DZERO CRYOGENIC SYSTEM
VLPC & SOLENOID VACUUM SYSTEM
INSTRUMENTATION, CONTROL, AND LOGIC

ENGINEERING NOTE
3823.111-EN-482

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Fermi Accelerator Lab
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I. Introduction

The DZERO VLPC Cryostat and the Superconducting Solenoid both require an insulating Vacuum of 10^{-5} Torr or less. There is a vacuum system on the Detector Platform consisting of 2 Turbomolecular vacuum pumps and their associated piping, valves, instrumentation that are dedicated to this task.

This vacuum equipment requires an operator interface and control logic in order to function properly. The operator interface allows an operator to monitor, control and configure the proper pumping setup required at any given time. The control logic is needed to protect the Vacuum vessels and Vacuum equipment from catastrophic events that may harm them. This is typically done with interlock chains or strings.

II. User Interface Pictures

A. Overview
B. VLPC and Solenoid Turbo Pump Control

III. Picture Command Script
A. DZERO HE VACUUM PICTURE

PV-4520 (Open)  
closeDIG D0_CCRS2:pv-4250-v-open.F.CV [CR431]
PV-4520 (close)  
OPENDIG D0_CCRS2:pv-4250-v-open.F.CV [CR431]
PV-3231 (open)  
CLOSEDIG D0_CCRS2:pv-3231-v-open.F.CV [CR423]
PV-3231 (close)  
OPENDIG D0_CCRS2:pv-3231-v-open.F.CV [CR423]
PT-4252 (DEGAS)  
CLOSEDIG D0_CCRS2:PT4252DEGAS.F.CV [Y2688]
PAUSE 5
OPENDIG D0_CCRS2:PT4252DEGAS.F.CV [Y2688]
PT-3229 (DEGAS)  
CLOSEDIG D0_CCRS2:PT3229DEGAS.F.CV [Y2684]
PAUSE 5
OPENDIG D0_CCRS2:PT3229DEGAS.F.CV [Y2684]

B. DZERO SOLENOID TURBO PUMP PICTURE

START  
CLOSEDIG D0_CCRS2:sol_START.F.CV [CR419]
STOP  
OPENDIG D0_CCRS2:sol_START.F.CV [CR419]
LOW SPEED ON  
OPENDIG D0_CCRS2:sol_LOWSPD.F.CV [Y2682]
LOW SPEED OFF
  closeDIG D0_CCRS2:sol_LOWSPD.F_CV [Y2682]

C. DZERO VLPC TURBO PUMP PICTURE

START
  closeDIG D0_CCRS2:VLPC_START.F_CV [CR427]

STOP
  OPENDIG D0_CCRS2:VLPC_START.F_CV [CR427]

LOW SPEED ON
  OPENDIG D0_CCRS2:VLPC_LOWSPD.F_CV [Y2686]

LOW SPEED OFF
  closeDIG D0_CCRS2:VLPC_LOWSPD.F_CV [Y2686]

IV. Input/Output List

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<tr>
<th>Tagname</th>
<th>Description</th>
<th>Sex</th>
<th>Address</th>
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<tbody>
<tr>
<td>PT-2973-V</td>
<td>Solenoid turbo vacuum Exhaust to IV Header</td>
<td>4-20mA</td>
<td>WX2646</td>
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<tr>
<td>PT-2921-V</td>
<td>VLPC turbo vacuum Exhaust to IV Header</td>
<td>4-20mA</td>
<td>WX2647</td>
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<td>PT-2975-V</td>
<td>Solenoid turbo Inlet vacuum</td>
<td>1.5V-8.5V</td>
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<td>PT-2970-V</td>
<td>Sol &amp; VLPC Turbo Common Header</td>
<td>1.5V-8.5V</td>
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<td>PT-3259-V</td>
<td>Control dewar vacuum</td>
<td>1.5V-8.5V</td>
<td>WX2659</td>
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<td>PT-2925-V</td>
<td>VLPC turbo pump</td>
<td>1.5V-8.5V</td>
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<td>PT-4251-V</td>
<td>VLPC vacuum jacket /turbo pump</td>
<td>1.5V-8.5V</td>
<td>WX2662</td>
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<td>?PT-4252-V</td>
<td>VLPC vacuum jacket /turbo pump</td>
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<td>WX2665</td>
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<td>?PT-3229-V</td>
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<td>WX2666</td>
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<td>Solenoid Turbo Pump Current</td>
<td>2VDC=1A</td>
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<td>VLPC Turbo Pump Current</td>
<td>2VDC=1A</td>
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<td>Sol Turbo &quot;Start&quot;</td>
<td>On=on</td>
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<td>SOL_LOWSPD</td>
<td>Sol Turbo &quot;Low Speed&quot;</td>
<td>On=Low</td>
<td>Y2682</td>
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<tr>
<td>PT3229CON</td>
<td>Solenoid Ion Gage ON/OFF Control</td>
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<td>Y2683</td>
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<td>VLPC Turbo &quot;Start&quot;</td>
<td>On=on</td>
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<tr>
<td>PV-2915-V</td>
<td>Isolates UV header from VLPC,solenoid vacuums</td>
<td>On=Open</td>
<td>Y2689</td>
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<tr>
<td>PV-2920-V</td>
<td>Isolates IV header from VLPC, Solenoid vacuums</td>
<td>On=Open</td>
<td>Y2690</td>
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<tr>
<td>PV-2972-V</td>
<td>Isolate solenoid turbo from cntrl dwr, VLPC turbo</td>
<td>On=Open</td>
<td>Y2691</td>
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<td>PV-3231-V</td>
<td>Isolates control dewar from vacuums</td>
<td>On=Open</td>
<td>Y2692</td>
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<tr>
<td>PV-2930-V</td>
<td>Vacuum selector between VLPC and solenoid</td>
<td>On=Open</td>
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<td>PV-2925-V</td>
<td>VLPC turbo pump isolation from vacuum header</td>
<td>On=Open</td>
<td>Y2694</td>
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<td>PV-4250-V</td>
<td>VLPC vacuum isolation</td>
<td>On=Open</td>
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<td>PV-3231CL</td>
<td>Isolates control dewar from vac(Closed Switch)</td>
<td>On=Closed</td>
<td>X2705</td>
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<td>PV-3231OP</td>
<td>Isolates control dewar from vac (Open Switch)</td>
<td>On=Open</td>
<td>X2706</td>
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<td>PV-4250CL</td>
<td>VLPC vacuum isolation(Closed Switch)</td>
<td>On=Closed</td>
<td>X2707</td>
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<td>VLPC vacuum isolation(Open Switch)</td>
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<td>X2708</td>
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<td>PT3229STAT</td>
<td>Solenoid ION Gage Status</td>
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<td>X2709</td>
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<td>VLPC ION Gage Status</td>
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<td>VLPC ION Gage Degas Status</td>
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<td>SOL_FAULT</td>
<td>Sol Turbo &quot;Fault&quot;</td>
<td>On=Fault</td>
<td>X2713</td>
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<td>SOL_THRESHOLD</td>
<td>Sol Turbo &quot;R1 Speed Threshold&quot;</td>
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<td>X2714</td>
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<td>SOL_START_STATUS</td>
<td>Sol Turbo &quot;Start&quot;</td>
<td>On=Starting</td>
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<td>SOL_LOWSPD_MODE</td>
<td>Sol Turbo &quot;Low Speed Mode&quot;</td>
<td>On=Low</td>
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<td>VLPC Turbo &quot;Fault&quot;</td>
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<td>VLPC_START_STATUS</td>
<td>VLPC &quot;Start&quot;</td>
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<td>VLPC_LOWSPD_MODE</td>
<td>VLPC &quot;Low Speed Mode&quot;</td>
<td>On=Low</td>
<td>X2720</td>
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</table>

V. Control Logic

**PV-4250-V VLPC VACUUM SHELL ISOLATION VALVE OPEN**
- IF Operator Command to open
  - and
    - [PT2934V < 10 microns and NOT DISABLED] or DISABLED
    - and
    - [PT2934V < PT4251V and NOT DISABLED] or DISABLED

**PV-3231-V SOLENOID VACUUM SHELL ISOLATION VALVE OPEN**
- IF Operator Command to open
  - and
    - [PT2970V < 10 microns and NOT DISABLED] or DISABLED
    - and
    - [PT2970V < PT3259V and NOT DISABLED] or DISABLED

**SOLENOID TURBO PUMP is Running**
- IF Operator Command to Run
  - And
    - [PT2973V < 1000 microns and NOT DISABLED] or DISABLED
    - and
    - Control Turbo Chassis has no Faults

**VLPC TURBO PUMP is Running**
- IF Operator Command to Run
  - And
    - [PT2921V < 1000 microns and NOT DISABLED] or DISABLED
    - and
    - Control Turbo Chassis has no Faults
VI Ladder Logic
VII. Special Functions

A. SF PROGRAM 424

TITLE: PT-2973V
CONTINUE ON ERROR (Y,N): YES
ERROR STATUS ADDR (Y,C,WY,V): 
PROGRAM TYPE (N,P,C,R): NORMAL 
CYCLE TIME (SEC): 0.0

* THIS SPECIAL FUNCTION DETERMINES THE VACUUM PRESSURE GIVEN
A CURRENT INPUT OF 4-20 MILLI AMPS.
[GRANVILLE-PHILLIPS THERMOCOUPLE]

VAR -  VARIABLES
WX2646 = UNSCALED BINARY INPUT OF CURRENT
V784. = SCALED [4-20 MILLI AMPS] CURRENT
V808. = REAL CALCULATED PRESSURE IN MILLI TORR
V789 = UNSCALED V808. TO INTEGER

**STEP #1**
SCALE THE BINARY INPUT (WX3103) INTO A REAL VALUE (V775.)

IF WX2646 <= 6400
  MATH V784. = 4.0
ENDIF

**STEP #2**
DETERMINE THE RANGE THAT THE CURRENT (V775.) IS IN AND THEN
CALCULATE THE CORRESPONDING VACUUM PRESSURE (V800.) IN MILLI TORR

* ----RANGE: 4-10 MILLI AMPS
  IF V784. >= 4.0 AND V784. < 10.0
     MATH V808. := -55.91 + 18.862 * V784. - 8.9947 * V784. ** 2.0 + 1.9372
              * V784. ** 3.0
  ELSE
     -----RANGE : 10-16 MILLI AMPS
     IF V784. >= 10.0 AND V784. < 16.0
        MATH V808. := -2.0218E5 + 5.2375E4 * V784. - 4482.6 * V784. ** 2.0 +
                          128.23 * V784. ** 3.0
     ELSE
        -----RANGE: 16-20 MILLI AMPS
        IF V784. >= 16.0 AND V784. <= 20.0
           MATH V808. := 5.677E7 - 8.3461E6 * V784. + 3.895E5 * V784. ** 2.0 -
                                  5584.4 * V784. ** 3.0
        ENDIF
     ENDIF
  ENDIF
ENDIF

* *** END ***

UNSCALE SCALED INPUT.: V808. BINARY RESULT.: V789
LOW LIMIT.....: 0.0   HIGH LIMIT....: 1.0E6
20% OFFSET....: NO   BIPOLAR.......: NO

**** END ****
B. SF PROGRAM 425
TITLE: PT-2921V
CONTINUE ON ERROR (Y,N): YES
ERROR STATUS ADDR (Y,C,WY,V):
PROGRAM TYPE (N,P,C,R): NORMAL
CYCLE TIME (SEC): 0.0

00001  * THIS SPECIAL FUNCTION DETERMINES THE VACUUM PRESSURE GIVEN
     * A CURRENT INPUT OF 4-20 MILLI AMPS.
     [GRANVILLE-PHILLIPS THERMOCOUPLE]

00002  *  ===VARIABLES===
     WX2647 = UNSCALED BINARY INPUT OF CURRENT
     V786. = SCALED [4-20 MILLI AMPS] CURRENT
     V810. = REAL CALCULATED PRESSURE IN MILLI TORR
     V788 = UNSCALED V810. TO INTEGER

00003  *  **STEP #1**
     SCALE THE BINARY INPUT (WX3103) INTO A REAL VALUE (V775.)
00004  SCALE  BINARY INPUT...: WX2647  SCALED RESULT.: V786.
     LOW LIMIT.....: 4.0  HIGH LIMIT.....: 20.0
     20% OFFSET....: YES  BIPOLAR.......: NO
00005  IF  WX2647 <= 6400
00006  MATH  V786. := 4.0
00007  ENDIF
00008  *  **STEP #2**
     DETERMINE THE RANGE THAT THE CURRENT (V786.) IS IN AND THEN
     CALCULATE THE CORRESPONDING VACUUM PRESSURE (V800.) IN MILLI TORR
00009  *  -----RANGE: 4-10 MILLI AMPS
00010  IF  V786. >= 4.0 AND V786. < 10.0
00011  MATH  V810. := -55.91 + 18.862 * V786. - 8.9947 * V786. ** 2.0 + 1.9372
     * V786. ** 3.0
00012  ELSE
00013  *  -----RANGE: 10-16 MILLI AMPS
00014  IF  V786. >= 10.0 AND V786. < 16.0
00015  MATH  V810. := -2.0218E5 + 5.2375E4 * V786. - 4482.6 * V786. ** 2.0 +
     128.23 * V786. ** 3.0
00016  ELSE
00017  *  -----RANGE: 16-20 MILLI AMPS
00018  IF  V786. >= 16.0 AND V786. <= 20.0
00019  MATH  V810. := 5.677E7 - 8.3461E6 * V786. + 3.895E5 * V786. ** 2.0 -
     5584.4 * V786. ** 3.0
00020  ENDIF
00021  ENDIF
00022  IF  V810. <= 0.0
00023  MATH  V800. := 0.0
00024  ENDIF
00025  ENDIF
00026  UNSCALE  SCALED INPUT.: V810.  BINARY RESULT.: V788
     LOW LIMIT.....: 0.0  HIGH LIMIT.....: 1.0E6
     20% OFFSET....: NO  BIPOLAR.......: NO

**** END ****
C. SF PROGRAM 426
TITLE: BALZERS I

CONTINUE ON ERROR (Y,N): YES
CYCLE TIME (SEC): 0.0

00001 * THIS SPECIAL FUNCTION IS USED FOR THE BALZERS PRESSURE
TRANSMITTERS. THE INPUT VOLTAGE [0-10 VOLTS] CONVERTS TO
[3.8E-9 - 750 TORR]
00002 * --STEP 1--
THE (WX----) IS CONVERTED TO A REAL NUMBER [0-10 VOLTS]
REPRESENTED BY V1136. - V1146.
00003 * --STEP 2--
NEXT, THE PRESSURE IS CALCULATED USING THE EQUATION
P = 10^((1.667*(U-D))
WHERE P = PRESSURE V812. - V822.
U = VOLTAGE [0-10 VOLTS]
D = 11.46 [CORRESPONDS TO OUTPUT IN TORR]

00004 * (PT-2975-V)
00005 MATH V1136. := WX2657 / 32000 * 10.0
00006 MATH V812. := 10.0 ** ( 1.667 * V1136. - 11.46 )
00007 *
00008 * (PT-2970-V)
00009 MATH V1138. := WX2658 / 32000 * 10.0
00010 MATH V814. := 10.0 ** ( 1.667 * V1138. - 11.46 )
00011 *
00012 * (PT-3259-V)
00013 MATH V1140. := WX2659 / 32000 * 10.0
00014 MATH V816. := 10.0 ** ( 1.667 * V1140. - 11.46 )
00015 *
00016 * (PT-2925-V)
00017 MATH V1142. := WX2660 / 32000 * 10.0
00018 MATH V818. := 10.0 ** ( 1.667 * V1142. - 11.46 )
00019 *
00020 * (PT-2934-V)
00021 MATH V1144. := WX2661 / 32000 * 10.0
00022 MATH V820. := 10.0 ** ( 1.667 * V1144. - 11.46 )
00023 *
00024 * (PT-4251-V)
00025 MATH V1146. := WX2662 / 32000 * 10.0
00026 MATH V822. := 10.0 ** ( 1.667 * V1146. - 11.46 )

**** END ****
D. SF PROGRAM 427

TITLE: SOL_VLPC
CONTINUE ON ERROR (Y,N): YES
ERROR STATUS ADDR (Y,C,WY,V): 
PROGRAM TYPE (N,P,C,R): NORMAL
CYCLE TIME (SEC): 0.0

00001 * THIS SPECIAL FUNCTION IS USED TO PERFORM COMPARISONS FOR THE
INTERLOCK ON VALVES PV-3231-V AND PV-4250-V

00002 * SOLENOID VALVE - PV-3231-V
00003 * ----COMPARISON #1: PT-2970-V < 10 MILLITORR
00004 * ------TURN COIL 421 ( ON OR OFF )
00005 IF V814. <= 0.01
00006 MATH C421 := 1
00007 ELSE
00008 MATH C421 := 0
00009 ENDIF

00010 * ----COMPARISON #2: PT-2970-V < PT-3259-V
00011 * ------TURN COIL 422 ( ON OR OFF )
00012 IF V814. <= V816.
00013 MATH C422 := 1
00014 ELSE
00015 MATH C422 := 0
00016 ENDIF

00017 * VLPC VALVE - PV-4250-V
00018 * ----COMPARISON #1: PT-2934-V < 10 MILLITORR
00019 * ------TURN COIL 429 ( ON OR OFF )
00020 IF V820. <= 0.01
00021 MATH C429 := 1
00022 ELSE
00023 MATH C429 := 0
00024 ENDIF

00025 * ----COMPARISON #2: PT-2934-V < PT-4251-V
00026 * ------TURN COIL 430 ( ON OR OFF )
00027 IF V820. <= V822.
00028 MATH C430 := 1
00029 ELSE
00030 MATH C430 := 0
00031 ENDIF

**** END ****
E. SF PROGRAM 428
TITLE: ION_GAGE
CONTINUE ON ERROR (Y,N): YES
ERROR STATUS ADDR (Y,C,WY,V):
PROGRAM TYPE (N,P,C,R): NORMAL
CYCLE TIME (SEC): 0.0

00001 * THIS SPECIAL FUNCTION IS USED TO CALCULATE THE VACUUM VIA ION
GAGES AS WELL AS CONTROL THESE GAGES.
NOTE: THIS IS FOR A (NITROGEN) GAS ION GAGE
00002 * SOLENOID ION GAGE - PT-3229-V
00003 * ---VARIABLES---
WX2666 = INTEGER VOLTAGE SIGNAL
V790. = REAL VOLTAGE (0-8 VOLTS)
V824. = CALCULATED VACUUM PRESSURE [TORR]
Y2683 = ION GAGE STATUS (1=ON) (0=OFF)
X2709 = GAGE OUTPUT
00004 SCALE BINARY INPUT: WX2666 SCALED RESULT: V790.
LOW LIMIT....: 0.0 HIGH LIMIT....: 8.0
20% OFFSET....: NO BIPOLAR......: NO
00005 MATH V824. := 10.0 ** V790. * 1.0E-9
00006 * IF (ION STATUS IS OFF AND VACCUM < 1.0E-3) THEN (TURN ON GAGE)
00007 IF Y2683 = 0 AND V816. <= 1.0E-3
00008 IMATH Y2683 := 1
00009 ELSE
00010 * IF (GAGE STATUS IS OFF) THEN (TURN OFF GAGE)
00011 IF Y2709 = 0
00012 IMATH Y2683 := 0
00013 ENDF
00014 ENDF
00015 *
00016 * VLPC ION GAGE - PT-4252-V
00017 * ---COMPARISON #1: PT-2934-V < 10 MILLITORR
00018 * ---VARIABLES---
WX2662 = INTEGER VOLTAGE SIGNAL
V792. = REAL VOLTAGE (0-8 VOLTS)
V826. = CALCULATED VACUUM PRESSURE [TORR]
Y2687 = ION GAGE STATUS (1=ON) (0=OFF)
X2711 = GAGE OUTPUT
00019 SCALE BINARY INPUT: WX2662 SCALED RESULT: V792.
LOW LIMIT....: 0.0 HIGH LIMIT....: 8.0
20% OFFSET....: NO BIPOLAR......: NO
00020 MATH V826. := 10.0 ** V792. * 1.0E-9
00021 * IF (ION STATUS IS OFF AND VACCUM IS < 1.0E-3) THEN (TURN ON GAGE)
00022 IF Y2687 = 0 AND V822. < 1.0E-3
00023 IMATH Y2687 := 1
00024 ELSE
00025 * IF (GAGE STATUS IS ON) THEN (TURN OFF GAGE)
00026 IF X2711 = 0
00027 IMATH Y2687 := 0
00028 ENDF
00029 ENDF
**** END ****
VIII. Vacuum Instrumentation and Vacuum Valves

The Vacuum system for the Solenoid and VLPC system must monitor and maintain a vacuum below 10^-4 Torr. This system employs 2 Turbo-Molecular pumps, Vacuum transducers and Vacuum slide valves.

The Vacuum system uses three transducers to convert vacuum into a voltage measurement that the control system can read. The three transducers are Granville-Phillips model 275 thermocouple gage, Granville-Phillips model 343 Ion gage, and a Balzer combination thermocouple-Cold cathode gage.

A. Thermocouple

The Thermocouple has a useful range of 760 Torr down to 10^-3 Torr. The model 275 has the signal conditioning electronics built into the unit, this allows for a direct voltage input into the control system. The curve fit is broken into 3 segments.

Granville-Phillips Model 275 Tags:
1. PT2973V Solenoid Turbo Foreline Pressure.
2. PT2921V VLPC Turbo Foreline Pressure.

The following equations are used to curve fit the voltage output into the vacuum units:

**GRANVILLE-PHILLIPS SERIES**

**275 THERMOCOUPLE**

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<thead>
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<th>TRUE PRESSURE (N2) [milli Torr]</th>
<th>Iout mADC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>4.000</td>
</tr>
<tr>
<td>1.00</td>
<td>4.027</td>
</tr>
<tr>
<td>2.00</td>
<td>4.051</td>
</tr>
<tr>
<td>5.00</td>
<td>4.127</td>
</tr>
<tr>
<td>10.00</td>
<td>4.245</td>
</tr>
<tr>
<td>20.00</td>
<td>4.459</td>
</tr>
<tr>
<td>50.00</td>
<td>4.928</td>
</tr>
<tr>
<td>100.00</td>
<td>5.522</td>
</tr>
<tr>
<td>200.00</td>
<td>6.360</td>
</tr>
<tr>
<td>500.00</td>
<td>7.958</td>
</tr>
<tr>
<td>1000.00</td>
<td>9.573</td>
</tr>
<tr>
<td>2000.00</td>
<td>11.465</td>
</tr>
<tr>
<td>5000.00</td>
<td>13.985</td>
</tr>
<tr>
<td>10000.00</td>
<td>15.592</td>
</tr>
<tr>
<td>20000.00</td>
<td>16.715</td>
</tr>
<tr>
<td>50000.00</td>
<td>17.529</td>
</tr>
<tr>
<td>100000.00</td>
<td>17.829</td>
</tr>
<tr>
<td>200000.00</td>
<td>18.052</td>
</tr>
<tr>
<td>300000.00</td>
<td>18.331</td>
</tr>
<tr>
<td>400000.00</td>
<td>18.673</td>
</tr>
<tr>
<td>500000.00</td>
<td>18.991</td>
</tr>
</tbody>
</table>
Granville-Phillips model 275 Thermocouple

600000.00  19.263
700000.00  19.493
760000.00  19.611
800000.00  19.684
900000.00  19.853
1000000.00 20.000
Thermocouple 275 Connector Wiring

<table>
<thead>
<tr>
<th>Pin#</th>
<th>Function</th>
<th>PT2973V</th>
<th>PT2921V</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>+ Power 11-16VDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>- Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>+ Signal WX2646</td>
<td>WX2647</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>- Signal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B. Ion Gage

The Ion gage has a useful range of 10^-3 Torr down to 10^-8 Torr. It is highly accurate and has good repeatability. It does need turn-off protection for when the vacuum is above 10^-3 Torr. It also need some control logic to turn them back on when the vacuum goes below 10^-3 Torr. The Ion gage will be used on each vacuum vessel in conjunction with the Balzer combination transducer.

Granville-Phillips Model 343 Mini-Ion Tags:
1. PT3229V Solenoid Vacuum Vessel.
2. PT4252V VLPC Vacuum Vessel.

Ion Gage:(Nitrogen Gas) Pressure vs. Analog Output Signal

<table>
<thead>
<tr>
<th>Analog Output Signal [Volts DC]</th>
<th>Pressure [Torr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00000001</td>
</tr>
<tr>
<td>1.5</td>
<td>3.16228E-08</td>
</tr>
<tr>
<td>2</td>
<td>0.00000001</td>
</tr>
<tr>
<td>2.5</td>
<td>3.16228E-07</td>
</tr>
<tr>
<td>3</td>
<td>0.0000001</td>
</tr>
<tr>
<td>3.5</td>
<td>3.16228E-06</td>
</tr>
<tr>
<td>4</td>
<td>0.00001</td>
</tr>
<tr>
<td>4.5</td>
<td>3.16228E-05</td>
</tr>
<tr>
<td>5</td>
<td>0.0001</td>
</tr>
<tr>
<td>5.5</td>
<td>0.000316228</td>
</tr>
<tr>
<td>6</td>
<td>0.001</td>
</tr>
<tr>
<td>6.5</td>
<td>0.003162276</td>
</tr>
<tr>
<td>7</td>
<td>0.01</td>
</tr>
<tr>
<td>7.5</td>
<td>0.031622777</td>
</tr>
<tr>
<td>8</td>
<td>0.1</td>
</tr>
</tbody>
</table>
C. Balzer Combination Cold Cathode-Thermocouple

The Balzer combination transducer is a combination cold cathode and thermocouple in one housing with one signal output. It has a useful range from 760 Torr down to 10^-9 Torr. It is not as accurate or repeatable as a Ion gage below 10^-3 Torr, however the Balzer needs no range protection. The Balzer will be used
throughout the pumping circuit as well as in conjunction with the Ion gage on the Vacuum vessels.

Balzer PKR250 Tags:
1. PT3259V Solenoid Vacuum Shell.
2. PT4251V VLPC Vacuum Shell.
3. PT2970V Solenoid Turbo Crossover.
4. PT2975V Solenoid Turbo Inlet.
5. PT2934V VLPC Turbo Crossover.
6. PT2925V VLPC Turbo Inlet.

### Pressure vs. Signal for BALZERS

<table>
<thead>
<tr>
<th>Signal [volts]</th>
<th>Pressure [Torr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5</td>
<td>ERROR</td>
</tr>
<tr>
<td>0.5 ... 1.82</td>
<td>UNDER RANGE</td>
</tr>
<tr>
<td>1.82</td>
<td>3.80E-09</td>
</tr>
<tr>
<td>2</td>
<td>7.50E-09</td>
</tr>
<tr>
<td>2.6</td>
<td>7.50E-08</td>
</tr>
<tr>
<td>3.2</td>
<td>7.50E-07</td>
</tr>
<tr>
<td>3.8</td>
<td>7.50E-06</td>
</tr>
<tr>
<td>4.4</td>
<td>7.50E-05</td>
</tr>
<tr>
<td>5</td>
<td>7.50E-04</td>
</tr>
<tr>
<td>5.6</td>
<td>7.50E-03</td>
</tr>
<tr>
<td>6.2</td>
<td>7.50E-02</td>
</tr>
<tr>
<td>6.8</td>
<td>7.50E-01</td>
</tr>
<tr>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>8</td>
<td>75</td>
</tr>
<tr>
<td>8.6</td>
<td>750</td>
</tr>
<tr>
<td>8.6 ... 9.5</td>
<td>OVER RANGE</td>
</tr>
</tbody>
</table>

### Balzer Connector Wiring

<table>
<thead>
<tr>
<th>Pin#</th>
<th>Function</th>
<th>PT3259V</th>
<th>PT4251V</th>
<th>PT2970V</th>
<th>PT2975V</th>
<th>PT2934V</th>
<th>PT2925V</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>+ Signal WX2659 WX2662 WX2658 WX2657 WX2661 WX2660</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>- Signal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>+ Power 15-30VDC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>- Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Shield (Earth Ground)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### D. Gate Valve

The Dzero Detector Platform Vacuum system uses slide gate valves for isolating piping sections. The gate valves are pneumatically driven. The pneumatics are directed by a 24VDC solenoid that is purchased with the valve and is mounted to it. The pneumatic solenoid is wired to the PLC I/O Base #7.