**DZERO HVAC
HEAT PUMP CONTROLS**

**ENGINEERING NOTE
3740.510-EN-572**

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I. ABSTRACT

This engineering note documents the integration of Dzero Heat Pump 1 through Heat Pump 15 into the cryo/gas process control system commonly referred to as the cryo control system.

II. INTRODUCTION

Heat pumps 1 through 15 control the ambient air temperature on the 3rd, 5th, and 6th floor office areas at Dzero. The entire Johnson HVAC control system was replaced with a Siemens control system in 1999 leaving behind the 15 heat pumps with stand-alone Johnson controllers.

Now, these 15 heat pump Johnson controllers are being replaced with small stand alone Beckhoff BC9000 controllers. The Beckhoff BC9000 controllers are network able into the existing Intellution control system. The Beckhoff BC9000 controllers use the cryo private Ethernet network and an OPC driver to get data into the Intellution SCADA node databases. The BC9000 is also programmed over this same Ethernet network.

III. SPECIFICATIONS

Heat Pump Control

Heat Set point = Set point -2F

Cool Set point = Set point +2F

Compressor Min Off Time = 5 minutes

Compressor Min On Time = 2 minutes

Reversing Valve ON = Heating

Reversing Valve OFF = Cooling

Temperature Sensor

Each temperature sensor is located in the return duct to the respective Heat Pump. The sensor is a Johnson Controls 1000 ohm RTD sensor with a model number TE-6000-1.

IV. OVERVIEW

The Beckhoff Heat pump controllers are physically networked to D0-CCRS5 through the Dzero Industrial private Ethernet network. D0-CCRS5 is located in room 215. The TwinCat OPC server collects the data from each controller and communicates it to the D0-CCRS5 Intellution database. Once the data is in the D0-CCRS5 SCADA node it can be readily distributed to the rest of the Intellution control system.

Physical System Layout/Connection

V. BECKHOFF BC9000

The BC9000 PLC must be configured on startup by using the Beckhoff KS2000 software. This connection is made through a serial port on the front of the BC9000.

The BC9000 network address must also be configured to a free address within the local network. The first three bytes of the IP address are set using the KS2000 software. The fourth byte is set using the dip switches on the BC9000.

DIP switches The first 8 switches are needed for the 4th byte of the TCP/IP number. Bit 9 indicates the network class, and bit 10 the DHCP service.

Example

$$\text{Bits } 1-8 \quad 2^0 + 0_1 + 0_2 + 2^3 + 0_4 + 0_5 + 2^6 + 2^7 = 201$$

$$1 + 0 + 0 + 8 + 0 + 0 + 64 + 128 = 201$$

Mainmenu

BC9000 Common Settings

BC9000 Common Settings

FieldBus settings

KL3202 Settings (RTD Input Module)

VI. TWINCAT

TwinCat PLC is Beckhoff's PLC programming software. It is 1131 compliant and D0-CCRS5 is fully licensed to run TwinCat PLC, TwinCat system manager, and TwinCat OPC server. TwinCat PLC is used to program the remote BC9000 PLC's over the private Ethernet network as well as 4 runtime PLC systems on D0-CCRS5. TwinCat system manager is used to configure the Beckhoff PLC's, Network, and their relationship to each other. TwinCat System Manger can also be used to map variables between PLC systems. TwinCat OPC server is used to map variables from any Beckhoff PLC to other OPC clients, such as the Intellution software.

For details or help with TwinCat go to WWW.Beckhoff.com.

Right clicking the TwinCat icon in the lower right hand corner of the screen on D0-CCRS5 may launch TwinCat functions.

TwinCat PLC

TwinCat PLC is used off line to modify a BC9000 PLC program and recompiled each time a modification is made. The compiled PLC program is stored locally on the hard drive. To download any modifications, the programmer need only go on line to the respective controller after a modification is made, and the programmer will be prompted to download

any changes. Whenever a new program is downloaded, the programmer will need to go to the run mode on the BC9000. The programmer should always create a new boot project on line after a download. This will insure the program will be in permanent memory.

TwinCat PLC can also be used on line to check variable values. Variables can also be forced while on line to check for correct program function.

TwinCat System Manager

TwinCat System Manager is a tool used to configure a system of PLC's and their relationships to one another. This tool allows you to establish communication settings, I/O mapping between controllers, as well as any virtual devices.

twincatnew - TwinCAT System Manager

File Edit Actions View Options Help

SYSTEM - Configuration
 PLC - Configuration
 I/O - Configuration
 I/O Devices
 Device 1 (Virtual-Ethernet)
 Device I-Image
 Inputs
 Outputs
 HP-12
 HP-10
 HP-11
 PLC Variables
 Inputs
 Outputs
 Term 12 (KL2012)
 Term 13 (KL2012)
 Term 14 (KL3202)
 Term 15 (KL1104)
 End Term (KL9010)
 HP-15
 HP-14
 HP-8
 HP-7
 HP-9
 HP-13
 HP-1
 HP-2
 HP-3
 HP-4
 HP-5
 HP-6
 Mappings

General ADS

Name: Device 1 (Virtual-Ethernet Id: 1

Type: Virtual Ethernet Interface

Comment:

☐ Disabled ☐ Create symbols

Number	Box Name	Address	Type	In Size	Out Size
1	HP-12	192.16...	BC9000	12.0	18.0
2	HP-10	192.16...	BC9000	22.0	16.0
3	HP-11	192.16...	BC9000	12.0	18.0
4	HP-15	192.16...	BC9000	22.0	16.0
5	HP-14	192.16...	BC9000	22.0	16.0
6	HP-8	192.16...	BC9000	22.0	16.0
7	HP-7	192.16...	BC9000	22.0	16.0
8	HP-9	192.16...	BC9000	22.0	16.0
9	HP-13	192.16...	BC9000	22.0	16.0
10	HP-1	192.16...	BC9000	22.0	16.0
11	HP-2	192.16...	BC9000	22.0	16.0
12	HP-3	192.16...	BC9000	22.0	16.0
13	HP-4	192.16...	BC9000	22.0	16.0
14	HP-5	192.16...	BC9000	22.0	16.0
15	HP-6	192.16...	BC9000	22.0	16.0

TwinCat OPC Server

TwinCat OPC server is a Beckhoff driver that allows other OPC clients to send and receive information to any of the controllers on a network. The easiest way to set up the OPC server variables is to go to TwinCat PLC and export the variables you would like to establish communications with by using OPC. You can then go to the OPC server and import the groups of variables that were exported from TwinCat PLC.

Any OPC client can now send and receive variables from the OPC server. D0-CCRS5 is running the Intellution OPC client, which allows direct transfer of variables to and from the BC9000 controllers to the Intellution database blocks.

C:\twinca\OPC\DO_heatpumps.tcf - TwinCAT OPC Server

File Add Edit View Help

HP-1
HP-1
Global Variables
hp-10
HP-12
HP-11
HP-13
HP-14
HP-15
HP-2
HP-3
HP-4
HP-5
HP-6
HP-7
HP-8
HP-9
labf
Global Variablen

Name	Value	Access Type	Index Group	Index Offset	Description
COMP_STAT	Off	By address: (Physical Outputs) - %QX	0xF031	0x91 (145)	
COMPRESSOR	?????	By address: (Physical Outputs) - %QX	0xF031	0x8 (8)	
COOL_PROP_BAND	?????	By name	0xF005	0x0 (0)	
COOL_SP	?????	By name	0xF005	0x0 (0)	
EMERGENCY_OFF	?????	By address: (Physical Inputs) - %IX	0xF021	0x8 (8)	
FAN	?????	By address: (Physical Outputs) - %QX	0xF031	0x8 (8)	
FAN_STAT	On	By address: (Physical Outputs) - %QX	0xF031	0x91 (145)	
HEAT_PROP_BAND	?????	By name	0xF005	0x0 (0)	
HEAT_SP	?????	By name	0xF005	0x0 (0)	
HP1_CON	200	By generic ADS	0xF020	0x84 (132)	
HP1_CONTROL	1053.555	By address: (Memory Range) - %MX	0x4021	0xC (12)	
HP1_SP_STAT	?????	By address: (Physical Outputs) - %Q	0xF030	0x84 (132)	
HP1_TEMP	?????	By address: (Physical Inputs) - %I	0xF020	0x2 (2)	
HP1_TEMP_SP_CON	73	By generic ADS	0xF020	0x80 (128)	
HP1_TEMP_SP_STAT	73	By address: (Memory Range) - %M	0x4020	0x0 (0)	
HP1_TEMP_SP_STAT_DB	?????	By name	0xF005	0x0 (0)	
HP1_TEMP_STAT	72.3098	By address: (Physical Outputs) - %Q	0xF030	0x80 (128)	
REV_VALVE	?????	By address: (Physical Outputs) - %QX	0xF031	0x8 (8)	
REV_VALVE_STAT	On	By address: (Physical Outputs) - %QX	0xF031	0x91 (145)	

Ready Global Variables has 19 Tags

VII. LOGIC

The programmed logic in the BC9000 is embedded in each Heat Pump Controller. Even though all the BC9000 controllers are on a network, each controller can operate in a stand-alone mode. The following section displays the typical logic and variable structure in each heat pump controller.

MAIN

CALCS

```
CALCS (PRG-ST)
PROGRAM CALCS
VAR
  OFF_TIME: REAL;
  HP1_TEMP_C_REAL: REAL;
END_VAR

VAR CONSTANT
  ON_TIME: REAL := 120000;
END_VAR

IF HP1_TEMP_SP_STAT > HP1_TEMP_STAT THEN
  OFF_TIME := 300000;
  COMP_OFF_TIME := REAL_TO_TIME(OFF_TIME);
  COMP_ON_TIME := REAL_TO_TIME(ON_TIME);
ELSE
  OFF_TIME := 300000;
  COMP_OFF_TIME := REAL_TO_TIME(OFF_TIME);
  COMP_ON_TIME := REAL_TO_TIME(ON_TIME);
END_IF;

HP1_TEMP_C_REAL := INT_TO_REAL(HP1_TEMP);
HP1_TEMP_STAT := ((HP1_TEMP_C_REAL / 10) * 0.2293) - 160.98;

IF HP1_TEMP_SP_CON > 65.0 AND HP1_TEMP_SP_CON < 85.0 THEN
  HP1_TEMP_SP_STAT := HP1_TEMP_SP_CON;
END_IF;

IF HP1_TEMP_SP_STAT < 65.0 OR HP1_TEMP_SP_STAT > 85.0 THEN
  HP1_TEMP_SP_STAT := 72;
END_IF;

HP1_SP_STAT := HP1_TEMP_SP_STAT;
HP1_TEMP_SP_STAT_DB := HP1_TEMP_SP_STAT + 0.2;

COOL_SP := HP1_TEMP_SP_STAT + COOL_PROP_BAND;
HEAT_SP := HP1_TEMP_SP_STAT - HEAT_PROP_BAND;

IF HP1_TEMP_STAT < 40.0 OR HP1_TEMP_STAT > 100.0 THEN
  HP1_CONTROL := 0;
ELSE
  IF HP1_CON = 100 THEN
    HP1_CONTROL := 0;
  END_IF;
  IF HP1_CON = 200 THEN
    HP1_CONTROL := 1;
  END_IF;
END_IF;
```

Global Variables

```
Global_Variables
VAR_GLOBAL
  FAN AT %QX8.0: BOOL;
  REV_VALVE AT %QX8.1:  BOOL;
  COMPRESSOR AT %QX8.2:  BOOL;
  EMERGENCY_OFF AT %IX8.0: BOOL;
  HP1_TEMP AT %IB2: INT;

  HP1_TEMP_STAT AT %QB128: REAL;
  HP1_TEMP_SP_CON AT %IB128: REAL;
  HP1_TEMP_SP_STAT AT %MB0: REAL := 72.0;
  HP1_SP_STAT AT %QB132: REAL;
  HP1_CON AT %IB132: INT;

  HP1_CONTROL AT %MX12.0: BOOL;
  COMP_OFF_TIME: TIME;
  COMP_ON_TIME: TIME;
  COOL_SP: REAL;
  HEAT_SP: REAL;

  FAN_STAT AT %QX145.0: BOOL;
  REV_VALVE_STAT AT %QX145.1: BOOL;
  COMP_STAT AT %QX145.2: BOOL;

  HP1_TEMP_SP_STAT_DB: REAL;
END_VAR

VAR_GLOBAL CONSTANT
  COOL_PROP_BAND: REAL := 2.0;
  HEAT_PROP_BAND: REAL := 2.0;
END_VAR
```

VIII. INTELLUTION SCADA NODE

D0-CCRS5 is the SCADA node for all the Dzero Heat Pumps. The SCADA node communicates directly with the BC9000 controllers using the Dzero Controls Private Ethernet. The SCADA node database blocks are set up to poll the BC9000 data into the blocks using the OPC server client architecture. The D0-CCRS5 data is shared with all other Intellution operational nodes, giving operators full access to the Heat Pump settings and controls. Security and alarming are also handled by D0-CCRS5.

OPC Client

The Intellution OPC client can be configured by running the driver power tool on the SCADA node. The typical configuration settings are shown below. Setting the AutoCreate to "on" allows for less configuration work, by automatically generating client entries whenever there is an entry in a database block address field.

Database

The D0-CCRS5 database houses each variable in a database block. Each block can be configured for security and alarming. Careful attention should be paid to the database block I/O address. Each Heat Pump has 7 variables transmitted between the BC9000 controller and the Database.

HP1_COMP_STAT	DI		1	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.comp_STAT,no AccessPath	OFF	D0 HVAC
HP1_CON	AR		—	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.HP1_CON,no AccessPath	200	D0 HVAC
HP1_FAN_STAT	DI		1	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.FAN_STAT,no AccessPath	RUN	D0 HVAC
HP1_REV_VALVE_STAT	DI		1	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.rev_valve_STAT,no AccessPath	HEAT	D0 HVAC
HP1_TEMP_SP_CON	AR		—	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.HP1_TEMP_SP_CON,no AccessPa	73.00	D0 HVAC
HP1_TEMP_SP_STAT	AI		3	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.HP1_TEMP_sp_statno AccessPa	73.00	D0 HVAC
HP1_TEMP_STAT	AI		3	OPC	Server1.hp-1:HP-1:HP1.Global_Variables.HP1_TEMP_statno AccessPath	71.87	D0 HVAC
HP2_COMP_STAT	DI		1	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.comp_STAT,no AccessPath	OFF	D0 HVAC
HP2_CON	AR		—	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.HP1_CON,no AccessPath	200	D0 HVAC
HP2_FAN_STAT	DI		1	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.FAN_STAT,no AccessPath	RUN	D0 HVAC
HP2_REV_VALVE_STAT	DI		1	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.rev_valve_STAT,no AccessPath	COOL	D0 HVAC
HP2_TEMP_SP_CON	AR		—	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.HP1_TEMP_SP_CON,no Access	0.00	D0 HVAC
HP2_TEMP_SP_STAT	AI		3	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.HP1_TEMP_sp_statno AccessPa	72.00	D0 HVAC
HP2_TEMP_STAT	AI		3	OPC	Server1.hp-2:HP-2:HP2.Global_Variables.HP1_TEMP_statno AccessPath	73.09	D0 HVAC

?

||

X

Basic

Alarms

Advanced

Tag Name :

HP1_TEMP_SP_STAT

Description :

Previous :

Next :

...

Addressing

Driver :

OPC OPC Client v7.33

I/O Configuration...

I/O Address :

Server1.hp-1:HP-1:HP1.Global_Variables.HP1_TEMP_sp_statno AccessPath

Signal Conditioning:

None

Hardware Options:

Server

Scan Settings

☐ Process by Exception

Scan Time : 3

Phase At :

Engineering Units

Low Limit :

0.00

High Limit :

100.00

Units :

Save

Cancel

Help

Pictures

Each Heat Pump can be controlled through a graphical picture located on the picture server. These pictures are built into the standard operator picture trees through the HVAC directory. These pictures can be accessed from any Intellution operations node at Dzero.

This picture allows for display of data as well as control of the unit and it's current temperature set point.

X. Other Reference Material

Fermi Drawing

3823.000-EE-330314

D0 Detector Upgrade

D0 HVAC System Heat Pumps

Control Wiring Diagram DAB 5 & 6

Web Sites

WWW.Beckhoff.Com/

<http://d0-hist.fnal.gov>