SAND90-8224
Unlimited Release
Printed September 1990

SAND--90-8224

DE91 000883

DESIGN OF A DUAL PORT VOLUME MEASURING SYSTEM

Paul A. Klevgard
Measurement Standards, Calibration, &
Photography Division
Sandia National Laboratories
Livermore, California

ABSTRACT

A volume measuring system is described which uses the ideal gas law and pressure measurements to determine an unknown vessel's volume when a gas expands into that vessel from a known volume. The design, the engineering principles, the calibration, and the accuracy of this computer-controlled system are all discussed. A set of electrical and mechanical drawings of the system is included.

MASTER

rb

CONTENTS

	<u>Page</u>
Introduction	7
Pressure and Tubing Ratios	11
Helium Metering Manifold	13
Hardware Design	15
Software	20
Calibration	21
Test Results	22
Drawings	23
Bibliography	23
APPENDIX A - SOFTWARE	A1
APPENDIX B - PVMS DRAWINGS	B1

ILLUSTRATIONS

<u>No.</u>		<u>Page</u>
1	Simplified System	8
2	Full System	10
3	Helium Metering System	14
4	Water Bath	16
5	Valve Drivers and Manifold	17
6	PVMS Computer, Instrument Rack, and Vacuum Pump	18
A1	Software Flowchart	A3

DESIGN OF A DUAL PORT VOLUME MEASURING SYSTEM

Introduction

The component development groups of Department 8440 at Sandia National Laboratory-Livermore are often required to measure the internal volumes of a variety of pressure vessels, valves, and manifold assemblies. To expedite these measurements, a computer-driven, automated, volume measuring system was designed, fabricated, and calibrated.

A precision volume measuring system (PVMS) uses a gas ratioing system to measure the pressure of the gas in a known volume and the pressure of that same gas expanded into an unknown volume. Using helium at sub-ambient pressure levels ensures that the ideal gas law applies in this process. The volume of the known and the unknown vessels are then related by their respective pressures through Boyle's law, $P_1 \times V_1 = P_2 \times V_2$, where P_1 is the initial pressure in the initial volume V_1 , and P_2 is the final pressure in the final volume V_2 .

In schematic form, Figure 1, the PVMS may be regarded as a helium supply connected to a vacuum pump by a valved manifold from which projects a known volume and the unknown test volume. The "forward" measuring cycle begins with valves B and C open, evacuating V_{ref} until the vacuum gage reads less than 100 millitorr (100 microns of Hg) of pressure. Valves B and C are then closed and A and D opened. Valve D is closed when the pressure equals 10 psia. A delay interval of 6 to 8 minutes then follows, allowing the thermal effects of charging to dissipate. At the end of this interval a pressure reading P_1 is taken. Valve C is then opened, admitting the gas from V_t and V_{unk} . After another delay interval, a second pressure reading, P_2 , is taken. This gives a single equation with two unknowns:

$$P_1 \times (V_t + V_{unk}) = P_2 \times (V_t + V_{unk} + V_{ref})$$

The "reverse" measuring cycle then begins by evacuating V_t and V_{unk} . When the vacuum level is lower than 100 millitorr, valves B and A are closed. Valves D and C are opened to admit helium up to 10 psia, at which time valve D is closed. After a delay interval, a pressure reading P_3 is

V_t = unknown volume of tubing between valves A, B, C, and D
 V_{unk} = unknown volume of test vessel
 V_{ref} = known volume of reference vessel

Figure 1. - Simplified System

taken. Valve A is then opened and, after another delay, pressure reading P4 is taken. A second equation with two unknowns may then be written:

$$P3 \times (V_t + V_{ref}) = P4 \times (V_t + V_{ref} + V_{unk})$$

Eliminating V_t between the two equations then yields V_{unk} in terms of 4 pressure readings and V_{ref} :

$$V_{unk} = V_{ref} \times \frac{P3 (P1 - P2)}{P1 (P3 - P4)}$$

A complete description of the operation and the calibration of a PVMS is set forth in a previous report ("Precision Volume Measuring System", SAND84-8014) by the same author. The algebraic derivation of the equation for V_{unk} from Boyle's law is also included in this report.

Since Boyle's law assumes that the temperature of the gas involved stays constant throughout the measurement cycle, some care must be taken to preserve isothermal conditions. There are two sources of gas temperature change within the manifold and the reference and test volumes: 1) changes of ambient conditions, and 2) heating and cooling effects during vessel filling and during the gas expansion processes. A constant temperature water bath will ensure that ambient conditions do not change during the test. And agitating the bath water will even out the inevitable heating and cooling effects of the helium gas.

Submerging the manifold assembly in the water does not present any great difficulties. The pressure transducer used was a submersible model 8010 depth sensor from Paroscientific, Inc. of Redmond, Washington. The valve bodies themselves may be submersed, although their pneumatic drivers should be kept above the water line by means of stand-off couplers. The vacuum gage may be located just outside the bath on the tubing leading to the vacuum pump. Because the vacuum gage and its connecting tubing sees small temperature changes due to air currents, a valve within the bath is used to isolate this section from the manifold itself. To allow the testing of a wide range of unknowns, reference volumes of various sizes are connected to the manifold. Adding a computer which reads temperature, pressure, and vacuum, and which controls temperature and valve operation, completes the system. The resulting schematic is shown in Figure 2.

What the system regards as the "test unknown" is everything after the last valve leading to the test vessel. The operator must subtract any connecting tubing volume to find the actual volume of his vessel. This is normally done by running the test a second time with the vessel removed and the tubing capped off. This external tubing must be distinguished from the internal tubing, V_t . The latter is never assigned a value, although it plays its role in the gas expansion process characterizing both the forward and the reverse cycles.

Figure 2. - Full System

Pressure and Tubing Ratios

All volume calculations are based on the equation cited above:

$$V_{\text{unk}} = V_{\text{ref}} \times \frac{P_3 (P_1 - P_2)}{P_1 (P_3 - P_4)}$$

P1 is the starting pressure for the forward ratioing cycle and P3 is the starting pressure for the reverse ratioing cycle. Both are software controlled to be a nominal 10 psia, which means that the ratio of P3 over P1 is simply 1. As a result, the volume calculation actually depends upon the ratio of two pressure differences, (P1 - P2) and (P3 - P4). This provides one advantage and imposes one constraint.

The advantage of ratioing pressure differences is that offsets do not affect the calculations. If the pressure transducer reads 1 psi high throughout its range, the pressure differences are unaffected and the accuracy of the volume calculation is preserved. The constraint involves the relative values of the two differences: neither the numerator nor the denominator should be a small value. The ratio is especially unstable and susceptible to error magnification if the denominator is a small value and the numerator is not, or vice versa. The system, both in hardware and in software, must be designed to permit a significant pressure drop from P1 to P2 and from P3 to P4. A couple of examples may best illustrate this.

Suppose that an unknown plus tubing totals about 350 cc, the internal tubing is about 80 cc, and the reference selected is about 300 cc. If the expansion goes into the reference vessel and the beginning pressure is 10 psia, then P2 is:

$$10 (80 + 350) = P_2 (80 + 350 + 300)$$

$$P_2 = 5.89 \text{ psia}$$

For the reverse cycle, if P3 is 10 then $P_4 = 10 (380)/730 = 5.2 \text{ psia}$.

As a second example, suppose that an unknown plus tubing totals only 10 cc, the internal tubing is still 80 cc, and the reference selected is 10 cc. For the forward cycle:

$$10 (80 + 10) = P_2 (80 + 10 + 10)$$

$$P_2 = 9 \text{ psia}$$

For the reverse cycle, P4 also equals 9 psia.

In the first example the ratio of (P1 - P2) over (P3 - P4) is 4.11/4.8. Both numerator and denominator are large enough so that random errors have little effect upon the ratio value. In the second example, where the ratio is 1/1, both random errors and resolution errors can play a much larger role. The problem in this latter case is that the internal tubing value, V_t , is too large relative to the volume of the unknown. A similar effect obtains if the reference volume is very much larger than the unknown vessel. From these examples, two conclusions follow: 1) the internal tubing volume must be proportioned to the smallest reference volume of the manifold system, and 2) any test unknown should be ratioed against a known reference vessel of approximately equal size.

For this particular PVMS the measurement requirements were an accuracy of better than 0.3% over a range of 2 liters down to 3 cc. This necessitated two differently sized internal tubings and a total of six references from 1000 cc down to 10 cc. The internal tubing connecting all the reference vessels was split into two sections by a valve: one section had the larger vessels, 1000, 300, 150, and 75 cc, and the other section had the two smaller reference vessels, 40 and 10 cc. The valve dividing these references remained open when testing large unknowns and closed when testing small unknowns.

A schematic of the entire system is shown in Appendix B, Drawing 99626. All the reference vessels are labeled with their nominal volume values and all vessels and their valves are submerged in the water bath. Valves 106, 108, 202, 109, 200, 201 plus their connecting tubing are also submerged; all remaining valves and tubing are outside of the bath. Valve 200 is a three-way valve which is open toward valve 201 when testing large unknowns. The internal tubing volume delimited by valves 106, 202, and 201 is 37 cc. When testing small unknowns, valve 200 is open toward valve 109 and valve 108 is closed during all gas fills and gas expansions. The internal tubing volume delimited by valves 108, 202, and 109 is only 6.4 cc. This is achieved by using eighth-inch diameter tubing in this section.

The volume system measures (ratios) any volume after its last valve, 201 for large vessels, 109 for small vessels. Extending from this valve there must be a length of tubing which connects to the operator's unknown vessel. When the test vessel is removed, the capped off "external" tubing represents the smallest volume the system effectively measures. Working through the mathematics of desired pressures after gas expansion, one finds that the optimum external tubing volume is simply the equal of the internal tubing volume. Hence, after valve 201 there is a "tag-along" volume of 37 cc before the fitting which connects to the unknown. This takes the form of about 13 inches of half-inch diameter tubing which is joined to the external tubing at one end and sealed off at the other end. The tag-along volume after valve 109 is 6.4 cc (about 9 inches of quarter-inch diameter tubing).

The differing external tubing volumes for testing large versus small vessels is what creates the need for two test ports and a three-way valve. The same effect can be achieved with a single port if one is willing to connect fittings to the last valve with different tag-along volume values for large versus small vessel tests. The design used here imposes fewer plumbing connections upon the operator and requires but a single decision: connect the vessel directly to the large port or to the small port.

Helium Metering Manifold

Any PVMS is likely to be used to test vessels whose size differs greatly. In this case, the smallest "vessel" would be the capped off tubing of the small port, namely 6.4 cc. The largest vessel might be two liters; vessels even larger than two liters could be tested, although with decreasing accuracy. If the helium system consists simply of a bottle, a regulator, and a single metering valve, then problems appear. If the metering valve is closed down to a flow rate appropriate to small vessels, then large vessels, either reference or test, will take too long to fill. And if the metering valve is set to a flow rate appropriate to large vessels, then the small vessels tend to overfill well beyond the 10 psia target value. The best solution is to have a variable helium metering system under computer control. This avoids both overfills and long fill times. Without overfills, both P1 and P3 are nearly identical, which has some advantages as mentioned above.

A variable helium metering system is depicted in Figure 3. Two regulators are used for safety considerations. The first regulator is on the gas bottle and it reduces the pressure down to 100 psig. Valve 207 is an electric solenoid valve, helium leak tight, that only opens when the computer calls for helium. Downstream from this valve comes the second regulator which reduces the pressure to about 5 psig. A relief valve set to 10 psig follows which serves to protect the pressure transducer down line. Three electrically operated solenoids follow, valves 204 through 206, mounted on a single manifold. Up to the manifold the tubing used is one-quarter inch diameter; after the manifold the tubing is one-eighth inch until pneumatically-actuated ball valve 203. This smaller tubing reduces the helium reservoir downstream from the three solenoid valves; this in turn eliminates a helium surge when valve 203 opens to an evacuated internal tubing.

① PETER PAUL ELECTRONICS CO.
480 JOHN DOWNEY DR.
NEW BRITAIN, CT 06050
(203) 229-4884

② CIRCLE SEAL - LOCAL DISTRIBUTORS
HOME OFFICE: (714) 774-6110
P. O. BOX 3666
ANAHEIM, CA 92803

③ SOLENOID/MANIFOLD ASSEMBLY:
ESM-2011-120 3BC-24VDC
VERSA PRODUCT CO., INC.
22 SPRING VALLEY ROAD
PARAMUS, NJ 07652
(201) 843-2400

Figure 3. - Helium Metering System

Each of the metering manifold's three exits are only open if the corresponding solenoid is energized. One of these exit lines allows free flow, a second exit line is partly constricted by a metering valve, and the third exit line is severely restricted. The result is a flow system that is variable through the computer's choice of opening any combination of the three solenoids. The software can do this by using the size of the reference vessel selected as an indication of flow rate. An alternative software approach is to start with a default flow rate and adjust it on the basis of the rate of pressure rise over the course of executing a measurement loop.

Hardware Design

The bath used for this PVMS is an old calorimetry bath fabricated by Mound Laboratory (Figures 4 and 5). It holds about 200 gallons of water, the level of which can be raised or lowered by reversing the rotation of the agitator impeller. The bath and all of the submerged manifold hardware are stainless steel; a small amount of "Rust Raider" by Radiator Specialty Company of Charlotte, N.C., is nevertheless added in case a test item is subject to corrosion. The bath's original fast heater (220 vac) failed and was replaced with a similar model, CNBS1-352, from Proheco Manufacturing Company of Pomona, California. The latter is protected from overheating by a meltable fuse. Both heaters are under simple off-on control from the computer. Cooling is achieved by heat loss to the room; heating comes from the energy of the impeller, as well as the two heater elements. A stable operating temperature of 27.0° C was found to be ideal for the thermodynamics of the system.

Exclusive of the computer, all the electronics are housed in a 19 inch rack about 4 feet high (Figure 6). This rack has an instrument panel (drawing title "PVMS Front Panel Parts Layout" in the appendix) featuring a manifold schematic displaying the location and status of the various manifold valves. A lit green LED indicates an open valve; a lit red LED indicates a closed valve. The three-way valve, V200, has two green LEDs which indicate the direction in which the valve is open. Since pressure, temperature, vacuum, and valve status are all displayed on the instrument panel, the operator is given complete information on the state of the system.

For ease of communication, all instrumentation should be selected which offers IEEE-488 bus connections to the computer. The Newport RTD temperature readout is so equipped. When the Granville-Phillips vacuum gage was ordered an IEEE-488 option was not available; output was in BCD format. Rather than install a BCD card in the IBM computer, a converter box was used (model 4833 from ICS Electronics Corp., San Jose, California) to get from BCD to IEEE-488. This would now be unnecessary; Granville-Phillips offers a "Convectron" vacuum gage and readout with an IEEE-488

Figure 4. - Water Bath

Figure 5. - Valve Drivers and Manifold

Figure 6. - PVMS Computer, Instrument Rack, and Vacuum Pump

option (model 316 for up to three sensors). The second vacuum gage on the manifold is not read by the computer. It is used to help isolate any leaks which occur in the manifold.

The Hewlett-Packard model 3488A Switch/Control Unit is a versatile interface box whose function depends upon the specific module plugged into one of its five available slots. For the PVMS, three slots are filled with option 011 cards, a ten-channel general purpose relay. Upon computer command via the IEEE-488 bus, these cards actuate relays operating at 24 vdc. Electric solenoid valves, V204-V207, are operated directly by these relays; pneumatic valves (V100-V106, and V108-V203) are operated via the Tyna_Mite valves which control house air (50 psig). Relays (channels) 208, 209, and 301 actuate remote high current relays which in turn control the two heater circuits and the vacuum pump motor.

The bath agitator must be turned on manually. All other electric power is through an off-on key switch on the instrument panel. Once this key is turned to "on", all the electronics have power and the computer boots itself from a hard disk. An autoexec.bat file loads and runs the appropriate software, and the operator is presented with a graphics screen listing his choices. One of the choices presented is that of "shutdown". When the test is finished or aborted and shutdown is selected, the computer shuts off the heaters and vacuum pump and closes all valves. Once the vacuum pump is off, the helium inlet valves are opened to bring the vacuum line up to atmospheric pressure. This prevents any migration of pump oil into the vacuum line and hence to the manifold. Once the vacuum line and manifold are at 14.3 psia, the helium inlet valves are closed and the computer screen tells the operator to turn the key switch to "off".

The vacuum line from the pump has an internal diameter of about 0.75 inches and the fittings are KF 16 couplings. Just before valve V107 the line switches to quarter-inch tubing. It would have been better to run this section in half-inch tubing up to valve V106 (in the bath). The larger pneumatic drivers required for half-inch valves would have been more awkward to install, but the vacuum characteristics of the manifold would have been improved. One quarter-inch tubing could have begun on the manifold side of V106. As presently built, the quarter-inch and eighth-inch tubing sections tend to slow down the vacuum response somewhat.

Except for the helium inlet valves, V203 through V207, all valves used are quarter-inch ball valves. These valves are ordered with Cajon-VCR fittings for two reasons: 1) this fitting is superior to Swagelok for vacuum service, and 2) the zero clearance of this fitting permits the easy replacement of valves if that becomes necessary. Those four valves, V106, V107, V202, and V203, which either terminate the ratioing manifold or isolate vacuum gages, have the standard configuration (unported) ball, Whitey part number SS43-VCR4. The remaining valves, with one exception, have the ported ball, SS43HL-VCR4. This porting configuration creates a constant-volume valve: the manifold volume is not changed by ball rotation

(see SAND84-8014). The exception is valve V108 which does not have to be constant-volume: it remains open when ratioing large vessels, and closed when ratioing small vessels. Unported ball valves have an extra sealing surface compared to ported ball valves and where possible they should be used.

That section of the manifold plumbed with one-eighth inch tubing also features one-quarter inch valves because Whitey does not make a one-eighth inch, constant-volume, ball valve. Cajon-VCR male weld glands must be used between these valves and the eighth-inch tubing. Cajon makes such a reducing gland (part # SS-2-VCR-3); an unbored (blind) gland, SS-4-VCR-3-.75LG-BL, may also be modified for this purpose. If modification is chosen, a shoulder should be cut into the gland to reduce the metal mass at the weld junction. If this is not done, the weld heat may burn through the tubing before melting the gland surface.

Software

A regular IBM-PC was available at the beginning of this project and was chosen as the controller. Cards provide for extra memory, graphics (Hercules graphics card), and IEEE-488 interface (National Instruments card). The software is a compiled BASIC; namely, Microsoft QuickBASIC, version 4.5. The graphics package is HALO 88, QuickBASIC, version 1.00.12, from Media Cybernetics. The custom software code, entitled "Volume", must be linked with an object file for the IEEE-488 interface, plus a graphics object file, plus a graphics library: LINK VOLUME.OBJ+QBIB1.OBJ+HALODVQB.OBJ,,HALOQB.LIB.

A software flowchart and the code itself is provided in Appendix A. The software was adapted from a previous project and includes only three subprograms: Close1, and Open1 to actuate valves, and Textcall to refresh the graphics screen. Both "close" and "open" are reserved words for QuickBASIC, hence the use of the numeral "1". All other functions are accomplished by "GOSUB" commands which branch to a named line label and then return. Most of these subroutines are self explanatory by their name, but some comments are appropriate. "Measure" controls the entire sequence of function gosubs and prints out the test results. "Volume" contains the loop which defines the forward and reverse cycles. "Evac", "Fill", and "Expand" all call valve sequences to fulfill the functions their names imply. "Refselect" does a quick ratioing of the unknown against a default reference and selects the appropriate set of reference vessels, depending upon the unknown's volume. Valves (and hence their reference vessels) are assigned integer numbers in "Refselect" on a binary basis: V100 = 1, V101 = 2, V102 = 4, V103 = 8, V104 = 16, V105 = 32. In the routine "Decode", these integers are converted to channel strings which the HP 3488A can interpret. "Presdsp" takes the value for pressure (Pres), rounds

it to two decimal places, converts each digit to a string of zeros and ones, and sums each string according to the place value of its ones. The resulting integer values are sent to the I/O module of the HP 3488A and hence to the seven-segment displays on the display panel.

Calibration

The first phase of calibration involves assigning volume values to the different reference vessels. The second phase of calibration involves testing the accuracy and precision of the system by measuring traceable, known, standard volumes.

The five larger reference vessels (40, 75, 150, 300, 1000 cc) along with their constant-volume valves were measured on the PVMS in the SNLL Standards Lab. The smallest reference of around 10 cc had to be measured by ratioing against a known standard. For this purpose, a precision cylinder (Drawing A42128) was fabricated and measured very precisely in the Dimensional Standards Lab. The cylinder was made of invar (70% iron, 30% nickel) to achieve a zero coefficient of thermal expansion. Two end caps were also made (of stainless steel), Drawings A42130 and A42131. The assembled cylinder plus end caps, and the connecting tubing, were then ratioed 12 times against the 10 cc reference. This gave an expression relating the unknown reference to the known standard plus the unknown connecting tubing. The cylinder was then disassembled and the brass plug (Drawing 782019) was then screwed into the ported end cap. This subtracted the known cylinder but did not change the connecting tubing. This tubing was then ratioed 12 times, the average of which gave an expression relating the unknown reference to the unknown tubing. Two unknowns (connecting tubing and reference) were then related by two independent equations; combining yielded a value for the reference, namely 10.309 cc (see line 17510 in the software).

With all of the reference vessels assigned a volume value, the accuracy and precision phase of the calibration could proceed. The testing was spread over some four months and yielded the test data below. Six precision reference standards of known dimensions were used for the accuracy testing. A seventh standard was generated by placing a ball bearing of known volume inside of Std. B. All measurements are traceable to local dimensional standards which in turn are traceable back to the Albuquerque Primary Standards Lab and hence to NIST.

Test Results

<u>Item</u>	<u>Test Value</u>	<u>Actual (cc)</u>	<u>Err</u>	<u>Err %</u>
<i>Tested on Small Port:</i>				
Std.B Minus Ball	3.933	3.9336	-.00058	-.015%
Std.B	7.118	7.1259	-.0079	-.11%
Std.C	7.976	7.9817	-.0057	-.07%
Std.50	49.692	49.7030	-.011	-.022%
<i>Tested on Large Port:</i>				
Std.155	155.23	155.2197	+.010	+.007%
Std.300	299.31	299.4428	-.133	-.044%
Std.500	500.84	500.606	+.234	+.047%

An average of 24 tests (repetitions) were performed on each standard volume listed above. The volume uncertainty of the dimensionally measured standards is a maximum of 0.001 cc. The possible error in the mean for a series of test runs is typically 0.0006 cc. Hence, when adding the bias to the error in the mean to the reference uncertainty to get the total systematic uncertainty, the bias overwhelms the other contributions. Assuming the customary three repetitions for any volume measurement, from 2000 cc down to 10 cc, the total systematic uncertainty of a measurement is +/- 0.1%, or one part in one thousand. For a measurement of 10 cc the uncertainty is 0.01 cc which is close to the absolute minimum uncertainty of the system. Hence, below 10 cc the systematic uncertainty is taken as a constant 0.01 cc. This high accuracy at the low range is made possible by the unique design of two separate manifolds in the measuring system. For a single measurement at a 90% confidence level, the 3 sigma random uncertainty over the entire range is less than 0.1% (e.g., 0.31 cc at 500 cc volume).

All calibration measurements were made on vessels in a water bath at 27.0° C. Future users will have the option of running a test: 1) in the bath but without temperature control, 2) outside the bath. Either method will increase the scatter without greatly affecting the accuracy. Nevertheless,

when used under these non-ideal conditions, the system should be assumed to have a systematic uncertainty of 0.2% of reading or 0.02 cc, whichever is larger.

Drawings

The drawings (Appendix B) are functionally complete for the electronics rack and for the manifold assembly. Since the bath was pre-existing, it was not drawn in any detail. Some of the bath's ancillary equipment was also omitted, namely the heaters and the pump-filter system. The heater relays, mounted on the bath, are only shown schematically.

Bibliography

R. L. Jones, "Precision Volume Measurement System," Sandia National Laboratories, SAND79-8057, October 1979.

P. A. Klevgard, "Precision Volume Measuring System," Sandia National Laboratories, SAND84-8014, November 1984.

R. L. Shaffer and D. A. Homan, "Computerized Automated Pressure/Volume Calibration System," Presented at The 1975 Monsanto Process Computer Symposium, Springfield, Massachusetts.

APPENDIX A

SOFTWARE

Figure A1. - Software Flowchart

Volume Measurement Software: MicroSoft QuickBasic for IBM-PC

```
DECLARE SUB Textcall (X1$, X2$, X3$, X4$, X5$, X6%)
DECLARE SUB CLOSE1 (Y$)
DECLARE SUB OPEN1 (Z$)
REM $INCLUDE: 'QBDECL4.BAS'

10 ' PROGRAM "VOLUME" TO CONTROL HPL PRECISION VOLUME
SYSTEM. Line numbers are optional in QuickBasic.
20 ON ERROR GOTO Err1
30 ' RE-WITTEN MAY 1989 BY P.A. KLEVGARD, 8285
40 '
50 '
60 '
65 '
70 '
75 '
80 '
85 OPTION BASE 0
100 DIM Pbcd%(4, 4), Predim%(16), VAC$(30), F%(1), Byte%(2),
Meter$(30)
105 DIM C(4), P(4), V(30), Save(30), Ref(127), Evac$(30), Fill$(30)
110 DIM Vref$(33), L$(50), TUBE$(15), Operator$(40), Item$(45)
DIM WRT$(80), F$(80), S$(15)
115 DEFINT I-J, N
118 GOSUB INITIALIZE ' TO 18000
120 '
130 ' * * * * * BEGIN MAIN PROGRAM * * * * *
140 Start:
145 DO
150 GOSUB UPDATE ' TO 250
160 LOOP ' PROGRAM ENDS VIA SOFTKEY
170 '
180 '
190 '
200 '
210 '
220 '
230 '
240 '
250 UPDATE:
260 GOSUB Pressub ' TO 11000
270 GOSUB TEMPSUB ' TO 11250
280 GOSUB Presdsp ' PANEL, TO 12000
285 GOSUB Vacuum ' TO 13500
290 RETURN
300 '

```

```

310
320
330
340
2000 Measure:
      Measureflag% = 1
2002 CALL CLOSE1("301") ' Vac Pump on
2005 Count% = 0
2006 Spreadmax% = 0
2007 GOSUB Testentry ' TO 14000
2010 CALL CLOSE1("106,107,108,202")
2020 SLEEP 1
2025 FOR I = 1 TO 2
2030     GOSUB Pressub
2035     GOSUB Presdsp
2036     SLEEP 1
2040 NEXT I
2050 Timeflag$ = "Short": IRuns% = 1
2055 Dispflag$ = "Part"
2060 GOSUB GRAPH
2065 GOSUB TEMPSUB
2066 GOSUB Vaccheck
2070 GOSUB Vacuum
2075 IF Mtorr > Maxtorr THEN GOSUB Vaccheck
2123 IF Bath$ <> "HEAT" THEN 2133
2124     MESSAGE$ = "WAITING FOR STABLE BATH TEMP"
2125     GOSUB GRAPH
2127     SLEEP 7
2128     GOSUB UPDATE
2129     IF Temp > 27 OR Temp < 26.99 THEN 2127
2130 MESSAGE$ = ""
2131 GOSUB GRAPH
2133 GOSUB Refselect ' To 9000
2135 GOSUB Decode ' Gets Vref$ & Vunk$, to 11400
2136 GOSUB VOLUME ' Exercise
2140 Runtot = 0
2145 Run2tot = 0
2150 Dispflag$ = "Full" ' Enables full CRT
2155 Timeflag$ = "Long" ' Enables long cycle
2156 GOSUB TEMPSUB
2157 LPRINT USING "    & ##.##&"; "TEST TEMPERATURE:"; Temp; "
F."
2160 Timestart = INT(TIMER) ' Seconds from "midnight"
2165 FOR IRuns% = 1 TO Runs%
2170     GOSUB GRAPH
2175     GOSUB VOLUME
2180     V(IRuns%) = V9
2190     Runtot = V(IRuns%) + Runtot
2200     IF Seq% = 1 THEN Save(IRuns%) = V(IRuns%)

```



```

2210 IF Seq% = 2 THEN
2215     Save(IRuns%) = ABS(Save(IRuns%) - V(IRuns%))
2220     Run2tot = Run2tot + Save(IRuns%)
2225 END IF
2228
2230     F$ = "    & #####          &###.##&"
2233 LPRINT USING F$; "VOLUME ="; V(IRuns%); "Temp= "; Temp;
"C."
     F$ = "    & #####          &###"
2235 LPRINT USING F$; "RATIO ="; Ratio; "Spread="; Spread%
2240 NEXT IRuns%
2240 Avg = Runtot / Runs%
2245 IF Runs% > 2 THEN GOSUB Stddev 'To 6000
2255 LPRINT USING "&    &#####"; LF$; "AVERAGE IS: ";
Avg
2260 IF Seq% <> 2 THEN 2305

```

SUBTRACTED VOLUME ROUTINE

```

2265     Avg = Run2tot / Runs%
2267     F$ = " * SUBTRACTED VOLUME CALCULATION FOLLOWS *"
2270 LPRINT USING "&&&    &"; LF$; LF$; LF$; F$
2275     FOR J = 1 TO Runs%
2280         V(J) = Save(J)
2283         F$ = "    & #####&"
2285         LPRINT USING F$; "VOLUME ="; V(J); " "
2290     NEXT J
2295 LPRINT USING F$; " * SUBTRACTED VOLUME AVERAGE IS: ";
Avg; "cc."
2296     S$ = "SUBTRACT" ' Flag for Stddev
2300     IF Runs% > 2 THEN GOSUB Stddev
2301     S$ = ""
2303     LPRINT USING "&"; CHR$(12) ' Formfeed
2304     END ROUTINE FOR SUBTRACTED VOLUMES
2305     IRuns% = 0
2310     Vol1 = 0
2311     Shutdown$ = "PARTIAL"
2312     GOSUB Shutdown
2313     Shutdown$ = "FULL"
2316     Measureflag% = 0: Evac$ = ""
2320     GOTO Start
2325
2330
2335
2340
2500 VOLUME:
2510 IF Timeflag$ = "Long" THEN
2520     Min = 1
2530 ELSE

```

```

2540     Min = .1
2550     END IF
2560     Jv% = 0
2570     FOR Iv% = 1 TO 2
2580         IF Iv% = 1 THEN
2590             Evac$ = Vunk$
2600             Fill$ = Vref$
2610         ELSE
2620             Evac$ = Vref$
2630             Fill$ = Vunk$
2640         END IF
2650         GOSUB Evac
2660         GOSUB Fill
2670         GOSUB Stable
2680         Jv% = Jv% + 1
2690         P(Jv%) = Pres ' P(1) & P(3)
2700         GOSUB Expand ' Open Evac$
2710         GOSUB Stable
2720         Jv% = Jv% + 1
2730         P(Jv%) = Pres ' P(2) & P(4)
2740     NEXT Iv%
2745     WRT$ = "CRESET1,2"
2750     CALL IBWRT(RELAY%, WRT$) ' Close all valves
2760     Ratio = P(3) * (P(1) - P(2)) / (P(1) * (P(3) - P(4)))
2763     SLEEP 1
2765     IF V200$ = "LARGE" THEN CALL CLOSE1("200")
2770     V9 = Ratio * Ref(Vref%)
2771     IF Tube$ <> "TUBE" THEN GOSUB Correct
2780     RETURN
2790
2800
2810
2820
3000 Evac:
3002     GOSUB KeyOn
3005     CALL OPEN1(Fill$)
3006     IF V200$ = "" THEN GOSUB CHOOSE
3007     CALL CLOSE1("106,107,108,202,203," + Evac$) ' Open valves
3020     MESSAGE$ = "ATTEMPTING TO REACH HI VAC"
3030     GOSUB GRAPH
3034     SLEEP 3
3036     CALL OPEN1("203")
3040     GOSUB Vacuum
3050     GOSUB Pressub
3060     GOSUB Presdsp
3065     GOSUB TEMPSUB
3070     SLEEP 5
3080     IF Mtorr > Maxtorr THEN 3040
3081     MESSAGE$ = ""

```

```

3085 GOSUB GRAPH
3090 GOSUB UPDATE
3100 GOSUB GRAPH
3108 SLEEP 7
3110 GOSUB TEMPSUB
3111 SLEEP 8
3113 GOSUB TEMPSUB
3114 SLEEP 7
3116 GOSUB TEMPSUB
3117 SLEEP 8
3120 CALL OPEN1("106") ' Seal off vac. pump
3122 SLEEP 7
3127 GOSUB TEMPSUB
3130 SLEEP 8
3135 GOSUB TEMPSUB
3140 GOSUB Vacuum ' Test after 15 sec.
3150 IF Mtorr > Maxtorr THEN 3000
3160 ' Evacuation successful
3170 CALL CLOSE1("106")
3180 SLEEP 10
3185 GOSUB TEMPSUB
3210 RETURN
3220
3230
3240
3250
3500 Fill:
3510 CALL OPEN1(Evac$ + ",106") ' Close vac line
3520 IF Vref% > 3 THEN
3530 CALL CLOSE1("108")
3540 ELSE
3550 CALL OPEN1("108")
3560 END IF
3570 SLEEP 1
3580 IF Vref% < 4 THEN Meter$ = "204" ' Small valve
3590 IF Vref% = 4 THEN Meter$ = "205"
3600 IF Vref% > 4 THEN Meter$ = "204,205"
3610 Charge! = 10.1 ' Fill to 10 psia
3660 CALL CLOSE1(Fill$)
3670 SLEEP 2
3675 GOSUB TEMPSUB
3680 GOSUB Pressub
3690 IF Pres > (Charge! - 1) THEN 3790
3700 CALL CLOSE1("202,203"): Loop6% = 0
3710 GOSUB TEMPSUB
3720 GOSUB Pressub
3722 GOSUB Presdsp
3730 GOSUB Pressub ' Helium open in next line (#207)

```

```

3735 IF (Loop6% = 0) AND (Pres < Charge!) THEN CALL CLOSE1("207," +
      Meter$)
3737 Loop6% = Loop6% + 1
3740 IF Pres < (Charge! - .1) THEN 3720
3750 CALL OPEN1("202,203,204,205,206,207") ' He & Meter$ closed
3760 SLEEP 2
3770 GOSUB Vacuum ' Update Mtorr value
3790 GOSUB UPDATE
3800 RETURN
3810
3820
3830
3840
3850
4300 Stable:
4310 Factor = 7
4320 GOSUB Wait1 ' Min X Factor
4330 P5 = 0: C4 = 0
4340 FOR N% = 0 TO 4
4350 GOSUB Presub
4360 C(N%) = Ctr1 ' 5 decimal Digit% Counter value
4364 IF C(N%) > C4 THEN C4 = C(N%) ' max value
4365 IF N% = 0 THEN C5 = Ctr1
4366 IF C(N%) <= C5 THEN C5 = C(N%) ' min. value
4370 P5 = P5 + Pres
4380 GOSUB UPDATE
4390 NEXT N%
4400 IF Timeflag$ = "Short" THEN 4420
4410 Spread% = (C4 - C5) * 10 ^ 5
4415 IF Spread% > Spreadmax% THEN Spreadmax% = Spread%
4420 Pres = P5 / 5
4430 RETURN
4440
4450
4460
4470
4500 Expand:
4510 CALL CLOSE1(Evac$)
4520 GOSUB UPDATE
4530 GOSUB UPDATE
4540 RETURN
4550
4560
4570
4580
5000 Wait1:
5010 Timefini = INT(TIMER) + Min * Factor * 60
5020 GOSUB UPDATE
5040 SLEEP 4

```

```

5050 IF INT(TIMER) < Timefini THEN 5020
5060 RETURN
5070
5080
5090
5100
5570
5580
5590
5600
6000 Stddev:
6010 Sum = 0
6020 FOR I = 1 TO Runs%
6030 Sum = Sum + (V(I) - Avg) ^ 2
6040 NEXT I
6045 Sdev = SQR(Sum / (Runs% - 1))
6047 IF Sdev > 9.99 THEN 6052
    LPRINT USING "&    &#.#####"; LF$; "STANDARD DEVIATION : ";
    Sdev
6050 GOTO 6053
6052 LPRINT USING "&    &#.##"; LF$; "STANDARD DEVIATION IS: ";
    Sdev
6053 F$ = "MAX PRESSURE TRANSDUCER COUNT SPREAD = "
6055 LPRINT USING "&###"; F$; Spreadmax%
6058 IF Spreadmax% < 6 THEN
6060 LPRINT USING " & "Max. Count Spread Is Good"
6065 ELSE
6068 LPRINT USING " &"; "Max. Count Spread Is Poor"
6070 END IF
6075 Devrel = Sdev * 100 / Avg
6080 IF Devrel < .25 THEN RETURN
6090 IF S$ = "SUBTRACT" THEN RETURN
6095 F$ = " * * * * STANDARD DEVIATION IS LARGER THAN
    EXPECTED * * * *"
6100 LPRINT USING " &"; F$
6110 RETURN
6120
6130
6140
6150
7000 Shutdown:
    Measureflag% = 0
    MESSAGE2$ = ""
7005 MESSAGE$ = "SHUTTING DOWN - LEAVE POWER ON"
7010 GOSUB GRAPH
7015 GOSUB KeyOn
7020 WRT$ = "CRESET1,2" ' 3-WAY TO SMALL PORT
7025 CALL IBWRT(RELAY%, WRT$)
7030 SLEEP 1

```

```

7040 CALL CLOSE1("105,106,108,109,200,201") ' 3-WAY TO LARGE PORT
7050 SLEEP 1
7060 GOSUB Pressub
7070 IF Pres > 14 THEN 7120
7080 CALL CLOSE1("202,203,204,205,206,207") 'LARGE PORT FILLING
7090 GOSUB Pressub
7100 GOSUB Presdsp
7110 IF Pres < 14 THEN 7090
7120 CALL OPEN1("200,201,301") ' 109 STILL OPEN,PUMP OFF
7140 CALL CLOSE1("107") 'Vac line open
7150 SLEEP 2
7160 CALL OPEN1("105")
7170 GOSUB Pressub
7180 GOSUB Presdsp
7190 IF Pres < 14 THEN 7170
7200 WRT$ = "CRESET1,2"
7205 CALL IBWRT(RELAY%, WRT$) ' Open all relays,3-WAY TO
SMALL PORT
7210 IF Shutdown$ = "PARTIAL" THEN MESSAGE$ = "TEST
COMPLETED"
7220 IF Shutdown$ = "PARTIAL" THEN GOSUB GRAPH
7225 GOSUB Presdsp
7229 IF Shutdown$ = "PARTIAL" THEN RETURN
7232 MESSAGE$ = " TURN OFF POWER KEY SWITCH"
7234 MESSAGE2$ = ""
7240 GOSUB GRAPH
7250 BEEP
7270 SLEEP 3
7280 GOTO 7250 ' Program ended.
7290 RETURN ' Not used
7300 '
7310 '
7320 '
7330 '
9000 Refselect:
9010 ' Exercise cycle through 9240
9020 CALL OPEN1("109,201") ' Close 109 & 201;106-108,202 are open
9030 FOR I = 1 TO 1 ' Exercise for just 1 loop
9040 Factor = 1
9050 Min = 1
9060 GOSUB Wait1 ' Vac exercise in process
9070 CALL OPEN1("107") ' Vac line closed
9080 SLEEP 1
9090 CALL CLOSE1("203,204,207") ' Helium on
9100 GOSUB Pressub
9110 GOSUB Presdsp
9130 GOSUB Vacuum
9140 IF Pres < 10.5 THEN 9100
9150 CALL OPEN1("203,204,207")

```

```

9160     Factor = 1
9170     Min = 1
9180     GOSUB Wait1      'Pressure exercise
9190     CALL CLOSE1("107") 'To vac again
9200 NEXT I
9210 GOSUB Vacuum
9220 GOSUB UPDATE
9230 GOSUB Vacuum
9240     ' Exercise done
9250
9260 IF V200$ = "LARGE" THEN Vref% = 8 ELSE Vref% = 2 ' see Testentry
9280 GOSUB Decode
9290 Timeflag$ = "Short" 'Short cycle
9300 GOSUB VOLUME
9310 Vol1 = V9
9320     IF 25 > Vol1 THEN Vref% = 1
9330     IF Vol1 >= 25 THEN Vref% = 2
9340 IF V200$ <> "LARGE" THEN RETURN
9350     IF 70 > Vol1 THEN Vref% = 4
9360     IF 70 <= Vol1 AND 105 > Vol1 THEN Vref% = 6
9370     IF 105 <= Vol1 AND 135 > Vol1 THEN Vref% = 8
9380     IF 135 <= Vol1 AND 170 > Vol1 THEN Vref% = 10
9390     IF 170 <= Vol1 AND 202 > Vol1 THEN Vref% = 14
9400     IF 202 <= Vol1 AND 270 > Vol1 THEN Vref% = 16
9410     IF 270 <= Vol1 AND 405 > Vol1 THEN Vref% = 24
9420     IF 405 <= Vol1 AND 508 > Vol1 THEN Vref% = 30
9430     IF 508 <= Vol1 AND 900 > Vol1 THEN Vref% = 32
9440     IF 900 <= Vol1 AND 1170 > Vol1 THEN Vref% = 48
9450     IF 1170 <= Vol1 THEN Vref% = 62
        LPRINT USING "& &"; "REF. USED="; STR$(Vref%)
9460 RETURN
9470
9480
9490
9500
9510
10000 GRAPH:
10010 GOSUB Displaycrt
        CALL Textcall(Line1$, Line2$, Line3$, MESSAGE$, MESSAGE2$,
            Measureflag%)
10130 RETURN
10135
10140
10145
10150
10250 Atmos:
        Measureflag% = 0
        IF V200$ = "" THEN GOSUB CHOOSE
10251 IF V200$ = "LARGE" THEN

```

```

10252 MESSAGE$ = "BRINGING LARGE TEST PORT TO"
10255 ELSE
10258 MESSAGE$ = "BRINGING SMALL TEST PORT TO"
10259 END IF
10260 MESSAGE2$ = "ATMOSPHERE - PLEASE WAIT"
10262 GOSUB GRAPH
10265 WRT$ = "CRESET1"
10270 CALL IBWRT(RELAY%, WRT$)
      CALL OPEN1("208,209") ' HEATERS OFF
10275 IF V200$ = "LARGE" THEN
10277   CALL CLOSE1("200,201,202,203,204,205,206,207")
10278 ELSE
10279   CALL CLOSE1("109,202,203,204,207")
10280   CALL OPEN1("200")
10290 END IF
10300 SLEEP 1
10345 GOSUB Pressub
10350 GOSUB Presdsp
10355 IF Pres < 14 THEN 10345
10360 CALL OPEN1("109,201,202,203,204,205,206,207") ' Helium off
10365 MESSAGE$ = "TEST PORT READY FOR DISCONNECT"
10367 MESSAGE2$ = "HIT SPACE BAR WHEN RECONNECTED"
10370 GOSUB GRAPH
10375 BEEP
10380 BEEP
10385 BEEP
10390 S$ = INKEY$
10395 DO
10400 LOOP UNTIL INKEY$ = " "
10410 MESSAGE$ = ""
10420 MESSAGE2$ = ""
10430 GOSUB GRAPH
10435 RETURN
10440 :
10445 :
10450 :
10750 :
10760 :
10770 :
10780 :
10790 :
11000 Pressub:
11010 RD$ = SPACE$(19)
11020 CALL IBRD(CTR%, RD$)
      IF IBSTA% < 0 AND PTIMEOUT% = 0 THEN
        PTIMEOUT% = 1
        LPRINT "Pressub: ERROR, INSTA%="; INSTA%, " IBERR%=";
        IBERR%
      END IF

```



```

11030  Ctr1 = 10 * VAL(MID$(RD$, 5, 9))
11040  Ctr1 = INT(Ctr1 * 10 ^ 5 + .5) / 10 ^ 5
11045  IF Ctr1 = 0 THEN Ctr1 = 26
11050  R = 1 - (25.64884 / Ctr1) ^ 2 'RATIO
11060  Pres = 139.97611# * (R - .0622954 * R ^ 2) 'C&D Equation
11100  IF Pres < 0 THEN Pres = 0
11105  IF Pres > 18 THEN GOSUB Overpres
11110  RETURN
11120  '
11130  '
11140  '
11150  '
11250  TEMPSUB:
11260  RD$ = SPACE$(20)
11265  CALL IBRD(RTD%, RD$)
      IF IBSTA% < 0 AND TTIMEOUT% = 0 THEN
          TTIMEOUT% = 1
          LPRINT "Tempsub: ERROR, INSTA%="; INSTA%, " IBERR%=";
IBERR%
          END IF
          Tempold = Temp
11270  Temp = VAL(RD$)
11280  IF Bath$ = "COOL" THEN RETURN
11285  IF Temp < 18 THEN Temp = 35 ' AVOID OVERHEAT IF IEEE-488
FAILS
11290  IF Temp < 27! AND Temp > 26.92 THEN CALL CLOSE1("208") 'Slow
Heater
11300  IF Temp < 26.92 THEN CALL CLOSE1("209") ' Fast Heater
11305  IF Temp > 26.92 THEN CALL OPEN1("209")
11310  IF Temp < 27! THEN CALL CLOSE1("208") ' Slow Heater
11312  IF Temp + Tempold >= 2 * 27! THEN CALL OPEN1("208") ' Slow heat
11315  ' The above lines to control oven at 27 deg. C
11320  RETURN
11330  '
11340  '
11350  '
11360  '
11370  '
11400  Decode:
11410  SELECT CASE Vunk%
      CASE IS = 512
          Vunk$ = "109"
      CASE IS = 1024
          Vunk$ = "201"
11480  END SELECT
11490  '
11500  SELECT CASE Vref%
      CASE IS = 1
          Vref$ = "100"

```

```

CASE IS = 2
  Vref$ = "101"
CASE IS = 4
  Vref$ = "102"
CASE IS = 6
  Vref$ = "101,102"
CASE IS = 8
  Vref$ = "103"
CASE IS = 10
  Vref$ = "101,103"
CASE IS = 14
  Vref$ = "101,102,103"
CASE IS = 16
  Vref$ = "104"
CASE IS = 24
  Vref$ = "103,104"
CASE IS = 30
  Vref$ = "101,102,103,104"
CASE IS = 32
  Vref$ = "105"
CASE IS = 48
  Vref$ = "104,105"
CASE IS = 60
  Vref$ = "102,103,104,105"
CASE IS = 62
  Vref$ = "101,102,103,104,105"
11890 END SELECT
11900 RETURN
11910 '
11920 '
11930 '
11940 '
11950 '
12000 Presdsp:
12090 Pres1 = INT(100 * Pres + .5) / 100
12100 IF Pres1 = Lastpres THEN RETURN
12101 FOR I = 0 TO 4: FOR J = 0 TO 4
12103   Pbcd%(I, J) = 0: NEXT J
12110 NEXT I
12120 Lastpres = Pres1
12130 Pre$ = STR$(Pres1)
      Pre$ = LTRIM$(Pre$): Pre$ = RTRIM$(Pre$)
12140 IF INSTR(Pre$, ".") = 0 THEN Pre$ = Pre$ + ".00"
12150 IF INSTR(Pre$, ".") = 2 THEN Pre$ = "0" + Pre$
12155 IF INSTR(Pre$, ".") = 1 THEN Pre$ = "00" + Pre$
12160 L% = LEN(Pre$)
12170 J = 1
12180 FOR I = L% TO 1 STEP -1
12190   IF J = 3 THEN 12270 ' POSITION 3 IS DEC. PT.

```

```

12200   K% = J
12210   IF K% > 3 THEN K% = K% - 1
12220   Digit% = VAL(MID$(Pre$, J, 1))' Start from left end of Pre$
12230   IF Digit% > 7 THEN Pbcd%(K%, 4) = 1
12240   IF (Digit% > 3) AND (Digit% < 8) THEN Pbcd%(K%, 3) = 1
12250 IF (Digit% = 2) OR (Digit% = 3) OR (Digit% = 6) OR (Digit% = 7)
      THEN Pbcd%(K%, 2) = 1
12260   IF (Digit% / 2 - INT(Digit% / 2)) > 0 THEN Pbcd%(K%, 1) = 1
12270   J = J + 1
12280   NEXT I
12281   K% = 0
12282   FOR I = 1 TO 4: FOR J = 1 TO 4
12284   Predim%(K%) = Pbcd%(I, J)
12286   K% = K% + 1
12290   NEXT J: NEXT I
12300   Byte%(1) = 0: Byte%(2) = 0
12310   FOR I = 1 TO 2
12320     FOR J = 0 TO 7
12330       K% = J
12340       IF I = 2 THEN K% = K% + 8
12350       IF J = 0 AND Predim%(K%) = 0 THEN 12370' AVOID 0^0
12360       Byte%(I) = Byte%(I) + (2 * Predim%(K%)) ^ J
12370     NEXT J
12380   NEXT I
12390   '
12400   WRT$ = "DWRITE 400," + STR$(Byte%(1))
12405   CALL IBWRT(RELAY%, WRT$)
12410   WRT$ = "DWRITE 401," + STR$(Byte%(2))
12420   CALL IBWRT(RELAY%, WRT$)
12425   '
12440   RETURN
12450   '
12460   '
12470   '
12480   '
13200 Displayert: ' Called from Graph (10000)
      Line1$ = "": Line2$ = ""
      Line3$ = ""
      IF Measureflag% = 0 THEN RETURN
13210   IF Dispflag$ = "Part" THEN GOTO 13320
13220   Line1$ = "TEST: " + STR$(IRuns%) + " OF " + STR$(Runs%) +
      SPACE$(15)
13230   Line1$ = LEFT$(Line1$, 16)
13240   IF Timeflag$ = "Short" THEN GOTO 13320 ' ?
13250   IF IRuns% = 1 THEN 13320
13260   IF Count% = 1 THEN 13300
13270   Count% = 1
13280   Runtime = INT(TIMER) - Timestart
13290   Finishtime = Runtime * (Runs% - 1) + INT(TIMER)

```

```

13300
13314 IF (Finishtime - TIMER) \ 60 < 0 THEN Finishtime = TIMER
13315 Line1$=Line1$ + "MIN. LEFT: " + STR$((Finishtime - TIMER) \ 60)
13320 'Line1$ done:
13330 Line2$ = "TEST ITEM: " + Item$
13335 IF LEN(Line2$) > 30 THEN Line2$ = LEFT$(Line2$, 30)
13350 'Line2$ done:
13360 IF IRuns% > 1 THEN Vol1 = V(IRuns% - 1)
13365 Vol1 = INT(10 * Vol1 + .5) / 10 ' Round to 1 place
13370 Line3$ = "VOLUME: " + STR$(Vol1) + "cc" + SPACE$(10)
13375 Line3$ = LEFT$(Line3$, 17) + "SEQUENCE: " + STR$(Seq%)
13380 'Line3$ done
13390 RETURN
13420
13430
13440
13450
13500 Vacuum:
13510 RD$ = SPACE$(4)
13520 CALL IBRD(VAC%, RD$)
13530 Mtorr = VAL(RIGHT$(RD$, 3))
13540 IF VAL(LEFT$(RD$, 1)) = 1 THEN Mtorr = 1000
13560 RETURN
13570
13580
13900
13910
14000 Testentry:
14010 CALLS CLOSEGRAPHICS ' Back to text screen
14012 LINE INPUT "ENTER TEST ITEM IDENTIFICATION: "; Item$
14013 GOSUB Pressub
14014 GOSUB Presdsp
14024 GOSUB TEMPSUB
14026 INPUT "ENTER MAX IN MILLITORR "; Maxtorr
14027 MESSAGE$ = "": MESSAGE2$ = ""
14030 LINE INPUT "DATE OF TEST? "; Date1$
14035 GOSUB TEMPSUB
14036 INPUT "BATH TEMPERATURE: C=CONTROLLED; N=NOT
CONTROLLED"; Bath$
14037 IF UCASE$(LEFT$(Bath$, 1)) = "C" THEN
14038 Bath$ = "HEAT"
14039 ELSE
14040 Bath$ = "COOL"
14041 END IF
14042 LINE INPUT "ENTER YOUR NAME OR INITIALS AND YOUR
ORGANIZATION: "; Operator$
14043 GOSUB TEMPSUB
14044 INPUT "IS TEST ITEM ON LARGE PORT (OVER 12cc) OR
SMALL PORT?

```

```

      L = LARGE, S = SMALL "; V200$
14045 IF UCASE$(LEFT$(V200$, 1)) = "L" THEN
14046   V200$ = "LARGE"; Vunk% = 1024
14047   CALL CLOSE1("200,201") ' Valve 200 default is OPEN=SMALL
14048 ELSE
14050   V200$ = "SMALL"; Vunk% = 512
14051   CALL OPEN1("200"); CALL CLOSE1("109")
14052 END IF
14053 GOSUB TEMPSUB
14055 Runs% = 3
14060 INPUT "NUMBER OF RUNS? (DEFAULT = 3, PRESS ENTER
KEY) "; Runs%
14063 IF Runs% = 0 THEN Runs% = 3
14065 GOSUB TEMPSUB
14115 CLS
F$ = "THE TUBING RESULTS CAN BE SUBTRACTED FROM THE TUBE
+ VESSEL
      RESULTS BY"
14120 PRINT USING "&&&&&"; F$; LF$; SPC(28); "SPECIFYING A
      SEQUENCE"; LF$
14130 PRINT " 1 = FIRST RUN; 2 = SECOND RUN; 0 = NO
      SEQUENCE"; LF$
14140 INPUT "SPECIFY SEQUENCE: "; Seq%
14141 IF Seq% = 1 THEN Saveruns% = Runs%
14142 IF Seq% = 2 AND Saveruns% <> 0 THEN Runs% = Saveruns%
14150 CLS
14200 LPRINT USING " &&"; "VOLUME DETERMINATION"; LF$
14210 LPRINT USING " & &"; "TEST ITEM:"; Item$
14220 LPRINT USING " & &"; "DATE OF TEST:"; Date1$
14230 LPRINT USING " & &&"; "OPERATOR:"; Operator$; LF$
14250 RETURN
14260 '
14270 '
14280 '
14290 '
14300 '
14310 '
15000 Overpres:
15010 CALL CLOSE1("105,106,107,108")
15020 CALL OPEN1("109,201,202,203,204,205,206,207")
15030 MESSAGE$ = "EVACUATING SYSTEM"
15035 GOSUB GRAPH
15040 GOSUB Pressub
15050 IF Pres > 1 THEN 15040
15060 WRT$ = "CRESET 1" ' CLOSE ALL 100 VALVES
15065 CALL IBWRT(RELAY%, WRT$)
15070 MESSAGE$ = ""
15075 GOSUB GRAPH
15080 GOTO Start

```

```

15090 |
15100 |
15110 |
15120 |
16000 Evacuate:
      Measureflag% = 0: GOSUB KeyOn
      MESSAGE$ = "": MESSAGE2$ = ""
16010 CALL CLOSE1("106,107,108,301")
      GOSUB GRAPH
      IF V200$ = "" THEN GOSUB CHOOSE
16020 IF V200$ = "LARGE" THEN
16030   CALL CLOSE1("200,201,202")
16040 ELSE
16050   CALL CLOSE1("109,202")
16055   CALL OPEN1("200")
16060 END IF
16070 RETURN
16080 |
16090 |
16100 |
16110 |
16400 Vaccheck:
16410 GOSUB Vacuum
16420 IF Mtorr < Maxtorr THEN RETURN
16421   Measureflag% = 0
16422   MESSAGE$ = "POOR VACUUM: LEAK OR OUTGASSING"
16423   GOSUB GRAPH
16424   SLEEP 2
16425   GOSUB UPDATE
16470   GOSUB Vacuum
16480   IF Mtorr > Maxtorr THEN 16424
16490   MESSAGE$ = "": Measureflag% = 1
16510   Vacuum check done
16520 RETURN
16530 |
16540 |
16550 |
16560 |
17000 Reset1:
17010 WRT$ = "CRESET1,2"
17020 CALL IBWRT(RELAY%, WRT$)
17025 Measureflag% = 0
17030 MESSAGE$ = "": MESSAGE2$ = ""
17035 GOSUB GRAPH
      KEY(1) ON
      KEY(3) ON: KEY(5) ON
      KEY(7) ON: KEY(9) ON
17040 GOTO Start
17050 |

```

```

17060 '
17070 '
17080 '
17090 '
17500 Ref:
17510 Ref(1) = 10.309
17520 Ref(2) = 42.577
17530 Ref(4) = 80.464
17540 Ref(8) = 155.965
17550 Ref(16) = 303.787
17560 Ref(32) = 1014.9008#
17580 Ref(6) = Ref(4) + Ref(2)
17590 Ref(10) = Ref(8) + Ref(2)
17600 Ref(14) = Ref(10) + Ref(4)
17610 Ref(24) = Ref(16) + Ref(8)
17620 Ref(30) = Ref(24) + Ref(6)
17630 Ref(48) = Ref(32) + Ref(16)
17640 Ref(62) = Ref(48) + Ref(14)
17650 RETURN
17730 '
17740 '
17750 '
17760 '
17920 '
17930 '
17940 '
18000 INITIALIZE:
18044 LF$ = CHR$(10) + CHR$(13): Maxtorr = 30
18046 Bath$ = "COOL": TIMEOUT% = 0 ' Tempsub flag
18050 GOSUB GRAPH
18055 V200$ = "": PTIMEOUT% = 0 ' Pressub flag

```

```

CTR$ = SPACE$(20)
VAC$ = SPACE$(20)
RTD$ = SPACE$(20)
RELAY$ = SPACE$(20)

```

```

BDNAME$ = "GPIB0"
CALL IBFIND(BDNAME$, BD0%)

```

```

BDNAME$ = "CTR"
CALL IBFIND(BDNAME$, CTR%)

```

```

BDNAME$ = "VAC"
CALL IBFIND(BDNAME$, VAC%)

```

```

BDNAME$ = "RTD"
CALL IBFIND(BDNAME$, RTD%)

```

```

BDNAME$ = "RELAY"
CALL IBFIND(BDNAME$, RELAY%)

CALL IBSIC(BD0%)
CALL IBCLR(CTR%)
CALL IBCLR(VAC%)
CALL IBCLR(RTD%)

WRT$ = "IN,FU2,FI1,GA2"
CALL IBWRT(CTR%, WRT$)

SEC% = &H60 ' HEX 96
CALL IBSAD(VAC%, SEC%) ' SECONDARY ADDRESS
WRT$ = "N4,TB0,TP1,TH0,I1,O1,A0,B0"
CALL IBWRT(VAC%, WRT$)
SEC% = 0
CALL IBSAD(VAC%, SEC%)

WRT$ = "O1 Y3 L0 M1"
CALL IBWRT(RTD%, WRT$)

18160 GOSUB Ref
18165 WRT$ = "TEST"
18170 CALL IBWRT(RELAY%, WRT$)
18174 RD$ = SPACE$(20)
18177 CALL IBRD(RELAY%, RD$)
18180 A% = INT(VAL(RIGHT$(RD$, 3)))
18190 IF A% = 0 THEN 18301
18200 SELECT CASE A%
      CASE 1
        MESSAGE$ = "RELAY RAM FAILURE"
      CASE 2
        MESSAGE$ = "RELAY ROM FAILURE"
      CASE 4
        MESSAGE$ = "RELAY TIMER FAILURE"
      CASE 8
        MESSAGE$ = "RELAY HP-IB FAILURE"
18290 END SELECT
18292 CALLS CLOSEGRAPHICS
18293 PRINT MESSAGE$ + " PROGRAM IS HALTED"
18294 STOP
18301 WRT$ = "VIEW 301"
18302 CALL IBWRT(RELAY%, WRT$)
      RD$ = SPACE$(20)
18303 CALL IBRD(RELAY%, RD$) ' Vac Pump On?
18304 RD$ = RTRIM$(RD$)
18305 A% = VAL(RIGHT$(RD$, 3))
      WRT$ = "RESET"

```



```

18310 CALL IBWRT(RELAY%, WRT$) ' All relays open
18315 IF A% = 0 THEN CALL CLOSE1("301") ' Vac Pump Back On
18490 ON KEY(1) GOSUB Reset1
18530 ON KEY(3) GOSUB Evacuate
18540 ON KEY(5) GOSUB Shutdown
18560 ON KEY(7) GOSUB Atmos
18580 ON KEY(9) GOSUB Measure
18590 ON KEY(10) GOSUB Exit1
18600 GOSUB KeyOn
18630 RETURN
18640 '
18650 '
18660 '
18670 Err1:
18680 CALLS CLOSEGRAPHICS
18690 LPRINT "PROGRAM STOPPED. #"; ERR; "ERROR LINE:"; ERL
18700 WRT$ = "OPEN 203"
18710 CALL IBWRT(RELAY%, WRT$) Helium off
18720 STOP
18730 '

```

```

19000 KeyOn:
19010 KEY(1) ON: KEY(3) ON
19020 KEY(5) ON: KEY(7) ON
19030 KEY(9) ON: KEY(10) ON
19040 RETURN

```

```

19250 Exit1:
19260 CALL CLOSEGRAPHICS
19270 PRINT "DO YOU WISH TO EXIT TO DOS LEVEL?"; LF$
19280 INPUT " Y = YES      N = NO "; E$
19290 IF UCASE$(LEFT$(E$, 1)) = "Y" THEN 19300
19294 GOSUB GRAPH
19295 RETURN
19300 CLS
19310 STOP

```

```

19500 CHOOSE:
19510 CALL CLOSEGRAPHICS
19520 PRINT "IS YOUR TEST ITEM ON LARGE PORT OR SMALL
PORT?"; LF$
19530 INPUT " L = LARGE      S = SMALL "; E$
19540 IF UCASE$(LEFT$(E$, 1)) = "L" THEN
19550 V200$ = "LARGE"
19560 ELSE
19570 V200$ = "SMALL"

```

```
19580 END IF
19590 GOSUB GRAPH
19600 RETURN
```

```
SUB CLOSE1 (Vc$)
WRT$ = "CLOSE " + Vc$
CALL IBWRT(RELAY%, WRT$)
END SUB
```

```
SUB OPEN1 (Vo$)
WRT$ = "OPEN " + Vo$
CALL IBWRT(RELAY%, WRT$)
END SUB
```

```
SUB Textcall (L1$, L2$, L3$, M$, M2$, F%)
' PROGRAM "TITLE" TO
' DRAW TITLE BOX
'
```

```
X! = 0
Y! = 1000
X% = 0
DEVICES$ = "haloibmg.dev"
CALLS SETDEV(DEVICES$)
X2% = 0 ' MODE = 0 (16 COLORS)
CALLS INITGRAPHICS(X2%)
X1! = .01: Y1! = .01
X2! = .99: Y2! = .4
Y% = 2
CALLS SETVIEWPORT(X1!, Y1!, X2!, Y2!, Y%, Y%)
CALLS SETWORLD(X!, X!, Y!, Y!)
ASP! = .875
X2% = 1: X% = 1 ' MAGENTA ON BLUE
CALLS SETIPAL(X%, X2%)
CALLS SETASP(ASP!)
FONT$ = "HALO103.FNT"
CALLS SETFONT(FONT$)
X1! = 285
Y1! = .75
Z% = 0
CALLS SETSTEXT(X1!, Y1!, Z%)
X1! = 200
Y1! = 580
CALLS MOVTCURABS(X1!, Y1!)
TEXT$ = "VOLUME"
```

```

CALLS STTEXT(TEXT$)
X1! = 40: Y1! = 100
CALLS MOVTCURABS(X1!, Y1!)
X1! = 255
Y1! = .65
Z% = 0
CALLS SETSTEXT(X1!, Y1!, Z%)
TEXT$ = "MEASUREMENT"
CALLS STTEXT(TEXT$)
'X1! = .01 'X2! = .99
'Y1! = .37 'Y2! = .4
'CALLS BAR(X1!, Y1!, X2!, Y2!)
X1! = .01: Y1! = .41
X2! = .99: Y2! = .99
X% = 0: Y% = 0
CALLS SETVIEWPORT(X1!, Y1!, X2!, Y2!, X%, Y%)
X1! = 120
Y1! = .6
Z% = 0
CALLS SETSTEXT(X1!, Y1!, Z%)
TEXT$ = ""
FOR I% = 800 TO 400 STEP -200
X1! = 2
Y1! = I%
CALLS MOVTCURABS(X1!, Y1!)
SELECT CASE I%
CASE 800
TEXT$ = L1$
CASE 600
TEXT$ = L2$
CASE 400
TEXT$ = L3$
END SELECT
CALLS STTEXT(TEXT$)
NEXT I%
X1! = 0: Y1! = 200
IF F% = 0 THEN Y1! = 600
CALLS MOVTCURABS(X1!, Y1!)
X1! = 120
Y1! = .575
Z% = 0
CALLS SETSTEXT(X1!, Y1!, Z%)
CALLS STTEXT(M$)
IF M2$ <> "" THEN
X1! = 0
Y1! = 100
IF F% = 0 THEN Y1! = 300
CALLS MOVTCURABS(X1!, Y1!)
CALLS STTEXT(M2$)

```

```
END IF
TEXT$ = "F1RESET F3EVAC F5SHUTDN F7ATMOS F9TEST"
X1! = 100
Y1! = .538
Z% = 0
CALLS SETSTEXT(X1!, Y1!, Z%)
X1! = 0: Y1! = 0
CALLS MOVTCURABS(X1!, X1!)
CALLS STTEXT(TEXT$)
CALLS DELTCUR
END SUB
```

APPENDIX B
PVMS DRAWINGS

10.21

4 Digit Dis
(Pressure)

TOLERANCES UNLESS OTHERWISE SPECIFIED XX ±.03 .XXX ±.010 NONCUMULATIVE OR ON HOLE LOCATIONS, .028 DIA POSITIONAL TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER HOLES ANGLES ±		DRAWN _____ DATE _____ CHECKED _____ DATE _____ DESIGNER _____ DATE _____ ENGINEER _____ DATE _____ PROJECT ENGINEER _____ DATE _____	EG&G KIRTLAND OPERATIONS ENERGY MEASUREMENTS P.O. BOX 4339 STATION A, ALBUQUERQUE, NM 87194 ALBUQUERQUE-GOLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOBURN		
		PVMS Front Panel Parts Layout			
REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION _____		SIZE D CODE IDENT NO. 99626 DRAWING NUMBER Non: AutoCad drawing file PVMS_FP.DWG	REV A JOB NO/FY T332-02 SHEET 1 of 1

TOLERANCES UNLESS OTHERWISE SPECIFIED XX ± 0.1 XX ± 0.01 NOMINATIVE OR ON HOLE LOCATIONS 0.08 DIA. POSITIONAL TOLERANCE WITH RESPECT TO IMPROVED DATUMS AND OTHER HOLE'S ANGLES & REMOVE BODIES AND BREAK ALL SHARP CORNERS DON'T DO IT ALL FIRST	DRAWN CHECKED DESIGNER ENGINEER PROJECT ENGINEER	DATE DATE DATE DATE DATE	RUTLAND OPERATIONS P.O. BOX 4330 STATION A, ALBUQUERQUE, NM 87108 ALBUQUERQUE • COLETA • LAS VEGAS • LOS ALAMOS • SAN RAMON • WASHINGTON • MEMPHIS PVMS Wiring Diagram
	FOR MATERIALS SEE DETAIL'S, NOTES, OR LIST OF MATERIALS FOR DIMENSIONS SEE DETAIL'S OR NOTES DRAWING CLASSIFICATION		
	SIZE CODE IDENT NO D 99626		
	DRAWING NUMBER Notes AutoCad drawing Dim PV WIRL DWG		
DATE 10/10/98		REV A

TOLERANCES UNLESS OTHERWISE SPECIFIED .XX ± .03 .XXX ± .010 NONCUMULATIVE OR ON HOLE LOCATIONS .025 DIA POSITIONAL TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER HOLES ANGLES ± REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		DRAWN CHECKED DESIGNER ENGINEER PROJECT ENGINEER	DATE DATE DATE DATE DATE	EG&G ENERGY MEASUREMENTS KIRTLAND OPERATIONS P.O. BOX 4339 STATION A, ALBUQUERQUE, NM 87196 ALBUQUERQUE-GOLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOBBURN
FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS ON NOTES DRAWING CLASSIFICATION		PVMS Wiring Diagram		
SIZE D		CODE IDENT NO. 99626	DRAWING NUMBER None: AutoCad drawing file PV_WIRE2.DWG	REV A
SCALE		JOB NO/YY T332--02	SHEET 2 of 2	

Hole	From	X	Y	diam.	dim. B
A	X,Y	4.420	1.250	0.500	0.455
B	X,Y	5.985	1.250	0.500	0.455
C	X,Y	7.550	1.250	0.500	0.455
D	X,Y	1.390	4.230	1.350	-
D1	X,Y	0.815	4.805	0.125	-
D2	X,Y	1.965	4.805	0.125	-
D3	X,Y	0.815	3.655	0.125	-
D4	X,Y	1.965	3.655	0.125	-
E	X,Y	3.195	4.230	1.350	-
E1	X,Y	2.620	4.805	0.125	-
E2	X,Y	3.770	4.805	0.125	-
E3	X,Y	2.620	3.655	0.125	-
E4	X,Y	3.770	3.655	0.125	-
F	X,Y	5.030	4.230	1.100	-
F1	X,Y	4.545	4.725	0.125	-
F2	X,Y	5.515	4.725	0.125	-
F3	X,Y	4.545	3.740	0.125	-
F4	X,Y	5.515	3.740	0.125	-
G	X,Y	6.860	4.230	0.375	0.340
I	X,Y	10.480	4.230	0.975	-
I1	X,Y	10.010	4.680	0.125	-
I2	X,Y	10.910	4.680	0.125	-
I3	X,Y	10.010	3.780	0.125	-
I4	X,Y	10.910	3.780	0.125	-
J	X,Y	12.255	4.230	0.975	-
J1	X,Y	11.805	4.680	0.125	-
J2	X,Y	12.705	4.680	0.125	-
J3	X,Y	11.805	3.780	0.125	-
J4	X,Y	12.705	3.780	0.125	-
K	X,Y	14.055	4.230	0.975	-
K1	X,Y	13.605	4.680	0.125	-
K2	X,Y	14.505	4.680	0.125	-
K3	X,Y	13.605	3.780	0.125	-
K4	X,Y	14.505	3.780	0.125	-
L	X,Y	15.820	4.230	1.390	1.335
M	X,Y	13.585	8.920	4.530	-
M1	X,Y	11.525	10.975	0.166	-
M2	X,Y	15.650	10.975	0.166	-
M3	X,Y	11.525	6.850	0.166	-
M4	X,Y	15.650	6.850	0.166	-
N1	X,Y	1.390	1.250	0.125	-
N2	X,Y	2.970	1.250	0.125	-
C1	X,Y	8.750	1.250	0.106	-
C2	X,Y	10.600	1.250	0.166	-
P1	X,Y	11.620	1.250	0.125	-
P2	X,Y	13.180	1.250	0.125	-
Q1	X,Y	13.947	1.250	0.125	-
Q2	X,Y	15.500	1.250	0.125	-
R1	X,Y	2.250	10.560	0.157	-
R2	X,Y	2.250	10.260	0.157	-
R3	X,Y	4.125	10.560	0.157	-
R4	X,Y	4.125	10.260	0.157	-
S1	X,Y	2.250	9.010	0.157	-
S2	X,Y	2.250	8.710	0.157	-
S3	X,Y	4.125	9.010	0.157	-
S4	X,Y	4.125	8.710	0.157	-
T1	X,Y	2.250	7.460	0.157	-
T2	X,Y	2.250	7.160	0.157	-
T3	X,Y	4.125	7.460	0.157	-
T4	X,Y	4.125	7.160	0.157	-
U1	X,Y	9.500	8.920	0.157	-
U2	X,Y	10.700	8.920	0.157	-

TOLERANCES UNLESS OTHERWISE SPECIFIED .XX ± .03 .XXX ± .010 NONCUMULATIVE OR ON HOLE LOCATIONS, FOR DIA DIMENSIONS, TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER HOLES ANGLES ± REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT	DRAWN	DATE	EG&G ENERGY MEASUREMENTS KIRTLAND OPERATIONS P.O. BOX 4330 STATION A, ALBUQUERQUE, NM 87191 ALBUQUERQUE-GOLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOOD
	CHECKED	DATE	
	DESIGNER	DATE	
	ENGINEER	DATE	
	PROJECT ENGINEER	DATE	
FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION		PVMS Connector Plate Mechanical	
SIZE	CODE IDENT NO.	DRAWING NUMBER	
D	99626	None: AutoCad drawing. file PV_RPLAT.DWG	
SCALE	JOB NO./REV	1332-02	SHEET 1 of 1

J101

J102

J1

P101

P102

P1

Power Input

Switched 110VAC
Outlet (2 ea)

Note: All connectors viewed
from the SOLDER side

J103

J105

J106,J107,J108

J109

P103

P106,P107,P108

P109

J110

TOLERANCES UNLESS OTHERWISE SPECIFIED JOI & .03 JOOI & .010 NONCUMULATIVE OR ON HOLE LOCATIONS, .038 DIA. POSITIONAL TOLERANCE WITH RESPECT TO IMPLANT DATUMS AND OTHER HOLES ANGLES & REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		DRAWN _____ DATE _____ CHECKED _____ DATE _____ DESIGNER _____ DATE _____ ENGINEER _____ DATE _____ PROJECT ENGINEER _____ DATE _____	PORTLAND OPERATIONS P.O. BOX 4339 STATION A, ALBUQUERQUE, NM 87106 PORTLAND MEASUREMENTS ALBUQUERQUE-COOLETA-LAS VEGAS-LOS ALAMOS-SAN JUAN-WASHINGTON-WORURN	
FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION		PVMS Connector Pinouts		
SIZE C CODE IDENT NO. 99626 DRAWING NUMBER None: AutoCad drawing file CON_PINS.DWG REV A		SCALE JOB NO/YR T332-02 SHEET 1 of 1		

B8

3/16" hole
3 places

TOLERANCES UNLESS OTHERWISE SPECIFIED .001 & .002 .001 & .002 NONCUMULATIVE OR ON HOLE LOCATIONS .002 (A POSITIONAL TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER FEATURES ANGLES ±		DRAWN _____ DATE _____ CHECKED _____ DATE _____ DESIGNER _____ DATE _____ ENGINEER _____ DATE _____ PROJECT ENGINEER _____ DATE _____	EG&G ENERGY MEASUREMENTS P.O. BOX 4336 STATION A, ALBUQUERQUE, NM 87116 ALBUQUERQUE-GOLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOBBURN	
REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION _____	PVMS Side Plate SIZE C CODE IDENT NO. 99626 DRAWING NUMBER None: AutoCad drawing file PV_SIDE.DWG SCALE _____ JOB NO./YR 1332-02 SHEET 1 of 1

TOLERANCES UNLESS OTHERWISE SPECIFIED .XX .03 .005 .010 NONCUMULATIVE OR ON HOLE LOCATIONS, .008 DIA POSITIVELY TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER HOLES ANGLES A REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		DRAWN _____ DATE _____ CHECKED _____ DATE _____ DESIGNER _____ DATE _____ ENGINEER _____ DATE _____ PROJECT ENGINEER _____ DATE _____ FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION _____	EG&G ENERGY MEASUREMENTS KIRTLAND OPERATIONS P.O. BOX 4339 STATION A, ALBUQUERQUE, NM 87106 ALBUQUERQUE-COLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOOLBURN PVMS Component Plate SIZE C CODE IDENT NO. 99626 DRAWING NUMBER None! AutoCad drawing File PV_CPLAT.DWG REV A SCALE _____ JOB NO./FY T332-02 SHEET 1 of 1
--	--	---	---

TOLERANCES UNLESS OTHERWISE SPECIFIED .01 & .03 .01 & .010 NONCUMULATIVE OR ON HOLE LOCATIONS, .018 DIA POSITIONAL TOLERANCE WITH RESPECT TO IMPLIED DATUMS AND OTHER HOLES ANGLES ± REMOVE BURRS AND BREAK ALL SHARP CORNERS DO NOT SCALE PRINT		EG&G ENERGY MEASUREMENTS RITLAND OPERATIONS P.O. BOX 1330 STATION A, ALBUQUERQUE, NM 87106 ALBUQUERQUE-COLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WOOLRY	
DESIGNER DATE ENGINEER DATE PROJECT ENGINEER DATE		PVMS Interconnect Diagram	
FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES		SIZE CODE IDENT HUI C 99626	
DRAWING CLASSIFICATION		DRAWING NUMBER None: AutoCad drawing the PVMS/CON/OW	
SCALE		JOB NO./FY T332-02 SHEET 1 of 1

TOLERANCES UNLESS OTHERWISE SPECIFIED JOY .03 JOY .010 NONCUMULATIVE OR ON HOLE LOCATIONS .028 DIA POSITIONAL TOLERANCE WITH RESPECT TO IMPLD DATUMS AND OTHER HOLES ANGLES & REMOVE BURRS AND BREAK ALL SHARP EDGES DO NOT SCALE PRINT		DRAWN _____ DATE _____ CHECKED _____ DATE _____ DESIGNER _____ DATE _____ ENGINEER _____ DATE _____ PROJECT ENGINEER _____ DATE _____	U1,U3,U5 7407 U2,U4,U6 7405 P1 Alpha FCC-302-26 Mates with Alpha FCC-217-26 P2 Alpha FCC-302-34 Mates with Alpha FCC-217-34
FOR MATERIALS SEE DETAILS, NOTES, OR LIST OF MATERIALS FOR FINISH SEE DETAILS OR NOTES DRAWING CLASSIFICATION _____		EG&G PORTLAND OPERATIONS P.O. BOX 4330 STATION A, ALBUQUERQUE, NM 87106 ALBUQUERQUE-SOLETA-LAS VEGAS-LOS ALAMOS-SAN RAMON-WASHINGTON-WORWUN	
PVMS LED Driver Circuit		SIZE C CODE IDENT NO. 99626 DRAWING NUMBER None: AutoCad drawing file PVMS_CD.DWG REV A	SCALE 1/8"=1" 1332-02 SHEET 1 of 1

NOTES

1. MARK DRAWING NUM APPROXIMATE LOCAT OPTIONAL.
2. GENERAL REQUIRE INTERPRETATIONS A 99000000.
3. MATERIAL: INVAR

BEZ AND ISSUE IN
ION SHOWN, METHOD

MENTS AND DRAWING
BE DEFINED IN

REVISIONS		PREPARED BY	DATE	CHK	ISS
A	W. GILES, 557 BX/ P. KLEVGAARD, 8285.

$\phi.750 \pm .002$
 $\square \phi.001 \text{ (M) A}$

AGENCY APPROVALS				SHEET		TITLE	
ORG	DATE	APPROVAL	ISSUE	A		PRECISION CYLINDER B	
				SHEET INDEX			
				PART CLASSIFICATION			
				UNCLASSIFIED			
				DWD CLASSIFICATION LEVEL			
				UNCLASSIFIED			
				DWM FROM NO		DWD NUMBER	
				C 14214		A42129	
				SCALE		SHEET	
				2/1		OF 1	

NOTES

1. MARK PART NUMBER AT APPROXIMATE LOCATION

2. MATERIAL: BRASS

D SUFFIX IN
HOWN.

DESIGN AGENCY PART CONTROL NO.		REVISIONS			
782019-000	A	W. GILES, 557BX/ P. KLEVGAARD, 8205.	PREPARED BY	DATE	ISS
		Released 10-7-88 AS		11/13/87	PAK
	E	D. ARNOLD 131BX/ R. JONES 8445/ E. HERDE 131BX 887369BX		10/88	556
Released 12-1-88 J					

-/4-12UN-2A

DRC-2T

AGENCY APPROVALS			SHEET	TITLE	
ORG	DATE	APPROVAL	ISSUE	PLUG	
SHEET INDEX					
PART CLASSIFICATION					
UNCLASSIFIED					
DATE CLASSIFICATION LEVEL					
UNCLASSIFIED					
SCALE 2/1				DRAWING NO. 782019	
SHEET 1 OF 1

DETAIL B
 SCALE: 20/1

NOTES

1. MARK DRAWING NUMBER AND ISSUE IN APPROXIMATE LOCATION SHOWN, METHOD OPTIONAL.
2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 99000000.
3. MATERIAL: STAINLESS STEEL 316.

REVISIONS			
REV	DATE	DESCRIPTION	PREPARED BY
A		W. GILES, SS7BX / P. KLEVGAARD, 8285.

DETAIL A
SCALE 1 4/1

AGENCY APPROVALS				SHEET		TITLE	
ORG	DATE	APPROVAL	ISSUE	A		END CAP, PORT	
				SHEET INDEX			
				PART CLASSIFICATION			
				UNCLASSIFIED			
				DWS CLASSIFICATION LEVEL			
				UNCLASSIFIED			
				REVISION FOR		DWS NUMBER	
				0 14214		A42130	
				SCALE 2/1 (NOTED)		SHEET	
						OF	

NOTE

1. MA
AP
SH
2. GE
INT
SE
3. MA

WORK DRAWING NUMBER AND ISSUE IN
APPROXIMATE LOCATION SHOWN, METHOD
OWN.

GENERAL REQUIREMENTS AND DRAWING
INTERPRETATIONS ARE DEFINED IN
000000.

MATERIAL: STAINLESS STEEL 316.

REVISIONS		DESCRIPTION	PREPARED BY	DATE	CHK	APP
A		W. GILES, 3510X / P. KLEVGAARD, 3200.

AGENCY APPROVALS			SHEET	TITLE	
ORG	DATE	APPROVAL	ISSUE	A	END CAP, BLIND
			SHEET INDEX		
			PART CLASSIFICATION		
			UNCLASSIFIED		
			CLASSIFICATION LEVEL		
			UNCLASSIFIED		
			IDENTIFICATION NO.		
			D 14214 A42131		
			SCALE 2/1 (UNLESS OTHERWISE SPECIFIED)		
			SHEET		OF

NOTES: (CONTINUED)

15. ITEM(S) MAY BE PURCHASED FROM WISCO EQUIPT CO., INC., 4810 60, 36TH ST, PHOENIX, AZ 85040, (602) 248-4261.
16. ITEM(S) MAY BE PURCHASED FROM AERO SPACE SOUTHWEST, INC. 2432 WEST PEORIA, SUITE 1184, PHOENIX, AZ 85029 (602) 841-1785.
17. SIZE AND SELECT APPROPRIATE ATTACHING STAINLESS STEEL HARDWARE, UPON ASSEMBLY.
18. LOCATE PER EXISTING HOLE, DRILL AND TAP UPON ASSEMBLY.
19. APPLY TORR SEAL (ITEM 60) TO PIPE THREADS AS REQUIRED, PRIOR ASSEMBLY.
20. ITEM MAY BE PURCHASED FROM CIRCLE SEAL CONTROLS ANAHEIM, CA 92803, (714) 774-6110.

9. ITEM MAY BE PURCHASED FROM MOUND
LABORATORY, DAYTON, OHIO.

1. ITEM(S) MAY BE PURCHASED FROM FLUID POWER
TECH, INC., 10650 IRMA DR #12, NORTHGLENN,
CO 90233, (303) 450-5283.

2. ITEM MAY BE PURCHASED FROM HOFFMAN
ENGINEERING CO., 9TH AND TYLER ST. ANOKA
MINNESOTA 55305. (612) 421-2240

13 ITEM MAY BE PURCHASED FROM VARIAN
4940 EL CAMINO REAL, LOS ALTOS, CA
94022, (415) 866-4084.

4. ITEM MAY BE PURCHASED FROM OMEGA
ENGINEERING, INC., P.O. BOX 2649
STAMFORD, CT 06906, (800) 886-6342.

MARK DESIGN AGENCY PART NUMBER USING
BLACK .16 HIGH CHARACTERS PER 9919.00,
CLASS A2-A, LOCATE APPROXIMATELY AS SHOWN.

2. GENERAL REQUIREMENTS AND DRAWING INTERPRETATIONS ARE DEFINED IN 99000000

WELD AND INSPECT PER 9912119, CLASS II,
USING E308 (FOR 304 CRES) AND E316
(FOR 316 CRES) ELECTRODES PER AWS A5.4.

3. MAGNETITE ALL WELDED STAINLESS STEEL ASSEMBLIES PER MIL-S-5002.

▶ CHEM-FILM. PER MILCOSB41, CLAS. A,
(ITEMS 13, 17, 19 AND 21).

⚠ INSTALL PER MANUFACTURER'S INSTRUCTIONS,
AFTER CHEM-FILM.

7. WIRE FROM PYMS WIRING DIAGRAM

8. PLUMB PER PVMS PROCESS INSTRUMENTATION DIAGRAM

DISPATCH AGENCY	DATE	TIME	REMARKS	STATUS	DATE	TIME	REMARKS
45174-050							
A			WHITE MALE, 17 YEARS OLD				
B			WHITE MALE, 17 YEARS OLD				
C			ADDED ITEM # 42				
			P. KLEVARD 8285/V. SEJALCO 8271

10	PH 440-B	STUD SELF CUNCHING (1-40X11/8)	P&M	16	37
10	95-032-E	FASTENER SELF CLINCHING (10-88)	P&M	16	36
(11)	-500	CONNECTOR CYLINDER TO VALVE			5 35
1	304-HOF-1000	SAMPLE CYLINDER, 1000CC	WHITNEY	10	54
1	304-HDM-300			10	93
1	304-HDM-150			10	52
1	304-HDM-75			10	21
1	304-HDM-240			10	21
1	95-4C5-TM40	SAMPLE CYLINDER, 10CC		10	25
9	95-43H-VCR4	BALL VALVE		10	56
4	95-43-VCR4	BALL VALVE		10	57
	95-43H-VCR4	BALL VALVE, 3-WAY		10	23
14	MS-HB-19	MOUNTING KIT-VALVE		10	24
1	MS-18DA	ACTUATOR-180°		10	24
(18)	MS-18DA	ACTUATOR-180°	WHITNEY	10	23
	-500	CONNECTOR, CYLINDER TO VALVE			8 28
		SHEET, AL ALY, 5052-H32, .125 THICK			5 21
		ENCLOSURE, MAKE FROM HOFFMAN PM 1A2R84		12	5
1		SHEET, AL ALY, 5052-H32, .125 THICK			5 18
8		SHEET, CRCS, 304, .120 THICK			5 16
1		SHEET, AL ALY, 5052-H32, .125 THICK			5 17
1		SHEET, CRCS, 304, .125 THICK			4 12
	-401	TUBE, CRCS, 316, Ø. 978 X .055W			3 12
(11)	-400	TUBE ASSEMBLY			4 14
1	-301	SHEET, AL ALY, 5052-H32, .085 THICK			4 13
(11)	-300	CHASSIS ASSEMBLY			4 11
12		SQUARE, CRCS, 3052, .75 X .75			4 12
12	-202	CHANNEL, CRCS, 304, 1.0 X .75 X 1/2 THICK			3 10
12	-201	SHEET, CRCS, 304, .120 THICK			3 8
(12)	-200	STANDOFF ASSEMBLY, VALVE			3 6
1		SHEET, ACRYLIC, LUCITE L, .38 THICK			3 4
1	-105	SHEET, ACRYLIC, LUCITE L, .38 THICK			3 4
2	-102	SHEET, ACRYLIC, LUCITE L, .38 THICK			3 4
	-101	SHEET, ACRYLIC, LUCITE L, .38 THICK			3 2
(11)	-100	PALLET ASSEMBLY			3 2
1		WATER TANK W/REGULATION PUMP MOUNT LABS 9			1 1
NA		PROCESS INSTRUMENTATION DIAGRAM			
NA		WIRING DIAGRAM			
NA	9912119	WELDING STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			
NA	9919100	MARKING, GENERAL METHODS			

[illegible]

2	CU-4-KR-GR	VCR GASKET RETAINER ASSEMBLY CATON	101
2	SS-4-KR-GR	VCR DOUBLE TEMALE REDUCING UNION	100
4	SS-4-KR-GR	GLAND VCR SHORT	85
2	SS-4-KR-GR	STREET ELBOW 90°	88
1	SS-4-KR-GR	VCR REDUCING MALE WELD GLAND	87
3	SS-4-KR-GR	VCR BULLHEAD UNION	86
2	SS-4-KR-GR	VCR MALE NUT	85
AR	AT-4-H-L	CABLE TIE	84
5	SS-4-KR-GR	RIVET, FLUSH, 0.188"	83
2	SS-4-KR-GR	LAB STOPPER RUBBER #8 KROMETER CARM	82
AR		TUBE, NYLON, 0.188"	81
AR		TUBE, CRES, 3/16, 0.188 X 0.080 W	80
AR		TUBE, CRES, 3/16, 0.188 X 0.080 W	79
AR		TUBE, CRES, 3/16, 0.188 X 0.080 W	78
48	3115311	MALE CONNECTOR, 1/8"	77
12	3109311	MALE ELBOW CONNECTOR, 1/8"	76
2	SS-4-KR-GR	VCR GLAND	75
2	SS-4-KR-GR	VCR MALE WELD GLAND	74
3	SS-4-KR-GR	KEY NIPPLE, 1/8 NPT	73
1	SS-4-KR-GR	FEMALE CONNECTOR, 1/8"	72
1	SS-4-KR-GR	BUSHING REDUCING 3/8 TO 1/4	71
1	SS-4-KR-GR	ELBOW, TSW 0.188"	70
1	SS-4-KR-GR	TUE, TSW 0.188"	69
3	SS-4-KR-GR	TUE, TUBE SOCKET WELD 0.188"	68
3	SS-4-KR-GR	VCR MALE CONNECTOR	67
3	SS-4-KR-GR	VCR MALE CONNECTOR	66
3	SS-4-KR-GR	VCR GLAND, 1/8	65
3	SS-4-KR-GR	VCR GASKET	64
3	SS-4-KR-GR	VCR FEMALE NUT	63
1	SS-4-KR-GR	VCR MALE NUT	62
6	SS-4-KR-GR	VCR TO MALE 1/8 NPT ELBOW	61
1	SS-4-KR-GR	VCR TO MALE 1/8 NPT ELBOW	60
44	CU-4-KR-GR	VCR GASKET RETAINER ASSEMBLY	59
36	SS-4-KR-GR	VCR FEMALE NUT, 1/4"	58
7	SS-4-KR-GR	VCR GLAND, REDUCING 3/8"	57
16	SS-4-KR-GR	VCR GLAND, 0.188"	56
1	SS-4-KR-GR	THERMOCOUPLE CONNECTOR	55
3	W189X-18	RELAY, 24VDC	54
AR		SWITCH, 1/8"	53
AR		TERMINAL SEAL, 1/8" PRESS FRESH	52
1	4423708	TERMINAL BOARD, 0 TERM, TO 308 (SANDIA)	51
1	4423708	TERMINAL BOARD, 0 TERM, TO 308 (SANDIA)	50
5	4423708	TERMINAL BOARD, 0 TERM, TO 308 (SANDIA)	49
1		STRAIN RELIEF	48
AR		CONNECTOR CONDUIT, 1/2"	47
1	MS1800-48	CONNECTOR ELECTRICAL	46
1	SA 804-7	CONNECTOR ELECTRICAL	45
1	WFO080-380	CONNECTOR ELECTRICAL	44
1	275-4-VCR	TRANSDUCER, VACUUM	43
1		TRANSDUCER	42
1		PROBE, RTD	41
1	0851	GALVAN, VACUUM, 1/8 NPT	40
1	HEP080GV	SOLENOID VALVE, NC	39
1	106508PH	REGULATOR, W/PRESSURE GAUGES	38
1	HN 125 B	NEEDLE VALVE	37
1	5998-M-10	RELIEF VALVE	36
1	24-110-1	MANIFOLD	35
1	TH-7	MANIFOLD	34
1	24-110-1	SOLENOID VALVE, NC	33
14	24-110-1	SOLENOID VALVE, NC	32

LIST OF MATERIALS CONTINUED FROM SHEET 1

DATE: 10/1/74

UNCLASSIFIED

114214 A45174

PAGE 1/1

SHEET 2 OF 3

Technical drawing of a vertical component. The main view on the left shows a vertical profile with several horizontal features. At the top, there is a circular feature with a crosshair inside, labeled with dimensions 16.435 and 15.813. Below this, there is a horizontal line labeled 11.188. Further down, there is another circular feature with a crosshair inside, labeled with dimensions 8.188 and 4.125. A curved line with an arrow pointing to it is labeled R 3.00 ± .03. Below this, there are two more horizontal lines labeled 1.188 and 0.000. At the bottom, there is a label 2.000. To the right of the main view, there is a side view of the component, showing a vertical profile with a circular feature at the top labeled (20).

ITEM 6
SCALE 1/2
TOLERANCE .XX ± .015

DATE	C						
DATE CLASSIFICATION LEVEL							
UNCLASSIFIED							
EFFECTIVE DATE				DATE REVIEWED			
1/2/14				4/5/14			
SCALE POINTS				PRIORITY			
				3 OF 5

- END -

DATE FILMED

10 / 31 / 90