - Control and Regulator Board	Start/Stop or Status and Control circuit defective.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.2 Sect. 6.6.4

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
3. FAILURE indicator lights immediately after pressing START.	a. Electrical connections	Pump cable not plugged in or improperly mated.	Ensure that pump cable connectors are mated properly with converter and pump connectors.	Sect. 3.2.6
		Pump cable defective.	Check for broken wires in pump cable. Repair or replace cable, if necessary.	
	b. Pump overtemperature switch	Pump motor too hot causing its overtemperature switch to be open.	Allow pump to cool and try to restart. Ensure that the pump is being cooled by the cooling water flow or by the air cooling unit.	Sect. 3.3.4 Sect. 6.6.14
		Overtemperature switch or pump cable defective.	Disconnect pump cable and jumper thermal switch connections at output connector XO-5a and -5b, then restart pump. If NORMAL OPERATION indicator lights after approximately 2 seconds, check for broken wires in pump cable or replace overtemperature switch.	Figs. 8-1, 8-2, & 8-5
	c. A1 - Control and Regulator Board	Pump Cable Length Compensation control misadjusted.	Adjust potentiometer R64 as described in Section 5.5.2.	Figs. 5-11 & 8-5 Sect. 5.5.2 Sect. 6.6.9
		One of the circuits that apply a signal to the Failure Detector circuit is defective.	Replace A1 board.	Fig. 8-2 & 8-5 Sect. 6.6.11
	d. A2 - Six-Step Inverter Board	Fuse F2 blown.	Refer to Symptom 14.	Figs. 8-4
		Short circuit on the A2 board.	Disconnect pump cable and unplug converter. An ohmmeter with its positive lead connected to the chassis and its negative lead connected to the emitters of V5/V6, V9/V10, and V13/V14 should show infinite resistance. A resistance of approximately 5.6 k ohms should be measured at emitters of V7/V8, V11/V12, and V15/V16. If the ohmmeter indicates a much lower resistance, replace A2 board.	Figs. 8-2, 8-4, & 8-5

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
4. Converter switches from ACCELERATION to FAILURE within 15 minutes after pressing START.	a. Pump	Pump did not start.	Refer to Symptom 15.	
		Acceleration time period of 15 minutes expired before pump achieved at least one third of its rated rotational speed.	Refer to Symptom 16.	
	b. DC Link Power Supply	SCR heatsink became too hot before pump achieved at least one third of its rated rotational speed.	Allow converter to cool and then try to restart pump. Ensure that there is sufficient air circulation around converter.	Sect. 3.2.2
	c. Converter output	Short circuit at converter output.	Disconnect pump cable and jumper thermal switch connections at output connector XO-5a and -5b, then restart converter. If the NORMAL OPERATION indicator lights after approximately 2 seconds, check for a short circuit in the pump motor or pump cable.	Fig. 8-5 Sect. 6.6.10
	d. A1 - Control and Regulator Board	Pump Cable Length Compensation control misadjusted.	Adjust potentiometer R64 as described in Sect. 5.5.2.	Figs. 5-11 & 8-5 Sect. 5.5.2 Sect. 6.6.9
		One of the circuits that apply a signal to the Failure Detector circuit is defective.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.11
5. Converter switches from ACCELERATION to NORMAL OPERATION before the pump reaches the desired operating speed.	a. Pump	Acceleration time period of 15 minutes had expired.	Refer to Symptom 16.	
	b. DC Link Power Supply	SCR heatsink became too hot.	Pump will continue to accelerate but at reduced torque. Ensure that there is sufficient air circulation around converter.	Sect. 3.2.2 Sect. 6.6.4
	c. A1 - Control and Regulator Board	One of the circuits that control the operation of the NORMAL OPERATION indicator is defective.	Replace A1 board.	Fig. 8-5 Sect. 6.6.3 Sect. 6.6.4 Sect. 6.6.13

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
6. Pump attains only 50% of its rated rotational speed.	a. Rear panel connections	External speed control bypass jumper not installed.	Connect a jumper to terminals X1-9 and -10 when the external speed control is not used.	Figs. 3-2 & 8-5 Sect. 3.2.4.1
	b. Optional external speed control	Speed control incorrectly installed or misadjusted.	Ensure that the speed control is correctly installed as described in Section 3.2.4.5.	Fig. 3-2 & 8-5 Sect. 3.2.4.5
7. Pump speed cannot be lowered to 50% of its rated rotational speed using the optional external speed control.	a. Rear panel connections	External speed control bypass jumper is installed.	Remove jumper from terminals X1-9 and -10 when external speed control is used.	Fig. 3-2 & 8-5 Sect. 3.2.4.5
	b. Optional external speed control	Speed control incorrectly installed or misadjusted.	Ensure that the speed control is correctly installed as described in Section 3.2.4.5.	Fig. 3-2 & 8-5 Sect. 3.2.4.5
	c. A1 - Control and Regulator Board	Minimum Pump Speed control misadjusted.	Adjust potentiometer R52 as described in Section 5.5.1.	Figs. 5-11 & 8-5 Sect. 5.5.1 Sect. 6.6.13
		Voltage and Current Limiter circuit defective.	Replace A1 board.	Fig. 8-2
8. Maximum drive frequency 355 Hz instead of 605 Hz.	a. Pump cable	Wrong cable installed.	Install 7-conductor cable marked at both ends with heat-shrink tubing.	Sect. 3.2.6
	b. A1 - Control and Regulator Board	Pump Select or VCO circuit defective.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.9 Sect. 6.6.14
9. NORMAL OPERATION indicator does not light when pump achieves desired operating speed.	a. NORMAL OPERATION indicator	NORMAL OPERATION LED burned out.	Check for +24 V at NORMAL OPERATION LED. If +24 V is present, replace LED.	Figs. 8-2 & 8-5
	b. A1 - Control and Regulator Board	Acceleration Timer, Status and Control, or Voltage and Current Limiter circuit defective.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.3 Sect. 6.6.4 Sect.
10. Converter never switches from ACCELERATION to NORMAL OPERATION.	A1 - Control and Regulator Board	Status and Control or Acceleration Timer circuit defective.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.3 Sect. 6.6.4

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
11. FAILURE indicator lights after pump has been operating normally.	a. Pump	Pump became too hot, causing its overtemperature switch to open.	Check for clogged water lines, clogged water filter, low water pressure, or defective air cooling unit. Ensure that water temperature does not exceed 77°F (25°C) or ambient air tempature does not exceed 113°F (45°C).	Sect. 3.3.4
		Pump speed dropped below one third of its rated rotational speed.	Refer to Symptom 17.	
	b. Converter	Converter became defective	Disconnect pump cable and jumper thermal switch connections at output connector XO-5a and -5b, then restart converter. In approximately 2 seconds the NORMAL OPERATION indicator should light. Output voltage should measure approximately 42 V AC between any pair of output terminals (XO-1, -2, -3). The DC Link Power Supply output across capacitors C4/C5 should measure approximately 56 V DC. If any of the above conditions are not met, replace converter's A1 and/or A2 board, or troubleshoot DC Link Power Supply.	Figs. 8-2 & 8-5
12. Converter turns itself off without FAILURE indicator turning on.	a. Optional water flow switch	Insufficient water flow through the pump has caused the optional water flow switch to open.	Check for clogged water lines, clogged water filter, or low water pressure.	Sect. 3.3.4.1
		Water flow switch mis-adjusted.	Adjust water flow switch for a minimum flow rate of 0.13 gal/min (0.5 ltr/min).	Sect. 3.3.8
		Water flow switch defective.	Replace water flow switch.	
	b. FAILURE indicator	FAILURE LED burned out.	Simulate a failure by disconnecting pump cable. Check for +24 V at FAILURE LED. If +24 V is present, replace LED.	Fig. 8-5

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
13. Fuse F1 blown.	a. DC Link Power Supply	Short circuit in power supply.	Isolate the DC Link Power Supply by removing output connections X5 + and X5 -. Also remove A1 board connector X2. If F1 blows again, troubleshoot for defective part in power supply.	Figs. 8-2 & 8-5
	b. A2 - Six-Step Inverter Board	Short circuit on the A2 board.	Disconnect pump cable and unplug converter. An ohmmeter with its positive lead connected to the chassis and its negative lead connected to the emitters of V5/V6, V9/V10, and V13/V14 should show infinite resistance. A resistance of approximately 5.6 k ohms should be measured at emitters of V7/V8, V11/V12, and V15/V16. If the ohmmeter indicates a much lower resistance, replace A2 board.	Figs. 8-2 & 8-5 Sect. 6.6.7
	c. A1 - Control and Regulator Board	Short circuit in the Low Voltage Power Supply.	After determining there are no short circuits in the DC Link Power Supply and on the A2 board, remove connector X2 from the A1 board and reapply power. If F1 does not blow, replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.1
	d. Optional external hours meter	Hours meter defective.	Replace meter.	Figs. 3-2 & 8-5 Sect. 3.2.4.6

LEYBOLD-HERAEUS

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
14. Fuse F2 blown.	a. Converter output.	Short circuit at converter output.	Disconnect pump cable and jumper thermal switch connections at output connector XO-5a and -5b, then restart converter. If the NORMAL OPERATION indicator lights after approximately 2 seconds, check for a short circuit in the pump motor or pump cable.	Fig. 8-5 Sect. 6.6.10
	b. A2 - Six-Step Inverter Board	Short circuit on the A2 board.	Disconnect pump cable and unplug converter. An ohmmeter with its positive lead connected to the chassis and its negative lead connected to the emitters of V5/V6, V9/V10, and V13/V14 should show infinite resistance. A resistance of approximately 5.6 k ohms should be measured at emitters of V7/V8, V11/V12, and V15/V16. If the ohmmeter indicates a much lower resistance, replace A2 board.	Figs. 8-2 & 8-5 Sect. 6.6.7
	c. A1 - Control and Regulator Board	The Short Circuit Protection circuit is not turning off the Three-Phase Logic circuit when there is a short circuit at the converter's output.	Replace A1 board.	Figs. 8-2 & 8-5 Sect. 6.6.10
15. Pump does not start.	a. Converter	No output voltage from converter.	Refer to Symptoms 1, 2, 3.	
	b. Pump	Pump rotor cannot turn due to obstruction in rotor blades or defective motor bearings.	Remove pump from system. Turn pump rotor by hand and check for smooth running. If any resistance is felt, disassemble pump as described in Section 5.4 and determine cause of obstruction. Replace rotor/spindle with a new assembly, if necessary.	Sect. 5.4
		Motor stator defective.	Using an ohmmeter, check the stator's inter-phase resistance at pump connector terminals 6+7, 7+8, and 6+8. The resistance measured between any two phases should be 0.62 ±0.05 ohm. Replace stator, if necessary.	Fig. 5-5 Sect. 5.4.3

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
16. Pump does not attain desired rotational speed after 15 minutes of acceleration.	a. Fore-vacuum side	Fore-vacuum pressure greater than 10^{-2} mbar.	Check operation of backing pump as described in its manual. A larger pump may be necessary.	Sect. 3.3.3
			Ensure venting port is closed.	Sect. 3.3.5 Sect. 3.3.6
			Leak test fore-vacuum line and repair any leaks found.	
			Ensure pump electrical connector screws are tight.	
	b. High-vacuum side	Vacuum chamber too large.	Pump down chamber with backing pump to at least 5×10^{-1} mbar before turning on turbopump.	Sect. 4.3
		Leakage in chamber.	Leak test vacuum system and repair any leaks found.	
	c. Pump cable	Cable voltage drop too large.	When cable length is greater than 250 ft. (76 m), a larger diameter cable is required to reduce the voltage drop. Contact Leybold-Heraeus for correct pump cable required.	
	d. Converter	Maximum drive frequency 355 Hz instead of 605 Hz.	Refer to Symptom 8.	
		Pump Cable Length Compensation control misadjusted.	Adjust potentiometer R64 as described in Section 5.5.2.	Figs. 5-11 & 8-5 Sect. 5.5.2 Sect. 6.6.9
		External speed control bypass jumper not installed.	Connect a jumper to terminals X1-9 and -10 when the external speed control is not used.	Figs. 3-2 & 8-5 Sect. 3.2.4.1 Sect. 3.2.4.5
	e. Pump	Pump motor direction of rotation is incorrect.	Check pump motor sense of rotation as described in Section 3.2.7.	Sect. 3.2.7
		Motor bearing friction too high.	Remove pump from system. Turn rotor by hand and check for smooth running. If rotor turns stiffly, replace rotor/spindle assembly as described in Section 5.4.	Sect. 5.4

LEYBOLD-HERAEUS

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
17. Pump rotational speed drops from desired level.	a. Optional external pump speed control	Speed control NOT set to desired level.	Adjust speed control for desired pump motor speed.	Sect. 4-3
	b. High-vacuum side	Leakage in chamber causing intake pressure to exceed 10^{-2} mbar.	Leak test vacuum system and repair any leaks found.	
	c. Exhaust port	Fore-vacuum pressure is too high.	Check operation of backing pump as described in its manual.	Sect. 3.3.3
			Ensure venting port is closed.	Sect. 3.3.5 Sect. 3.3.6
			Ensure pump electrical connector screws are tight.	
			Leak test fore-vacuum line and repair any leaks found.	
	d. Converter	Low output voltage.	Disconnect pump cable and jumper thermal switch connections at output connector XO-5a and -5b, then restart converter. In approximately 2 seconds the NORMAL OPERATION indicator should light. Output voltage should measure approximately 42 V AC between any pair of output terminals (XO-1, -2, -3). The DC Link Power Supply output across capacitors C4/C5 should measure approximately 56 V DC. If any of the above conditions are not met, replace converter's A1 and/or A2 board, or troubleshoot DC Link Power Supply.	Fig. 8-5
	e. Pump	Motor bearing friction too high.	Remove pump from system. Turn rotor by hand and check for smooth running. If rotor turns stiffly, replace rotor/spindle assembly as described in Section 5.4.	Sect. 5.4
		Motor stator defective.	Using an ohmmeter, check the stator's inter-phase resistance at pump connector terminals 6+7, 7+8, and 6+8. The resistance measured between any two phases should be 0.62 ±0.05 ohm. Replace stator, if necessary.	Fig. 5-5 Sect. 5.4.3

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
18. FREQUENCY meter does not indicate 100% during normal operation.	a. Optional external pump speed control	This is a normal indication if speed control set to some value other than 100%.	Adjust speed control for desired pump motor speed from 50 to 100% of the pump's rated rotational speed.	Sect. 4-3
	b. A1 - Control and Regulator Board	Frequency meter calibration control misadjusted.	Adjust potentiometer R94 as described in Section 5.5.4.	Fig. 5-11 Sect. 5.5.4 Sect. 6.6.9
		VCO frequency control(s) misadjusted.	Adjust potentiometers R74 and R92 as described in Section 5.5.3.	Sect. 5.5.3 Sect. 6.6.9
	c. Pump	Pump not running at its full rotational speed.	Refer to Symptom 17.	
19. Pump is noisy or vibrates	a. Pumping system	Pump runs in natural frequency with pumping system.	Change configuration of pumping system.	
			Install damping bellows at pump's intake and exhaust ports.	Sect. 1.4.6 Sect. 3.3.2 Sect. 3.3.3
			Change pump's rotational speed.	Sect. 3.2.4.5
	b. Pump	Motor bearings are defective or rotor has become unbalanced.	Remove pump from system. Turn rotor by hand and check for smooth running. If rotor turns stiffly, is noisy, or turns irregularly, replace rotor/spindle assembly as described in Section 5.4.	Sect. 5-4
20. Pump becomes oily.	a. Backing pump fore-vacuum valve	Backing pump oil got into turbopump due to defective fore-vacuum line shut-off valve.	Check that fore-vacuum line valve automatically closes when backing pump is shut off. Repair or replace, if necessary.	Sect. 3.3.3
	b. Venting system	Turbopump is not being properly vented upon shutdown.	Ensure venting valve opens after turbopump is switched off. Repair or replace, if necessary.	Sect. 3.3.5 Sect. 3.3.6
			Check if metal filter or nozzle in lateral venting port is clogged. Clean or replace, if necessary.	

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
21. Pump fore-vacuum pressure too high (>10^{-2} mbar).	a. Vacuum gauge	Vacuum gauge defective.	Ensure that vacuum gauge is operating correctly before assuming a problem exists in pumping system.	
	b. Backing pump	Backing pump defective or too small.	Check operation of backing pump as described in its manual. A larger pump may be necessary.	Sect 3.3.3
	c. Venting system	Venting valve open.	Ensure venting valve closes when turbopump is switched on. Repair or replace, if necessary.	Sect. 3.3.5 Sect. 3.3.6
		Venting valve leaky.	Leak test venting valve. Repair or replace, if necessary.	
	d. Fore-vacuum space	Fore-vacuum line leaky.	Leak test components in fore-vacuum line and repair any leaks found.	
	e. Pump	Leak around pump housing or electrical connector.	Leak test turbopump and repair any leaks found.	Sect. 5.4.7.2
	f. Fore-vacuum line to backing pump	Line too long.	Use shorter line.	
		Conductance of line is inadequate.	Check for restrictions in line. Ensure that inside diameter of line is adequate.	

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
22. Pumping speed insufficient.	a. Fore-vacuum space	Fore-vacuum pressure too high.	When pumping out large chambers, fore-vacuum pressure should be at least 5×10^{-1} mbar before turning on turbopump.	Sect. 4.3
			Refer to Symptom 21.	
	b. Pump	Pump contaminated.	Clean pump as described in Section 5.3.	Sect. 5.3
			Refer to Symptom 20.	
		Wire mesh splinter guard located at inlet port clogged.	Remove pump from system and clean splinter guard.	Fig. 8-1
		Pump leaky.	Leak test turbopump and repair any leaks found.	Sect. 5.4.7.2
		Pump not assembled correctly.	Perform turbopump run-up test as described in Section 5.4.7.1. If necessary, disassemble and then reassemble pump as described in Section 5.4.	Sect. 5-4 Sect. 5.4.7.1
23. Pump does not attain desired ultimate pressure.	a. Vacuum gauge	Vacuum gauge defective.	Ensure that vacuum gauge is operating correctly before assuming a problem exists in pumping system.	
	b. Vacuum system	Vacuum system dirty or outgassing.	Clean and/or bake out vacuum system.	Sect. 4.6 Sect 5.3
		Vacuum system leaky.	Leak test vacuum system and repair any leaks found.	
	c. Fore-vacuum space	Fore-vacuum pressure too high (>10^{-2} mbar).	Refer to Symptom 21.	
	d. Pump	Pump leaky.	Leak test turbopump and repair any leaks found.	Sect. 5.4.7.2
		High vacuum space contaminated.	Clean pump as described in Section 5.3.	Fig. 5-2 Sect. 5.3
		Pump not assembled correctly.	Perform turbopump run-up test as described in Section 5.4.7.1. If necessary, disassemble and then reassemble pump as described in Section 5.4.	Sect. 5-4 Sect. 5.4.7.1

TABLE 7-1. TROUBLESHOOTING CHART (Continued)

Symptoms	Trouble Area	Probable Cause	Recommended Corrective Action	References
24. Pump housing temperature exceeds 131°F (55°C) during continous operation.	a. Cooling	Insufficient cooling water or air flow.	Check for clogged water lines, clogged water filter, low water pressure, or defective air cooling unit. Ensure that cooling water temperaure does not exceed 77°F (25°C) or ambient air temperature does not exceed 113°F (45°C).	Sect. 3.3.4
	b. Operating pressure	Operating pressure is greater than 10^{-1} mbar.	Leak test vacuum system and repair any leaks found.	
	c. Strong magnetic field	Pump is within a magnetic field.	Change configuration of pumping system to move pump out of magnetic field. Magnetic shielding may be necessary.	Sect. 3.3.1, Item 3
25. Pump emits pinging noises during venting.	Rotor blades	Rotor blades are hitting stator disks due to misaligned rotor assembly or incorrectly assembled pump.	Disassemble pump and check alignment of rotor as described in Section 5.4.4.4. Also check for overlapping of stator-disk halves.	Sect. 5.4 Sect. 5.4.4.4 Sect. 5.4.5 Sect. 5.4.7.3

SECTION 8
PARTS LISTS AND DIAGRAMS

8.1 GENERAL INFORMATION

This section contains parts lists, part location diagrams, and the NT-1000/1500 Frequency Converter electrical schematic. Note that Catalog Numbers for the turbopump, the frequency converter, and various accessory items are contained in Table III Ordering Information, located in the front of this manual.

8.2 PART ORDERING INFORMATION

Replacement parts can be ordered from the Order Services Department of Leybold-Heraeus in Export, PA or from your nearest Leybold-Heraeus representative.

When ordering a replacement part, please give its part number and description as listed in the TMP-1000 or NT-1000/1500 Parts List. Also, indicate the model and serial number of your particular unit.

8.3 TMP-1000 PARTS LIST

When ordering replacement parts for the TMP-1000 Turbomolecular pump, see Fig. 8-1 and refer to Table 8-1.

8.4 NT-1000/1500 PARTS LIST AND SCHEMATIC

When ordering replacement parts for the NT-1000/1500 Frequency Converter, see Figs. 8-2 thru 8-4 and refer to Tables 8-2 thru 8-4.

The schematic of the NT-1000/1500 is shown in Fig. 8-5.

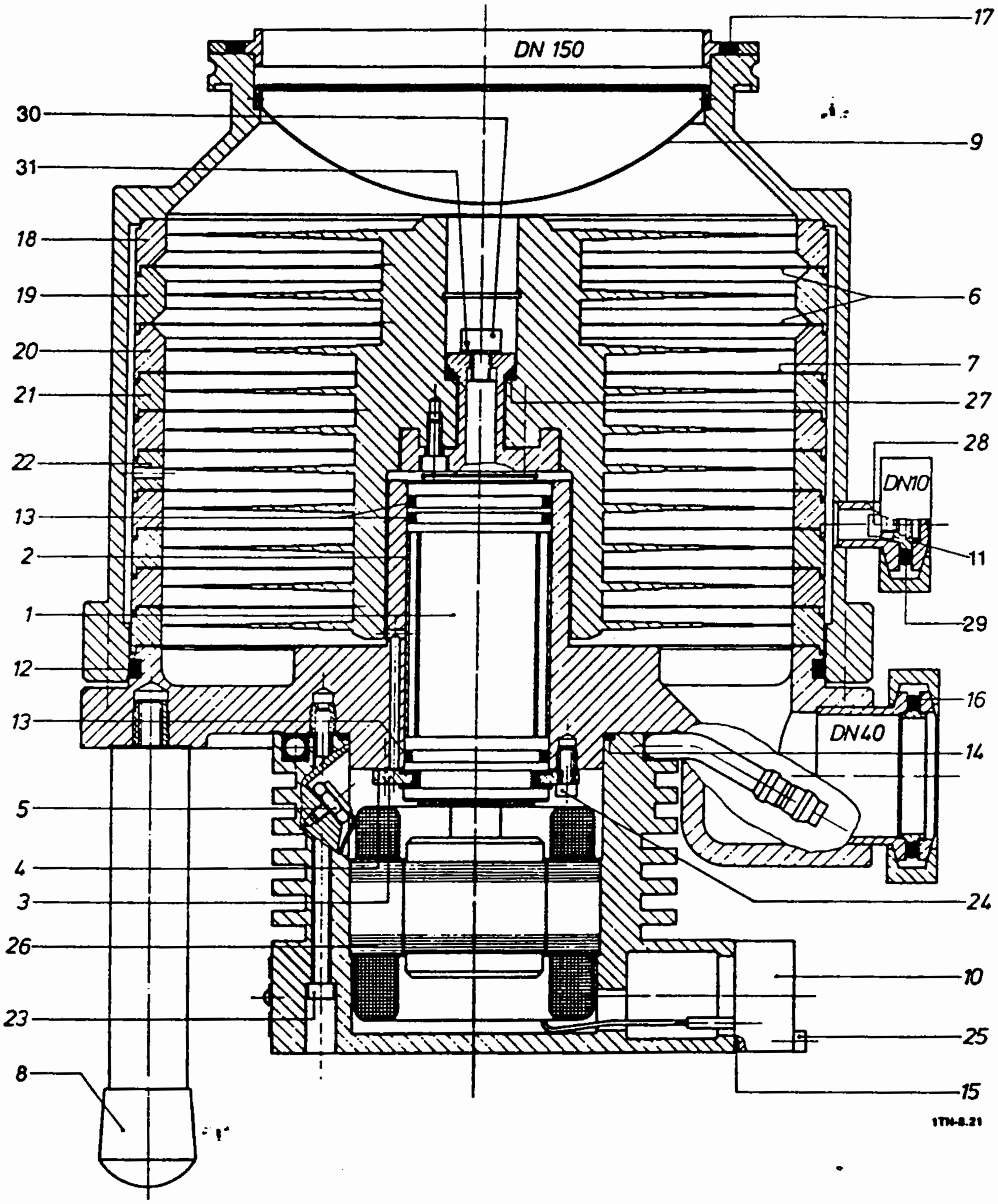


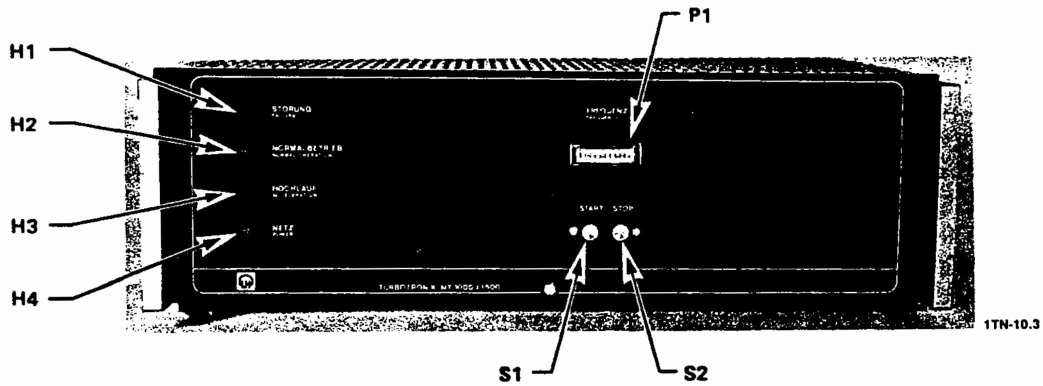
Figure 8-1. TMP-1000 Part Locations

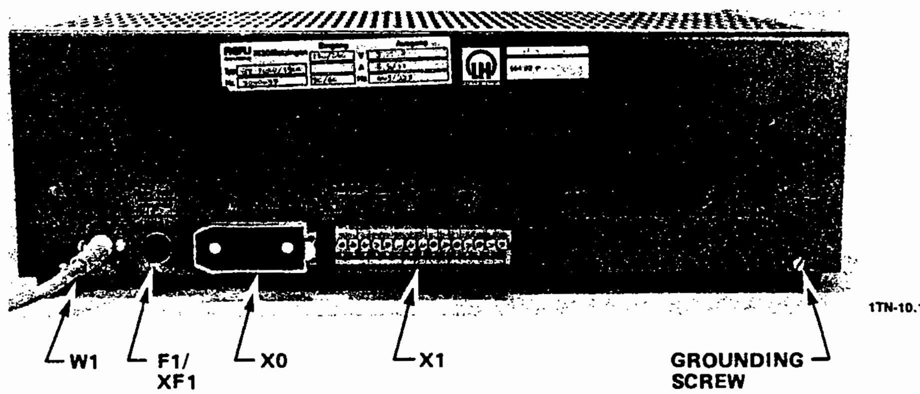
TABLE 8-1. TMP-1000 PARTS LIST*

Item	Part Number	Description
1	85564	Rotor/Spindle Assembly, Complete
2	200-17-001	Cooling Jacket
3	221-02-262	Divided Axial Support, 1/2
4	221-02-258	Pair of Shims
5	500-36-043	Thermostat, 56°C, +/-6%
6	221-02-260	Half Stator Disk, I.D. 70mm
7	221-02-261	Half Stator Disk, I.D. 87mm
8	200-17-047	Cap
9		Wire-Mesh Splinter Screen:
	200-17-247	150LF & 150CF
	200-17-248	200LF
	200-17-249	250LF
	200-17-206	6-inch ASA
10	500-17-311	Motor Electrical Connector
11	200-17-093	Sintered Metal Filter
12	239-50-735	O-Ring, 205 x 5 mm
13	239-49-223	O-Ring, 40.87 x 3.53 mm
14	239-50-179	O-Ring, 84 x 3 mm
15	239-50-145	O-Ring, 29.87 x 1.78 mm
16	239-50-115	O-Ring, 42 x 5 mm
17		O-Ring:
	239-70-512	150LF, 151.77 x 5.33 mm
	239-70-167	250LF, 265 x 5 mm
	200-17-009	6-in. ASA, 202.79 x 3.53 mm
18	233-81-177	Spacer Ring, 226 x 17.6 mm
19	233-81-176	Spacer Ring, 226 x 20.6 mm
20	233-81-178	Spacer Ring Wide, 226 x 17.6 mm
21	233-81-180	Spacer Ring Narrow, 226 x 14.7 mm
22	233-81-179	Spacer Ring with Hole, 226 x 14.7 mm
23	201-03-115	Allen Head Bolt, M5 x 90 mm
24	201-03-204	Allen Head Bolt, M4 x 12 mm
25	201-03-209	Allen Head Bolt, M4 x 25 mm
26	380-26-163	Motor Stator
27	239-70-154	O-Ring, 17 x 3 mm
28	392-25-109	Nozzle
29	239-50-193	O-Ring, 50 x 5 mm
30	200-17-105	Allen Head Bolt, M6 x 20 mm
31	230-02-102	Usit-Gasket

* For Catalog Numbers of various accessory items, refer to Table III Ordering Information located at the front of this manual.

Pass REFU Units





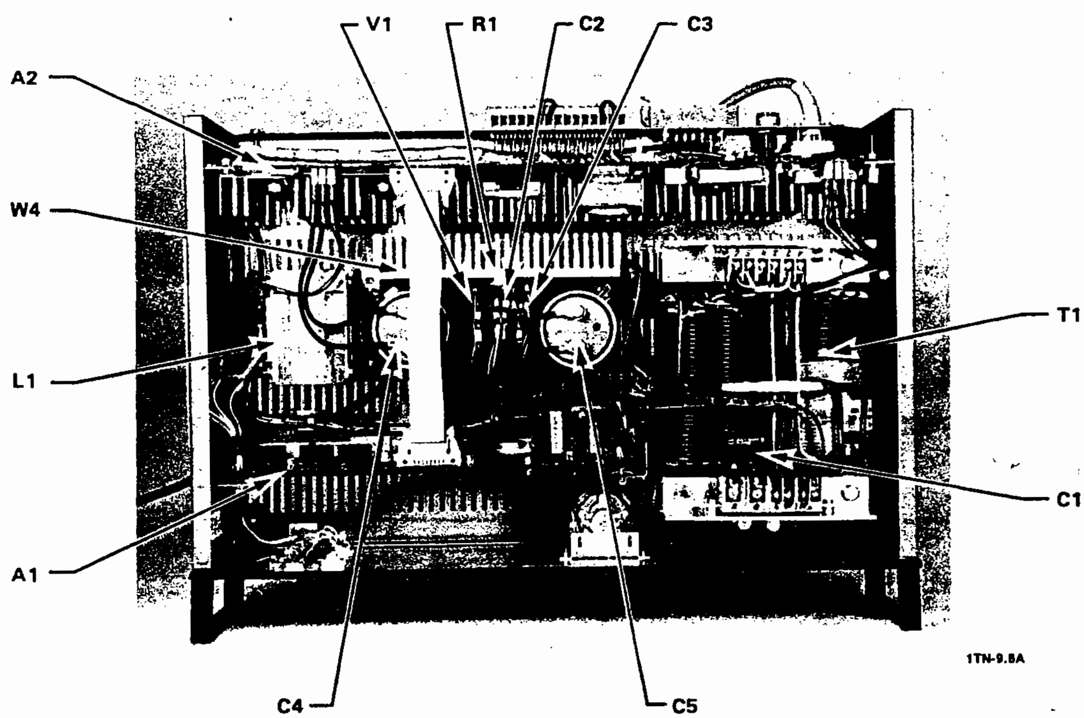


Figure 8-2. NT-1000/1500 Chassis Part Locations

TABLE 8-2. NT-1000/1500 CHASSIS PARTS LIST

Item	Part Number	Description
A1	200-17-043	Control and Regulator Board, Complete (See Table 8-3 for individual part numbers)
A2	200-17-044	Six-Step Inverter Board, Complete (See Table 8-4 for individual part numbers)
C1	--	Capacitor, 1 uF, 250 V
C2	--	Capacitor, 0.01 uF, 32 V
C3	--	Capacitor, 0.01 uF, 32 V
C4	--	Capacitor, 10,000 uF, 63 V
C5	--	Capacitor, 10,000 uF, 63 V
F1		Fuse, Chassis:
	520-25-321	T 6.3A/250 D, 200-240 V AC
	520-25-322	T 10A/250 D, 110-120 V AC
H1	510-43-128	LED, Red
H2	510-43-239	LED, Yellow
H3	510-43-240	LED, Green
H4	510-43-239	LED, Yellow
L1	--	Choke
P1	--	Meter, Frequency, 1 mA
R1	--	Thermistor, 60°C
S1	--	Switch, START
S2	--	Switch, STOP
T1	--	Transformer
V1	723-03-002	SCR Controlled Bridge Rectifier
W0	200-17-045	Pump Cable Assy., 7 Conductor, 5m
W1	--	AC Power Cord, with 115 V AC Plug
W4	--	16 Conductor Cable Assy.
X0	--	Connector, Pump
X1	--	Connector, External/Optional Equip.
XF1	528-28-103	Fuseholder, Socket, F1
	528-28-014	Fuseholder, Cap, F1
--	99-122-049	Power Cord Plug, 250 V AC Straight Blade
--	721-75-000	Extender Ears for 19-inch Rack-mount Installation (2 required)

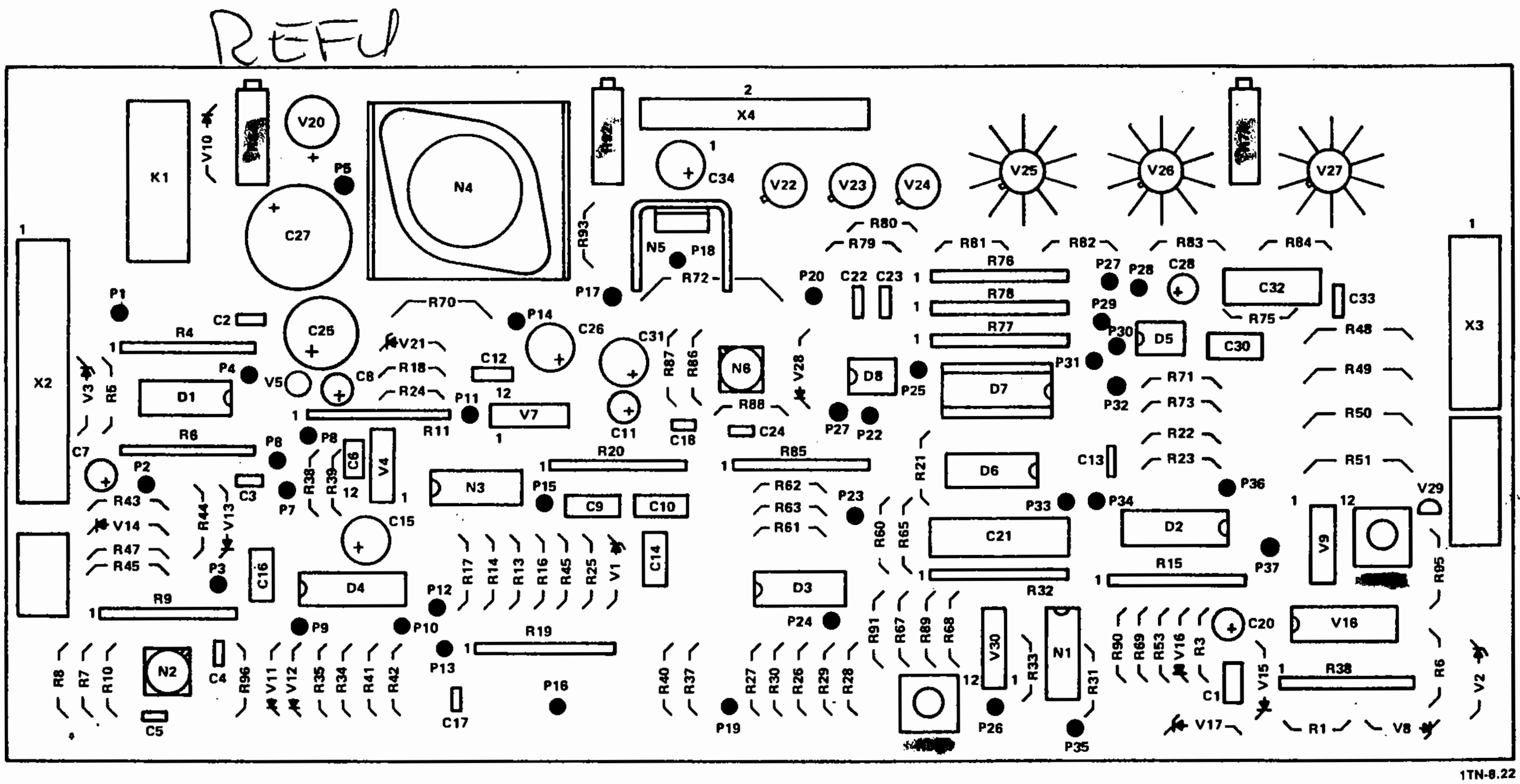


Figure 8-3. NT-1000/1500, A1 - Control and Regulator Board

TABLE 8-3. A1 - CONTROL AND REGULATOR BOARD PARTS LIST*

Item	Part Number	Description
D1	722-39-157	IC, 4011, Quad NAND Gate
D2	722-39-812	IC, 4536, Programmable Timer
D3	722-39-808	IC, 4016, Quad Analog Switch
D4	722-39-809	IC, TCA 280 A, SCR Trigger
D5	722-39-813	IC, 4151, Voltage Controlled Oscillator
D6	722-39-810	IC, 7492, Divider
D7	722-39-814	IC, TBP 18S030 N, 32x8 Bit PROM
D8	722-39-704	IC, 7555, Timer
		348 O.K. 10°C Higher temp.
N1	722-39-283	IC, LM 248 J, Quad Op Amp
N2	722-39-284	IC, LM 741 CH, Op Amp
N3	722-39-283	IC, LM 248 J, Quad Op Amp
N4	722-39-566	IC, LM 340 K-15, 15 V Regulator
N5	722-39-567	IC, LM 340 T-5, 5 V Regulator
N6	722-39-285	IC, TAA 762, Op Amp, High Current
V4	721-69-007	Diode Array, DN64448
V5	723-35-143	Transistor, BCY 78
V7	721-69-007	Diode Array, DN64448
V9	721-69-007	Diode Array, DN64448
V10	510-43-329	Diode, 1N4007
V15	510-43-605	Diode, 1N4148
V16	510-43-605	Diode, 1N4148
V20	722-39-811	Diode Bridge Rectifier, B80 C 800 GI
V22 thru V27	997-00-016	Transistor, 2N5415
V28	510-43-605	Diode, 1N4148
V29	723-35-282	Transistor - FET, VN 1304 N3
V30	721-69-007	Diode Array, DN64448

* See the NT-1000/1500 electrical schematic (Fig. 8-5) for component type numbers not listed in this table.

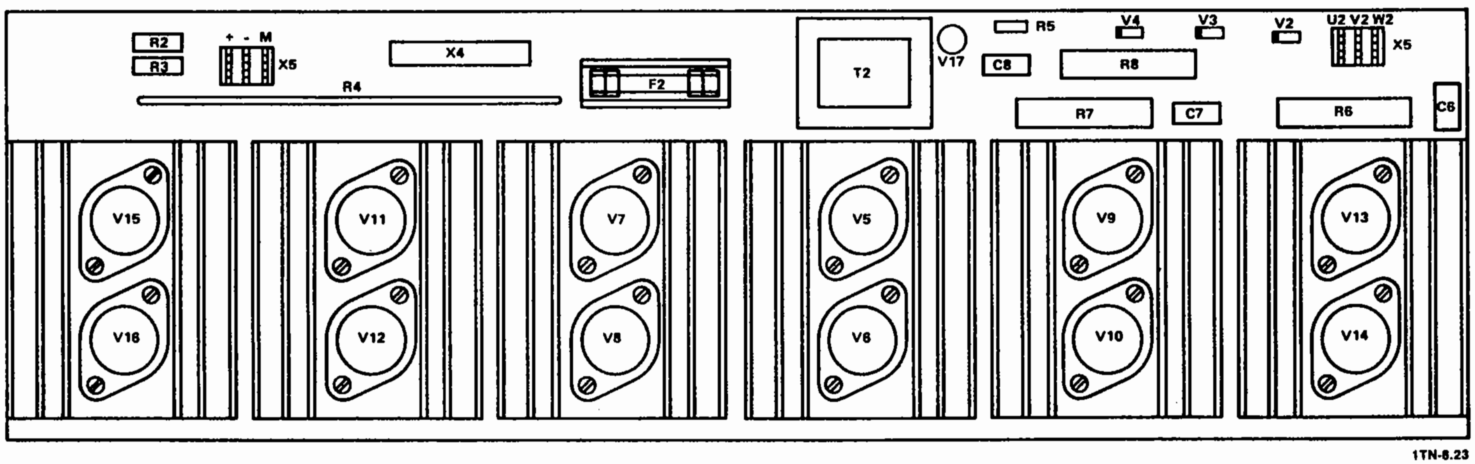
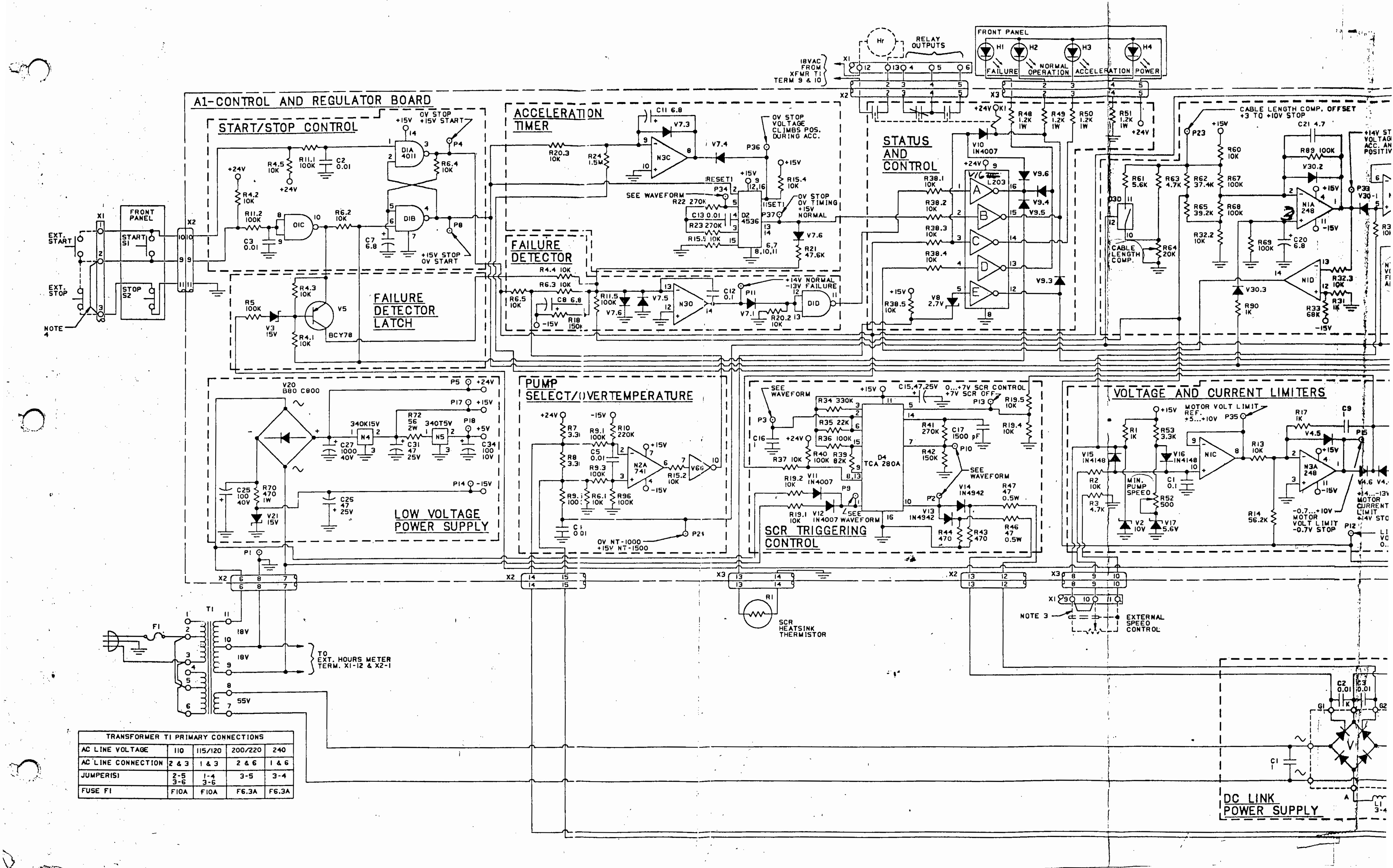


Figure 8-4. NT-1000/1500, A2 - Six-Step Inverter Board

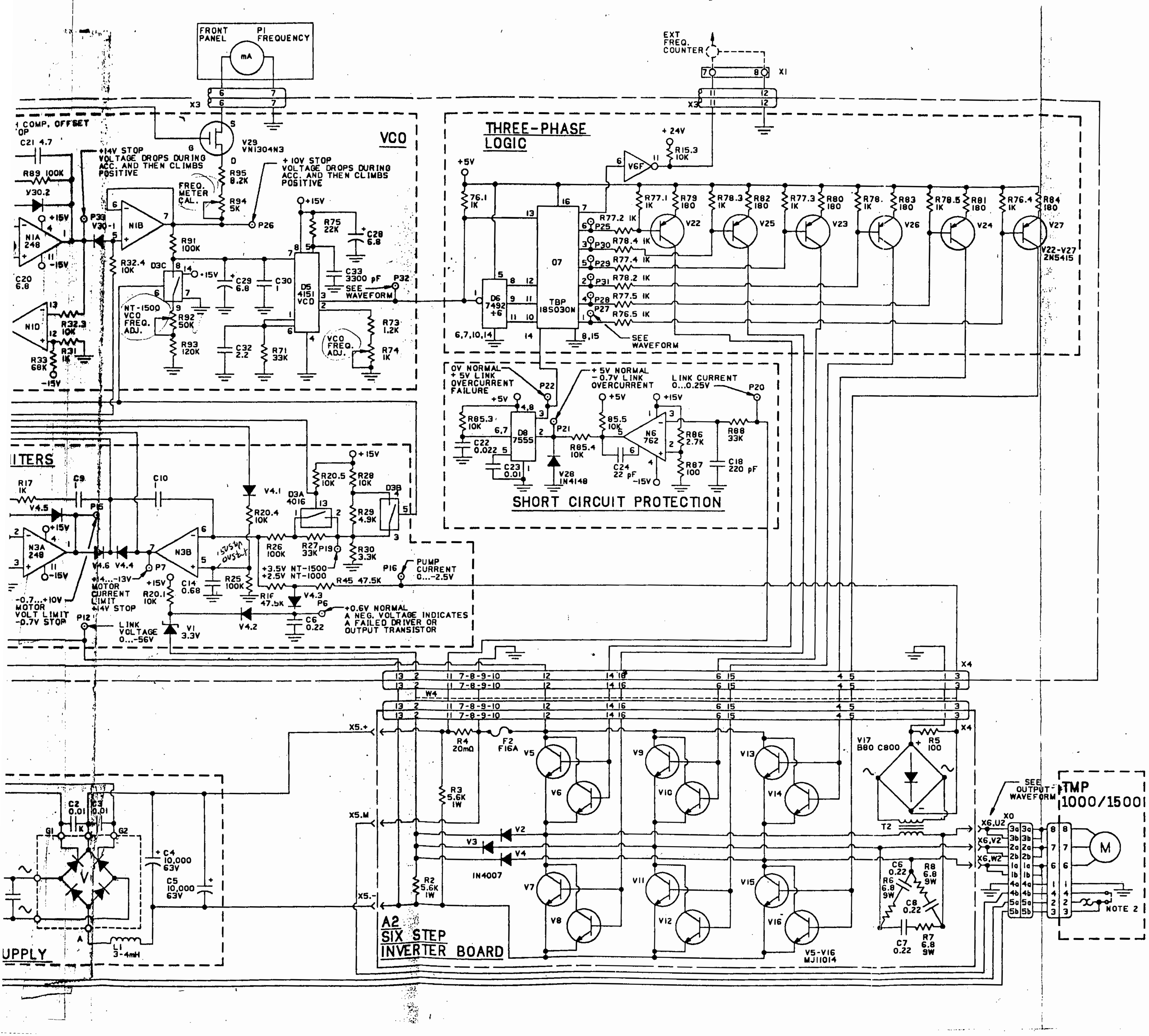
TABLE 8-4. A2 - SIX STEP INVERTER BOARD PARTS LIST*

Item	Part Number	Description
F2	520-25-122	Fuse, F 16A/250 G
V2 thru V4	510-43-329	Diode, 1N4007
V5 thru V16	723-35-004	Transistor, MJ 11014
V17	722-39-811	Diode Bridge Rectifier, B80 C 800 GI

* See the NT-1000/1500 electrical schematic (Fig. 8-5) for component type numbers not listed in this table.

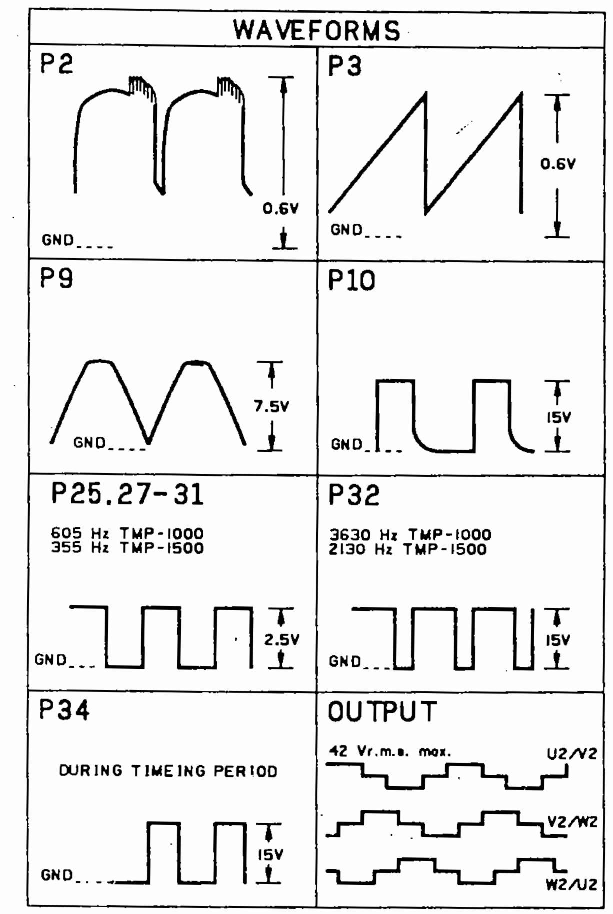


TRANSFORMER T1 PRIMARY CONNECTIONS				
AC LINE VOLTAGE	110	115/120	200/220	240
AC LINE CONNECTION	2 & 3	1 & 3	2 & 6	1 & 6
JUMPER(S)	2-5 3-6	1-4 3-6	3-5	3-4
FUSE F1	F10A	F10A	F6.3A	F6.3A



NOTES:

1. UNLESS OTHERWISE SPECIFIED, RESISTANCE VALUES ARE IN OHMS; CAPACITANCE VALUES ARE IN MICROFARADS.
2. JUMPER INSTALLED ONLY WHEN USING TMP-1000.
3. REMOVE JUMPER WHEN USING EXTERNAL SPEED CONTROL.
4. REMOVE JUMPER WHEN USING EXTERNAL START/STOP PUSHBUTTONS.



Dwg. No. SK3518

Figure 8-5. NT-1000/1500 Electrical Schematic

RLFU