Fermilab

UPC No. 112
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Proposal for

Satellite Refrigeration Control Interface

Transducers

Preferred transducer is a conventional pressure gauge with R(L)VDT mounted to it. The electronic processes will be located in the Service Building so that the gauge-transducer unit would be purely mechanical. The gauges will always give visual readout in the refrig building and transducers can be mounted or not depending on need. Each individual refrig. subsystem will have its own gauge panel which mounts on the unit; e.g. cold box, engines, valve box, magnet strings will have separate gauge panels.

The easiest gauge conversion appears to be possible by adding gear similar to the one which drives the pointer but which makes only 1/4 turn for one turn of needle. An RVDT could then be mounted to this (where desired) with a readout range of ±45 degrees.

Electronic Processor

A single processor unit would be located in each Service Building. It would contain an ac oscilator supplying ac to all R(L)VDT's and accepting 32/64 channels of ac read back signal, which are converted to analog and multiplex digitized with 9 bit resolution(min) and speed $\geq$ 1/sec for scan of all channels. Signals will be directed to data storage, alarms and limits and MCR reading or to feedback loops. Some of the channels will probably be pure A/D bypassing the ac processor. One channel will be for calibration.

Other Options

Other read back options can also be considered if we are unable to obtain the gauge transducer combination. It still seems best for us to supply the electronics and locate it in the Service Building. L(R)VDT circuits are suited to this. Strain gauge and capacitive circuits do not seem to be and electronics would have to be located in Refrigerator Building if not on individual transducer units. Also, strain gauges are temperature sensitive (~.008%/°F).

Valve Actuators

The Preferred Actuator is one with a motor drive and a position readout (not one which servos to specific position from an analog signal). Here again the electronics for the readout could be LVDT's and go to the same processor box as the transducers. The drive electronics could be very simple, namely just solid state switches to ac motors. Pulses or pulse duration would determine the amount of motion. Stepping motors may or may not be feasible and are probably expensive.

Servo actuators do not need position readouts but they do need D/A outputs. Their electronics with its own closed loop is redundant with the main loop control and they do not lend themselves to easy entry to and return from manual operation. (See Manual Operation).

Requirements of Valve Actuators Independent of Type Electrical Control

Travel	~9/16" useful range
Speed	~100 mils/sec

Mechanical - Mounting vertical

Weight - less than 30 lb., off center load < 10 inch/lb

Fail at set point preferred (not open or closed).

Stops - positive adjustable stops so that unit cannot under any circumstances move valve beyond these limits

Closed limit - valve seats - 200 lb seating force (positive stop would be past this point)

Open limit - valve opens to 9/16 positive limit

Duty factor - some valves may be in motion as much as 10% of the time

Forces - seating force of actuator - 200 lb.
maximum force on actuator (non seating) 150 lb (gas pressure or vacuum load)

Motor should either be able to stall at 200 lb force and stand continuous, operation installed condition, or actuator should be spring loaded and run to its own limits without exceeding the 200 lb force.

Motor can be dc, ac, stepping, or servoed. Motion characteristics of different types are to be specified by vendor so that we can make appropriate choice. Overrun, coasting, step size and drift from external load should be consistent with needed resolution.

Readout - readout or place to mount readout should be positioned at a place to minimize error or backlash.

Units per Service Building	Location	Position Accuracy	Max Ext Force Seating Force	Spec.
2	tunnel	< 5 mils	50/200 lb	no electronics on actuators
2	building	< 15 mils	150/200 lb	electronics okay (not preferred)
7	building	< 15 mils	50/200 lb	electronics okay (not preferred)

SERVO LOOPS - CONTROL POINTS AND VARIABLES

Valves	Servo Time Const Min	Process Point
1) PV4 (HxI, II)	2	A) TIC4C (HxII Supply temp.) Argon 100 psi 2%
2) PV6 (Gas Eng Speed)	2	B) TIC6 (HxIII, IV Return temp.) Hydrogen 100 PSI 2%
3) PV9 (JT) (fragile)	1	C) PIC8 (Sub Cool Supply Pres) 50 PSI 2%
4) PV8 (Wet Eng Speed)	1	" (Sub Cool Supply Press) Oscillation time constants of C) are 10 min., 1 min., 0.1 min.
5) PV10 (By Pass) (fragile)	.1	"
6) PV7 (CHL)		--
7) PV11 (US JT)	1	D) DPC11 (US 2Ø Δ Temp) 0-100" < 10% 150 lb
8) PV12 (DS JT) (US N_2)	1	E) DPC12 (DS2Ø Δ Temp) 0-100" < 1.0% 150 lb
9) PV13 (USN_2) (DS N_2)	200	F) TIC13 (USN_2 Temp) Nitrogen 100 PSI 2%
10) PV14(DSN_2) (HXI N_2)	200	G) TIC14(DSN_2 Temp) Nitrogen 100PSI 2%
11) PV5($HXIN_2$)		H) LLIC5(N_2 Liq Lev) 0-10" 10% 150 lb

Servo Loops

A model program for a single loop given below is to be tested at B12. There are three gains (one of which used only to estimate where the value will go to), two times, (a time constant and a sample rate), limits to the step size and the allowed valve range. Averaging of data is not done but may be necessary (electrical filters may also be used to reduce noise or unwanted oscillations).

Process Point (C)PIC8) acts in three loops: the wet engine speed, the JT valve, and the bypass valve. The wet engine and JT are similar in function and if the engine is not used then the regulation shifts to the JT. Otherwise, the JT is set to some position and left alone. The wet engine works on the 10 minute oscillations constant and the bypass on the 1 minute oscillations. It may be expected to go through full open - full close cycles.

Stages of Cooldown

Three stages of cooldown are determined by monitoring temperature at ends of magnet strings with resistors in 1 ϕ

1) Cooldown - to 25°

   Wet engine is set to run at full speed

   Magnet JT's are closed

   PV15 and 16 (magnet bypass values are open)

   PV10 (Refrig Bypass) is set to regulate to 2 ATM and under these conditions the gas engine will go full speed by its own control. Half the flow will be through the gas engine, 1/3 through the by pass and 1/6 through the magnet string.

2) Transition 25 degrees to 10 degrees

   Wet engine is still Sct to run full

   Magnet by pass values are closed and

magnet JT's operate through full range.
(PV10 still regulates to 2 ATM).

3) Operating 10 degrees and below
Wet engine is controlled by PIC8, -PV8 loop.
Magnet JT's are limited to 25-75% of full range.
(Each magnet string makes the transition independently).
Transition time from one mode to another would be sensed and initiated by the computer.

Manual Control

Manual control at the refrigerator building will be necessary for adjustment and changing of engines, etc. Also, local control of loops, activating and deactivating them is necessary.

A local-remote switch and raise lower button on each valve actuator will give the necessary control. A box with eleven controls located near the door would give convenient local override capability. This box can electrically couple in at the power drive level to the motors and does not have to communicate to the computer at all except to inhibit the computer loop.

Recovery from manual would cause an initialization of the computer loop and the maximum step limit would ensure slow enough recovery to normal operation. Some allowance for the value having been placed beyond its allowed limits must be made.

Emergency Operation

Whatever control necessary during power failure can be supplied at the Manual Control interface, also. If it is necessary, have standby control of the N_2 loops, for instance, the emergency operation of these valves would be provided by special hardware which enters at this point. Another possibility is for parallel pneumatic control of these loops which would be activated on power failure.

Local Parameter Entry Box

A box located near the manual control unit in the refrigerator building should be provided for entering data into loop parameters. This box could be similar to the QXR box with a digital display and thumb wheel data entry. Each loop would have a maximum of about ten parameters which could be changed. Probably only a subset of these would be implemented, e.g., Process Time Constant, Process Va Set Value, Proportional Gain, Process Control Readback Limits.

This box would not be used when extensive adjustment of the refrigerator was necessary, but only in regular maintenance and adjustment and would be a permanent installation.

A similar box could be in the Service Building.

TV Display of Monitor Points

A smart TV display will give page readouts of process points, monitor points and valve positions. Output should be available in volts, psi, and proper units. Algorithms for conversions will be stored in the display. It also could display loop parameters.

The TV display unit will be portable and should be general enough to display data from other parts of the control system, also.

A typical selection of monitor points is given below.

Portable Console

A portable console will be useful in initial debugging and analysis of the refrigerator system. It will have graphics, keyboard, and alpah numeric display and disk. The main use of such a device would be data logging and display and analysis of refrigerator operation. It would also have convenient ways of storing, loading and changing loop parameters. Alarms and limits display and adjustment could be incorporated. The Console should also be a general purpose device for the rest of the control system. Whether the 8010 will be sufficient will probably become clear at B12. It will probably only be worth setting up if extended periods of activity in the service building are expected, like > 6 hours.

<u>Monitor Points</u> - B12

Refrigerator	(1)	a)	F I 1(Supply flow)D P 0=100" DP2% 300 lb
	(2)	b)	PI12 (wet eng supply pressure) 1-400 lb ¼%
	(3)	c)	TI6(Hx2-3 supply temp) 0-100 lb ¼%
Dry Expander		d)	TI8 (dry engine supply temp) 30-0-100 lb ½%
		e)	TI9 (dry engine return temp) 30-0-100 lb
		f)	Speed
		g)	Hyd Press.
Wet Expander	(6)	h)	TI12 (wet engine supply temp) 0-100 lb ¼%
		i)	TI13 (wet engine returm temp) 0-100 lb
		j)	Speed
		k)	Hyd Press
Tunnel	(4)	l)	FI3 (US Mag Flow) 0-20" DP 2% 150 lb
	(5)	m)	FI4 (DS Mag Flow) 0-20" DP 2% 150 lb
		n)	PI14 (US Mag Supply Press) 0-30 lb ¼%
		o)	17 (DS Mag Supply Press) 0-30 lb
		p)	16 (US Mag Return Press) 0-30 lb
		q)	19 (DS Mag Return Press) 0-30 lb

engine readouts

Miscellaneous

System On/Off Valves

Status and control of refrigerator system main on/off valves and electrical control will also be necessary and must be worked out. Checks of proper valve status before operation will be necessary.

Resistors - resistors in every quad will be used to monitor 1 ϕ temperature, possibly sense low field quenches and control relief valve sequencing after quench. Monitoring of these resistors may go with the power supply protection system or with the refrigeration system.

Quench - refrigerator control on quench must be specified.

Engine - engine control and monitoring will be changed as electrical breaks become available.

Define

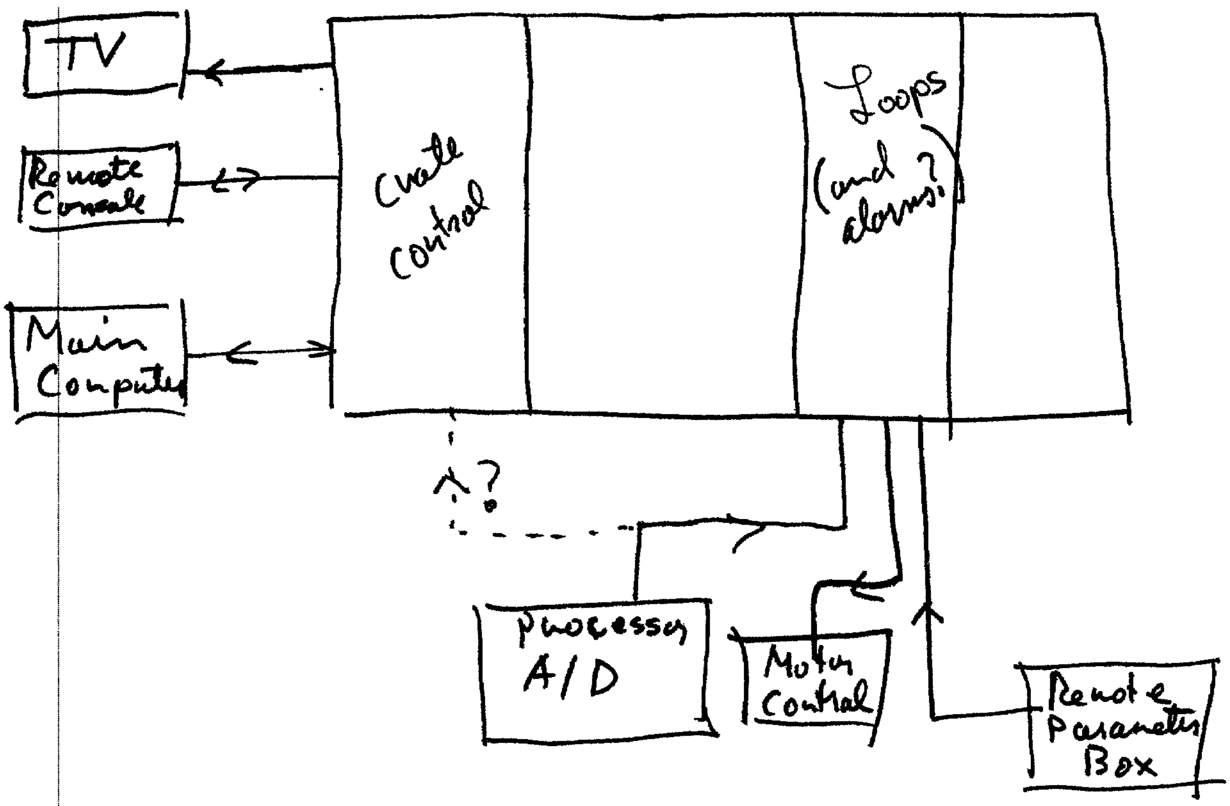
PV = Chan Ø	(Process Variable)
PC = SLOT 1	(Process Control Slot)
GAIN = 200	(Proportional Gain)
Δ GAIN = 200	(Derivite Gain)
PCV = CHAN 1	(Process Control Readback)
PCVLL = .5V	(Process Control Readback Lower Limit)
PCVUL = 9.5V	(Process Control Readback Upper Limit)
MAXSTEP = 200	(Maximum Step)
MINSTEP	(Minimum Step)
PSGAIN = 1/200	(Process Step Gain)
τ = 10	(Process Time Constant)
T = 1	(Sample Period)
I(1) = 0	(Loop Counter)
K1 = 0	(Initialization)
PVS = 5	(Process Variable Set Value)

Control is valve

```
Interrupt
     K1 = K1 + 1
     I1 = I1 + 1      loop counter
     IF (I1.LT. T)  60 To 101
     I1 = 0
     PV (2) = PV (1)
     Read PV1
     Error = PV5 - PV1
     ΔPV = PV2 - PV1
     IF (K.EQ.1) ΔPV = 0
     Out = GAIN*Error - ΔPV*ΔGAIN*(τ/T-1)
     IF (OUT.GT.MAXSTEP)  OUT = MAXSTEP
     IF (OUT.LT MINSTEP)  GOTO 101
     EXVALUE = OUT*PSGAIN+PCV
     IF(EXVALUE.GT.PCVUL) G0 TO 101
     IF (EXVALUE.LT.PCVLL) G0 TO 101
     WRITE (PC) OUT
101  CONTINUE
```

Controls

How do various pieces fit together?



1) Does A/D feed information to both loops μp and to Crate controller - thus to Host or Console.?

2) are alarms + limits done in loops μp or in "B" intelligence. If in loops μp does this imply each other controls device will have its own alarms.

What else.