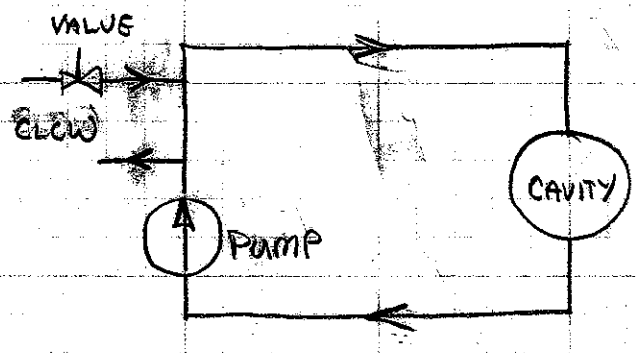
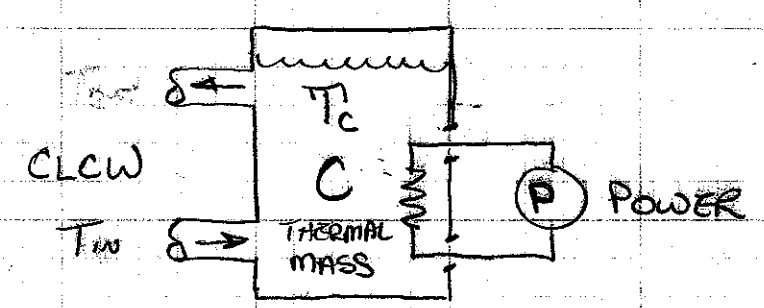
FREQUENCY CONTROL LOOPS





P = POWER RF 6.8kW (7.5MW 15HZ 60μs)
PUMP 7.5
14.3 kW

C = THERMAL CAPACITANCE

72 GAL WATER 1.1 MJ/°C
6800 lbs COPPER 1.2
2.3 MJ/°C

$T_{OUT} \simeq$ CAVITY TEMP 25°C
T_{IN} CLCW TEMP 15°C
$\Delta T \simeq$ 10°C

TIME CONSTANT FOR STEP CHANGE

$$\tau = \frac{C}{P}\Delta T = \begin{matrix} 1600 \text{ SECONDS (RF ON)} \\ 3100 \qquad\qquad \text{OFF} \end{matrix}$$

CONTROL TEMPERATURE WITH CLCW FLOW

DEFINE $\boxed{A = 3.814 \ \frac{°C - GPM}{KW}}$

HEAT CARRYING CAPACITY OF WATER

$$P_{OUT} = \frac{\Delta T \, F}{A} \qquad F = \text{FLOW}$$

RF ON	5.5 GPM
RF OFF	2.9

$$T_{CAVITY} = \frac{1}{C}\int P_{IN} - P_{OUT} \, dt$$

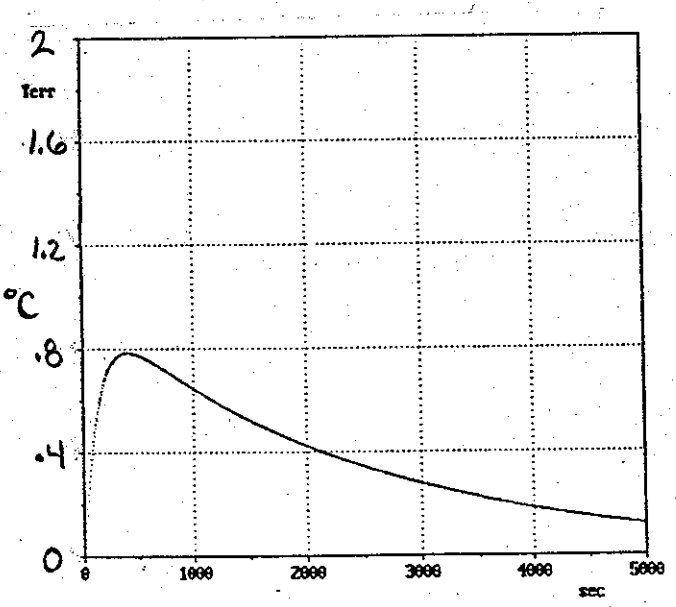
CLOSED LOOP BANDWIDTH .001 HZ

OPEN LOOP PHASE SHIFT AT .001 HZ

90°	INTEGRAL CONTROLLER
29°	FILM COEFFICIENT (88SEC)
8°	WATER TRAVEL TIME (22SEC)
7°	VALVE (19SEC)
134°	

46° PHASE MARGIN

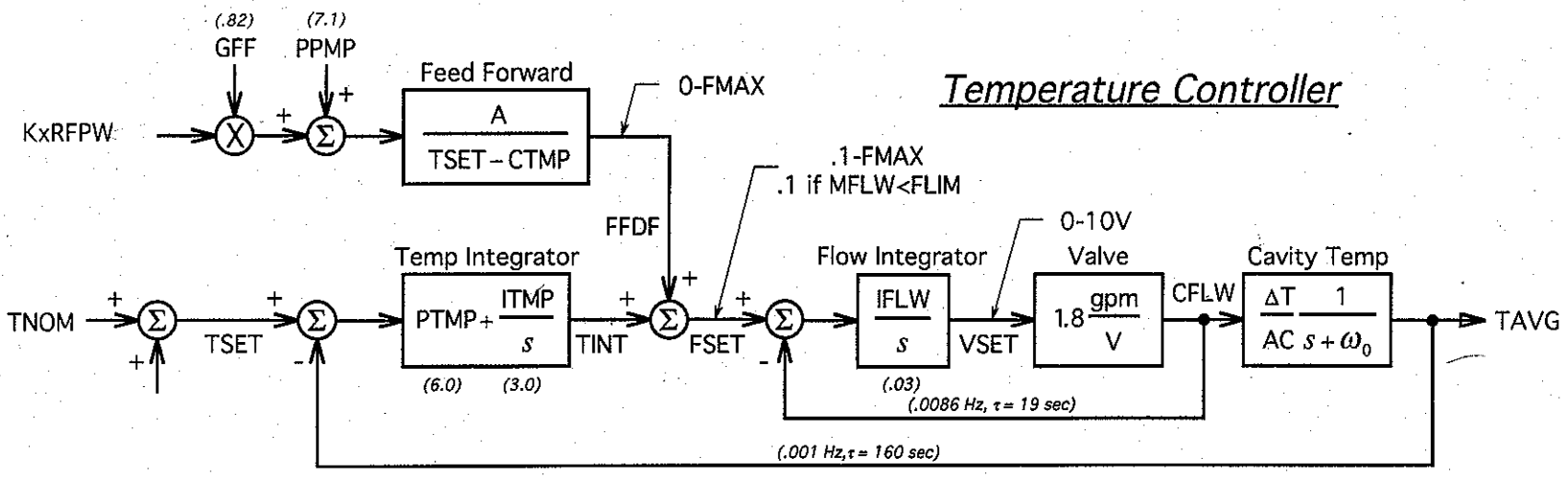
N = 160 SECONDS (10-20 TIMES FASTER)



CALCULATED TEMPERATURE ERROR CAUSED BY TURNING RF ON (6.8KW) WITH THE LOOP CLOSED

USE FEED FORWARD

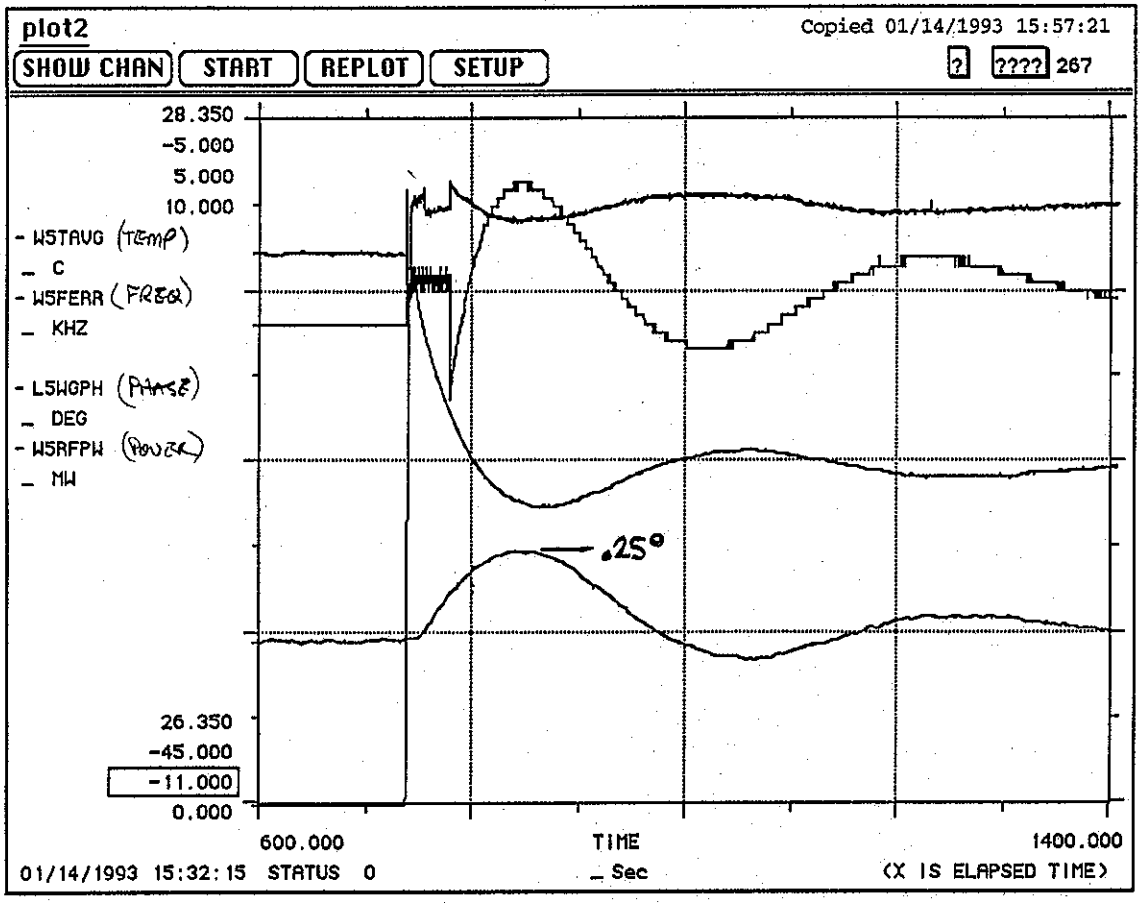
W x PPMP



Temperature Controller

WITH RF OFF ADJUST PPMP TO MAKE TINT = 0

" ON " GFF "



(8.5 MW PK 7.7 KW AVG)

RF POWER 2.5 MW/DIV

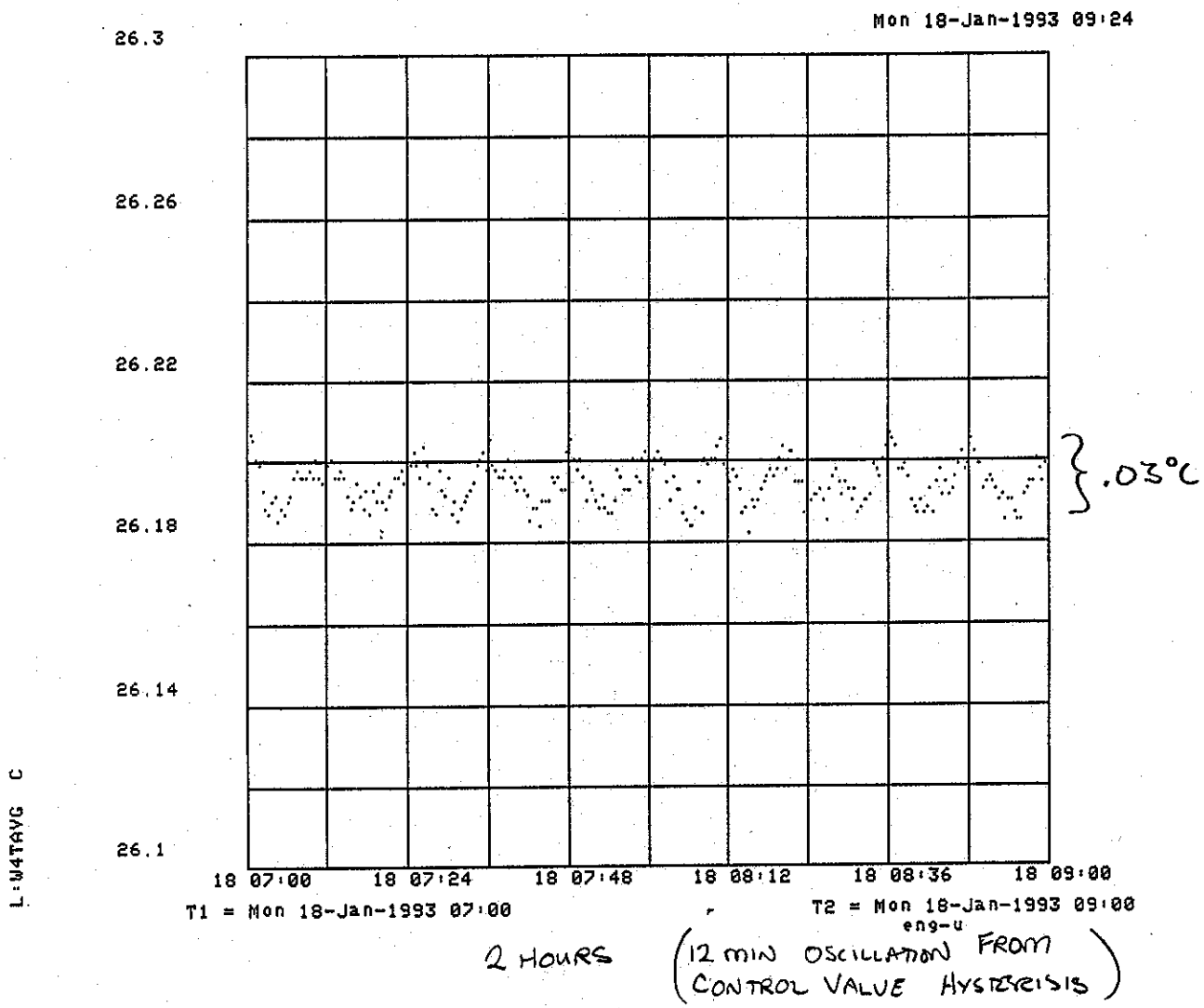
CAVITY PHASE 4°/DIV

CALCULATED FREQUENCY 10 KHZ/DIV

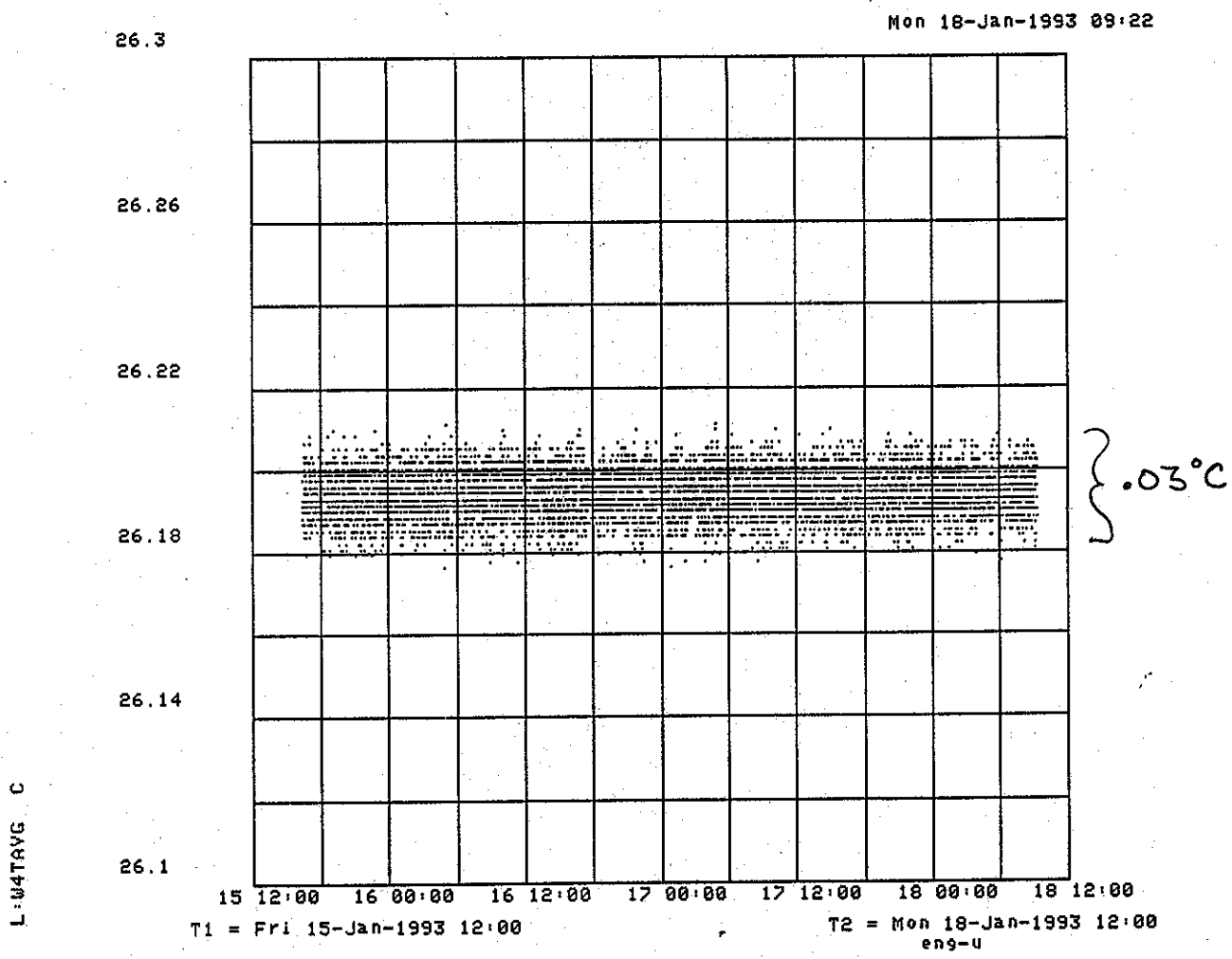
CAVITY TEMP .5°C/DIV

RF ON ↑ ↑ SWITCH TO REFERENCE FREQUENCY

REQUIRES ~ 40 SECONDS TO STABILIZE CAVITY TO WAVE GUIDE PHASE AT REFERENCE FREQUENCY

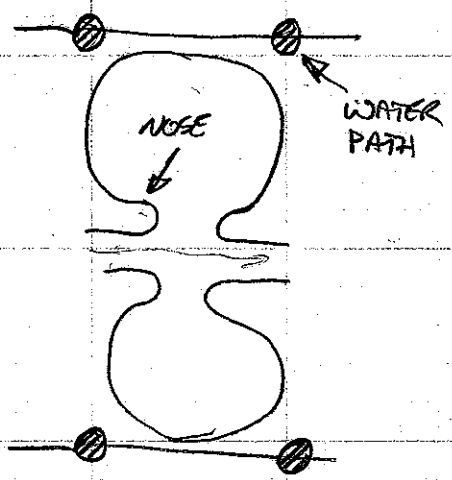


CONSOLE LOCATION 220
Linac Upgrade cav4 Temperature
18-JAN-1993 09:25



3 DAYS RF OFF TSET = 26.195°C

THERMAL GRADIENT



THE RF POWER INDUCES A .43°C THERMAL GRADIENT BETWEEN THE OUTSIDE SURFACE OF THE CAVITY AND THE NOSE CONES.

THE 1/e TIME CONSTANT SET BY THE GEOMETRY OF THE COPPER IS 43 SECONDS

IF THE OUTSIDE SURFACE IS HELD AT CONSTANT TEMPERATURE, THE CAVITY RESONANT FREQUENCY WILL DECREASE BY 15 KHZ

THE NOSE CONES REPRESENT ONLY 1.7% OF THE THERMAL MASS OF THE SYSTEM,

TO BALANCE THE NOSE CONE WOULD REQUIRE REDUCING THE TEMPERATURE BY 1°C

$$2.3 \frac{MJ}{°C} \; 1°C \; \frac{1}{43 sec} = 53 KW$$

(ALMOST 8 TIMES THE RF POWER)

SOLUTION

MAINTAIN THE SYSTEM AT THE REDUCED TEMPERATURE AND TRACK THE CAVITY FREQUENCY WITH THE RF POWER AT TURN ON.

AT AØ WITH THE "KERNS" VCO THE DESIRED FREQUENCY AND VCO DRIVE COULD BE CALCULATED FROM THE MEASURED RF POWER AND COPPER TEMPERATURE. WHEN THIS CALCULATED FREQUENCY IS WITHIN TOLERANCE OF THE NOMINAL THE SOURCE IS SWITCHED TO THE REFERENCE LINE.

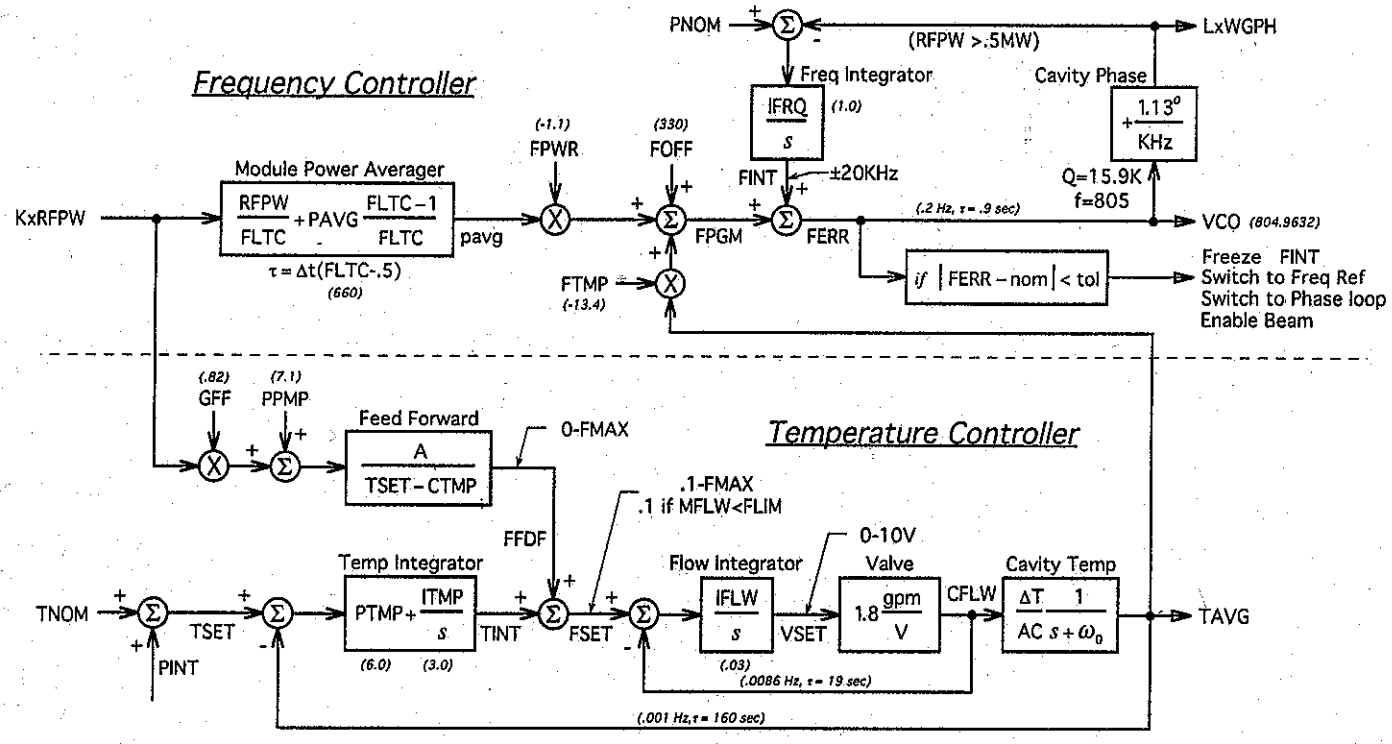
WxFERR USES NOMINAL AND TOLERANCE

PROBLEM

VCO's USED IN LLRF DRIFT. THE POWER TO THE VCO IS REMOVED WHEN RUNNING ON THE REFERENCE. THERMAL TIME CONSTANT IS ABOUT 1000 SECONDS, CHANGE ABOUT 1 KHZ

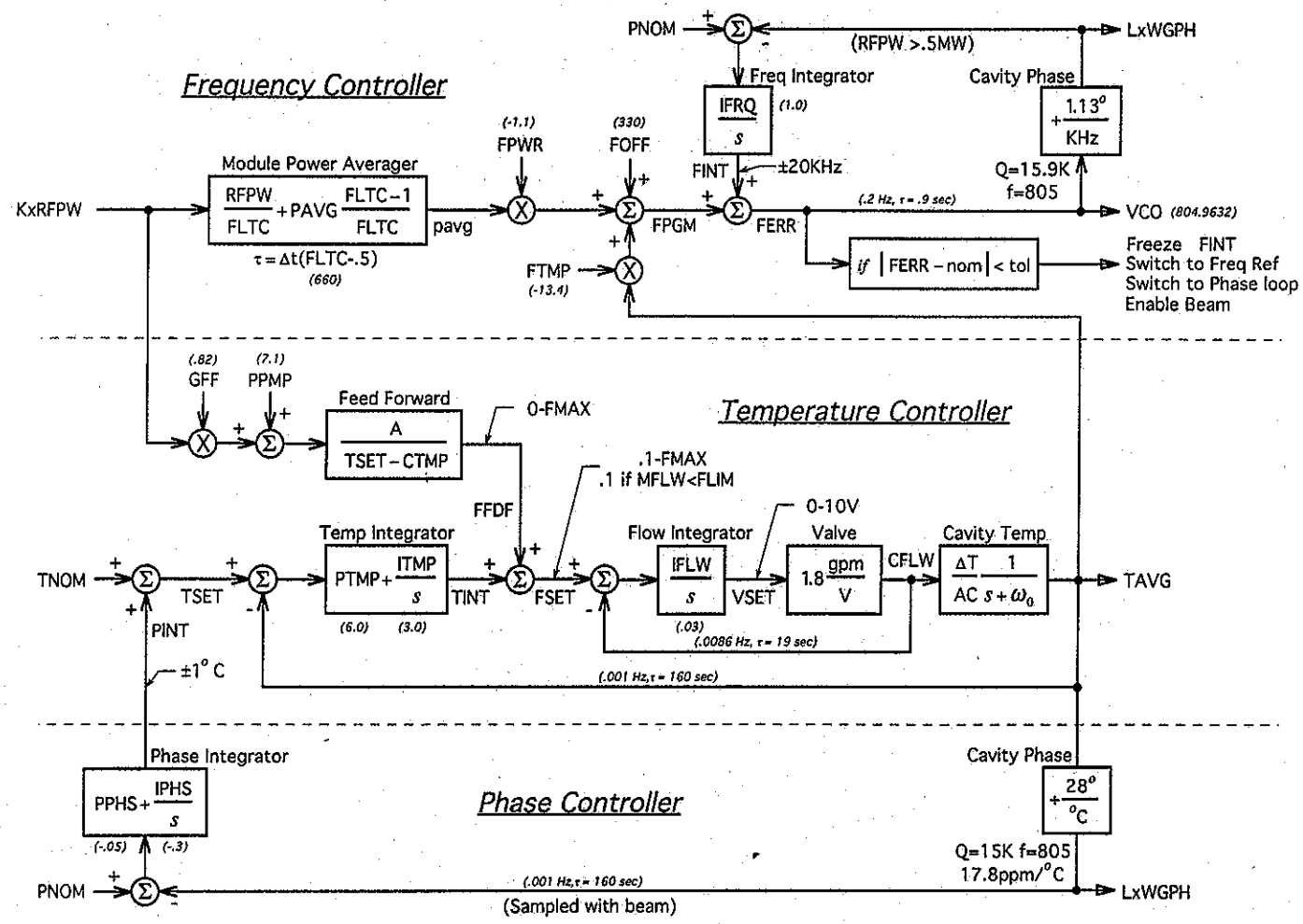
IMPLEMENTED INTEGRATING LOOP WHICH CORRECTS PROGRAM TO KEEP WAVE GUIDE TO CAVITY PHASE CONSTANT

THE REFLECTED POWER TRIP LEVEL IS ARBITRARILY SET WHICH MAKES THE FREQUENCY WINDOW UNKNOWN.


Frequency Controller
PNOM
LxWGPH
(RFPW >.5MW)
Freq Integrator
Cavity Phase
IFRQ
(1.0)
1.13°
KHz
(-1.1)
FPWR
(330)
FOFF
FINT
±20KHz
Q=15.9K
f=805
Module Power Averager
KxRFPW
RFPW/FLTC + PAVG (FLTC−1)/FLTC
pavg
τ = Δt(FLTC-.5)
(660)
FPGM
FERR
(.2 Hz, τ = .9 sec)
VCO (804.9632)
FTMP
(-13.4)
if |FERR − nom| < tol
Freeze FINT
Switch to Freq Ref
Switch to Phase loop
Enable Beam
(.82)
GFF
(7.1)
PPMP
Feed Forward
A/(TSET − CTMP)
0-FMAX
Temperature Controller
.1-FMAX
.1 if MFLW<FLIM
FFDF
Temp Integrator
Flow Integrator
0-10V
Valve
Cavity Temp
TNOM
TSET
PINT
PTMP + ITMP/s
(6.0)
(3.0)
TINT
FSET
IFLW/s
(.03)
VSET
1.8 gpm/V
CFLW
ΔT/AC · 1/(s + ω0)
TAVG
(.0086 Hz, τ = 19 sec)
(.001 Hz, τ = 160 sec)

W_x FPWR

Temperature, Phase, and Frequency Control Diagram



Crisp 1/8/93