PSS Beam Current Monitor Conceptual Design Review

May 23, 1995 2:00 - 5:00 pm Rm A110

Agenda:

Charge to Committee	A. Hutton	2 mi
Introduction	A. Hutton	5 mi
ARR 3 Issues addressed by the Beam Current Monitor System	A. Hutton	10 mi
Operations Plan	A. Hutton	5 mi
PSS Beam Current Monitor		
Introduction	K. Mahoney	5 mi
Requirements	K. Mahoney	15 mi
System Description	K. Mahoney	20 mi
Subsystem Description	K. Mahoney	45 mi
Status	K. Mahoney	10 mi
Panel Question and Answer Period		30 mi
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Beam Current Monitor System Summary Sheet

What is it ?

The BCM system is a redundant network of beam current measurement devices and fast beam shut down devices which are used for personnel protection.

What is each BCM composed of?

- A Three port RF Cavity
- Two Down converters (System A and System B)
- Two Logic Interface Units (System A and System B)
- One Test/Verification Unit

What does it do?

- Measures Beam Current in the injector and in front of each beam stopper.
- Detects if the beam current is greater than 180 uA (injector) or is greater than 100μA-ms.
- Shuts off the beam if a fault is detected.
- Provides a semi automated self test capability.

How does it do this?

- Downconverter subsystem provides a voltage linearly proportional to current and an integrating threshold detector.
- Logic Subsystem monitors faults and routes permissive signal to beam shutdown devices.
- Beam shutdown devices stop beam injection past 100 kV point of machine if permissive signal is not present.
- Test/Verification subsystem automatically sequences test of each BCM and shutdown device.

Where are the BCMs located?

Cavities are located in the beam line at:

- Injector after the 45 MeV dump
- East Arc after 1A01
- BSY before 1C01 and 3C01 (Halls A and C transport line)
- BSY before 2C03 (Hall B transport line)

Electronics are located in the upstairs service buildings at:

- Injector Service Building Rack IN03B04
- East Arc Service Building # 2 Rack E201B00
- Beam Switch yard service building Rack BS04B18

What are the Fast Beam Shutdown devices?

Fast ways of stopping beam. They do not necessarily stop beam emission altogether but inhibit beam from going past 100 kV section of injector.

Why are they necessary ?

Catastrophic damage could occur to a beam stopper before the PLC system could react to shut off beam by turning off the gun 100 kV.

How fast are the Fast Beam shutdown Devices?

Each can independently shut off the beam in < 200μs.

Where are the fast beam shutdown devices located?

- Beam Modulation Control Card - Injector Service building
- Thermionic gun control electrode driver Card - 100 kV deck I injector
- X-plane beam kicker - Between injector apertures 1 and 2.
- Y-plane beam kicker - Between injector apertures 1 and 2.
- Polarized Source Laser light table - Location not specified.

Is the BCM system completely separate from the PLC based PSS interlock system ?

No. Each BCM system receives a beam stopper status signal from the PLC systems. Each BCM system sends a fault signal to the PLC system so that the 100 kV will be shut down after a fast beam shut down has occurred.

The BCM system's ability to shut off the beam through the fast beam shutdown devices is independent from the PLC system.

How is this system different from the Machine Protection Beam Current Accounting ?

- The PSS BCM system is designed to protect people. The machine protection system is designed to protect CEBAF's investment in hardware.
- Both systems use similar technology and downconverter subsystems.
- The PSS system is implemented redundantly
- The PSS system does not use beam accounting - comparison of beam current in the injector to beam current at a beam dump.
- The PSS system uses dedicated beam shutdown devices instead of the Fast Shutdown System.
- The PSS system uses different permissive logic.

What BCM Faults will shut off the beam ?

- Injector Beam Current > 180 uA
- Beam current at any inserted beam stopper $I_b > 1\mu A$ AND $> 100\ \mu A\text{-ms}$
- Any BCM system card not connected
- Voltage out of regulation on any BCM subsystem
- Calibration Level out of limits
- Downconverter Local Oscillator out of limits
- Interconnecting coax or cables not connected
- Failure of Verification/Self Test
- Control Electrode or Kicker Bias Supplies out of range
- 625 kHz permissive signal missing for any reason
- Ambiguous beam stopper or PSS mode status indication from the PLCs

1.0 Introduction

The Beam Current Monitor system is designed as a solution to the CEBAF Accelerator Readiness Review (ARR) # 3, issue 1.1.7. Essentially the issue was that it was recognized that CEBAF's high power electron beam could burn through any potential stopping device in a time frame shorter than the PLC system could react.

ARR-3 Issues
Subsystem 1.1.7 -

Issue: A third independent line is necessary for disabling beam production in the injector.

Description: In areas where beam stoppers are used the devices will not survive full beam power indefinitely...

Originally, argon filled ion chambers were to be used. Tests of the ion chambers showed that they were too sensitive to tune-up beam. At the same time Beam Current Monitors were under development.

Purpose of System (Where does it fit in)

The BCM system is part of the over all protection of personnel through the Personnel Safety System. It is an active system that augments the PSS Programmable Logic Controllers (PLCs).

Problems Addressed by the BCM System:

Problem 1.

A.) High Power Beam Striking a beam stopper can burn through, endangering personnel downstream of the device.

B.) The worst case burn through time is faster than the PLC system can react to shut off beam.

There needs to be a faster, yet equally reliable way to shut off the beam on the order of a millisecond.

Problem 2.

CEBAF passive shielding is designed for a maximum of 200 uA. There needs to be a way of ensuring that the CEBAF operations envelope is never exceeded.

1.1 Concepts in the Implementation of PSS Subsystems

Concept 1. Mitigation and Verification

Hazards are Mitigated by the shielding design, administrative procedures, and the PSS. The status of each device interfaced to the PSS is monitored to Verify proper status or response.

Part 1.

Mitigation - Passive shielding (not part of the PSS) is designed to reduce worst case beam loss radiation to acceptable levels in occupied areas.

Verification - Radiation Dose rate is measured at the closest point between personnel and areas likely to experience beam loss. High dose rate will shut off beam.

i.e. beam is contained.

Part 2.

Mitigation - A Sweep of the Tunnel is performed to ensure that no one is in the tunnel during beam operations.

Verification - All access points are monitored. Access to a beam enclosure will shut off the beam.

i.e. people are kept away from beam

Part 3.

Mitigation - Critical Devices must be in place between an area where beam may be operated and an area where people may be to allow beam to be turned on.

Verification - Status and Viability of Critical Devices are measured and protected.

i.e. beam is kept away from people

The BCM system is part of the verification process of parts 1 and 3.
In part 1 the BCM system makes sure that the beam never goes above the maximum CEBAF design current.
In part 3 the BCM system makes sure that when a beam stopper is inserted it is not damaged to the point where beam could burn through and be transported to an area where people may be working.

Concept 2. Multiplicity, Diversity, and Redundancy

Part 1. Multiplicity - At least three critical devices must be in place to prevent beam from entering an occupied area. At least three means will be used to shut off the beam.

Part 2. Diversity - At least two different technologies must be used in the implementation of Critical Devices and beam shutdown devices.

Part 3. Redundancy - Each Critical Device must be sensed and controlled by two independent systems, A and B, any one of which can render the area safe.

In the BCM System Multiplicity and Diversity are used in the means of shutting off the beam. The Beam is shut off in three ways -
1.) Control Electrode Clamp
2.) X Plane Kicker Magnet
3.) Y Plane Kicker Magnet

In the BCM System the beam current is Redundantly sensed. Each of the beam shutdown devices above receive independent Redundant permissive signals from the BCM system. (the status of the beam shutdown devices is also verified)

1.1 Concepts for Implementation of PSS Subsystems - Continued

Concept 3. Fail Safe

Part 1. Any single failure of a PSS device must leave the area in a safe state.

Failure Modes of a Beam Stopper:
- Physically Stuck in or out
  - Both in and out positions are measured. If they ever indicate an ambiguous position, or the wrong position for a given machine configuration, beam is shut off.
- Beam Stopper plug Physically damaged
  - Pressure Chamber is sensed by the PSS. If Pressure < 1 ATM beam is shut off.
- Beam Burns through the beam stopper
  - Beam Current Monitor Senses excessive beam current and shuts off beam before catastrophic damage can occur.

The BCM System addresses the failure mode where beam could burn through a beam stopper.

Because of the critical nature of the BCM system it must also be designed to be as fail-safe as possible. Normally, in a fail-safe design, lack of positive proof of a safe state is assumed to be "unsafe" and the safety system will act to bring the area to a safe state. The BCM presents the problem that the safe state is when it detects no current, i.e. the unsafe state requires a positive indication.

Not only does the BCM require a positive indication for a fault, but it also trips on an analog value as opposed to a discrete, on-off, signal that would come from a switch. Under these circumstances it is not practical to make the BCM system completely fail safe.

The next best thing to fail safe is to "observe" (test) the system at a regular interval. The term observed is borrowed from the military standard reliability analysis MIL-E-217. The BCM system will use fail-safe design techniques where ever possible. The circuitry that will amplify and detect the beam current signal will be tested regularly using a built in test source. If the test does not fall within a given accuracy the system will treat this as a failed device and will shut off the beam like any other fail-safe device.

2.0 Requirements for the Beam Current Monitor System

General Requirements

2.1 The BCM System shall provide the following functions:

1.) Detect average beam current greater than 180 uA in at the 45 MeV section of the accelerator.
2.) Detect beam current greater than the damage threshold incident on an inserted beam stopper.
3.) Inhibit the beam from leaving the 100 kV section of the injector if conditions 1 or 2 are true.
4.) Remote self test and verification of proper operation through the injection of a test signal.

2.2 The System shall be fail safe against single mode failures not detected through the self test or verification.

2.3 The System shall be implemented as a parallel redundant system. Each leg of the system will be referred to as System A or System B.

2.4 Both System A and System B shall independently be able to monitor beam current, detect a fault, and render the beam to a safe state.

2.5 The System shall automatically configure for protection of an inserted beam stopper.

2.6 The System shall latch all faults. Faults may only be cleared by operator reset.

2.7 The System will provide an isolated current read back and fault status to the control system.

2.8 The final means of beam shutdown shall include removal of the electron gun(s) 100kV bias through the PSS Programmable Logic Controllers.

2.9 The System shall incorporate sufficient self test to isolate faults to the board level.

2.10 Beam Shutdown Time - 1ms

The minimum beam shutdown time is driven by the calculated beam stopper burn through time.[1] Figure 0 shows the temperature rise on axis of a beam stopper vs. time. Beam burn through experiments at SLAC show that initial damage occurs when the temperature of the device reaches the melting point. However, the ability of the device to stop beam is not compromised at this point. Catastrophic damage occurs when the temperature reaches the vaporization point of the metal (2800 K for copper). At this point vaporized metal may be ejected from the device.

The timing requirements for the BCM to shut off the beam were conservatively chosen to be based on the worst case onset of vaporization time for the stopper with an additional safety factor. The worst case melting time for a 6 GeV, 200μA beam is approximately 2 ms.

The Beam Current Monitors must shut off the beam within 1 ms of the onset of a worst case fault condition.

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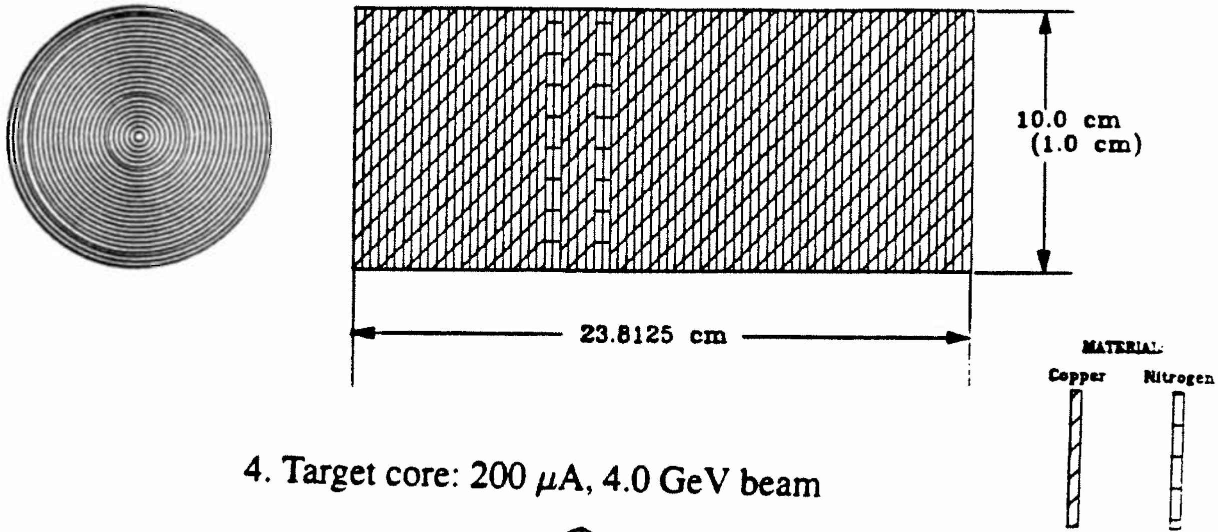
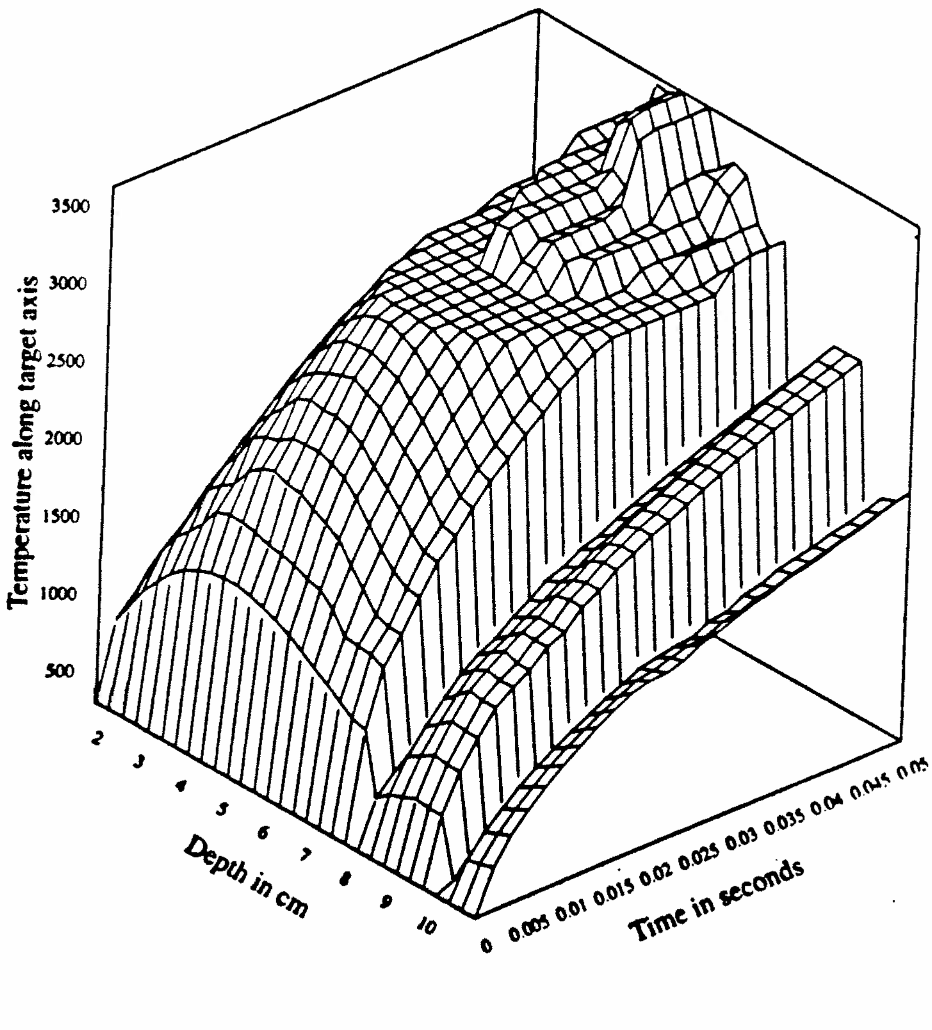
[1] TN 94-060 Finite Element Calculation of Burnthrough Times for Beam Stoppers, P.K. Kloeppel, Nov. 22, 1994

3. **Target design used in thermal analysis**



4. Target core: 200 μA, 4.0 GeV beam



2.0 Requirements for the Beam Current Monitor System - Continued

2.10 Shut down Time Requirement - Continued.

The injector Beam Current monitor is not required to shut off beam as fast as the Beam stopper protection BCMs. However, because the injector BCM essentially serves an ALARA function, the time shutdown time will be also be 1 ms max. from the onset of a fault condition.

2.11 The BCM system shall monitor the bias status of each shutdown device. If the bias of any one of the devices is not within tolerance the BCM system will remove permissive to all shutdown devices.

2.12 Software
Software is not required to implement the protection or verification functions of the BCM system.
Software will be used to remotely initiate the verification and self test functions.

3.0 System Description

The Personnel Safety Beam Current Monitor System is designed to reduce the risk that an errant high power electron beam will burn through a beam stopper. The system achieves this goal by placing a beam current monitor cavity upstream of a beam stopper. Each BCM has an internal threshold detector that will fault if the beam current exceeds 1 uA.

The system must work quickly enough to prevent catastrophic burn through of a stopper but must not be so sensitive that the system suffers from false trips. Simulations show that the burn through time of a beam stopper can be as little as 2.5 ms. This time frame is much shorter than the time required for the programmable logic controller (PLC) system to shut down the beam by turning off the gun high voltage. Therefore, in addition to the beam current detection system, there is also a fast beam shutoff system which removes beam from the accelerator within 1ms of the hazardous condition being present.
The system is implemented redundantly, i.e. there are parallel A and B systems just as in the Safety Interlock System. System A and System B are independent of one another all the way from the BCM cavity to the beam shutdown mechanisms.

Beam Current Monitors are located in three areas of the accelerator. The first is located in the injector. This monitor is used to measure the maximum beam current and trip off the injector if the current exceeds the CEBAF operations envelope of 180 uA. The other two locations are used for beam stopper protection.

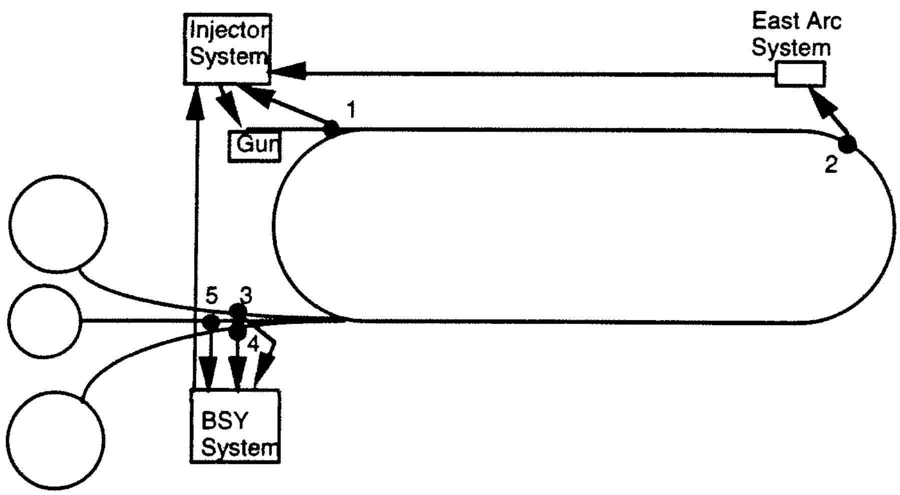


Figure 1. BCM Detector and Electronics Locations

3.1 The BCM System is distributed over three areas (fig. 1):
Injector System
- Master System. Receives Permissive from other areas.
- Monitors average beam current. Faults if > 180 μA.
- Distributes Permissive to beam shutdown devices in the injector tunnel.

East Arc System

Senses Position of East Arc Beam Stopper

Faults if stopper is IN and beam current is > 1μA average.

Beam Switchyard System

Three subsystems - one for each beam line.

Senses position of Hall A and C beam stoppers.

Faults if Hall A or C beam stoppers are IN and beam current is > 1μA average.

Faults any time Hall B beam current is > 1μA average.

3.2 Each BCM System is composed of three subsystems (fig. 2-4).

Beam Current Monitor

Converts beam induced RF into DC voltage proportional to beam current.

Integrates measured beam current.

Faults if measured current is > 100,000 μA-μs (Beam Stopper Systems)

OR Faults if measured beam current is > 180 uA for > 1ms (Injector System)

Logic/Interface Unit

Receives Input from PLC determining Beam Stopper status.

Monitors Health Status of BCM, Test/Verification, and beam shutdown devices.

Latches Faults

Routes Permissive through BCM integrator

Routes Permissive to Beam shutdown devices (Injector System)

Test/Verification Unit

Performs automated test of complete system.

Failure of test sent to Logic/Interface Unit as fault.

Monitors status of fast beam shutdown devices.

The Beam Current Monitor and Logic/Interface Unit are implemented redundantly (System A and System B)

3.3 Beam Stopper BCM

Beam Stoppers are located in:

The east arc first pass

Hall A, B, and C beam transport lines between the Lambertson magnet and the first Hall transport line arc dipole.

The measured beam current at the position at any beam stopper is > 1μA when the beam stopper is in the "IN" position. (Not Out).

Timing Requirements:

Worst Case:

The minimum time to fault shall be defined by the worst case beam interception and burn through time.

Worst Case Beam Current - 200μA, 6GeV

Worst Case Time to Damage - 2 ms @ 6GeV, 200 uA.

Safety Factor - 2

Worst Case time to shut off beam = 2ms/2 = 1ms

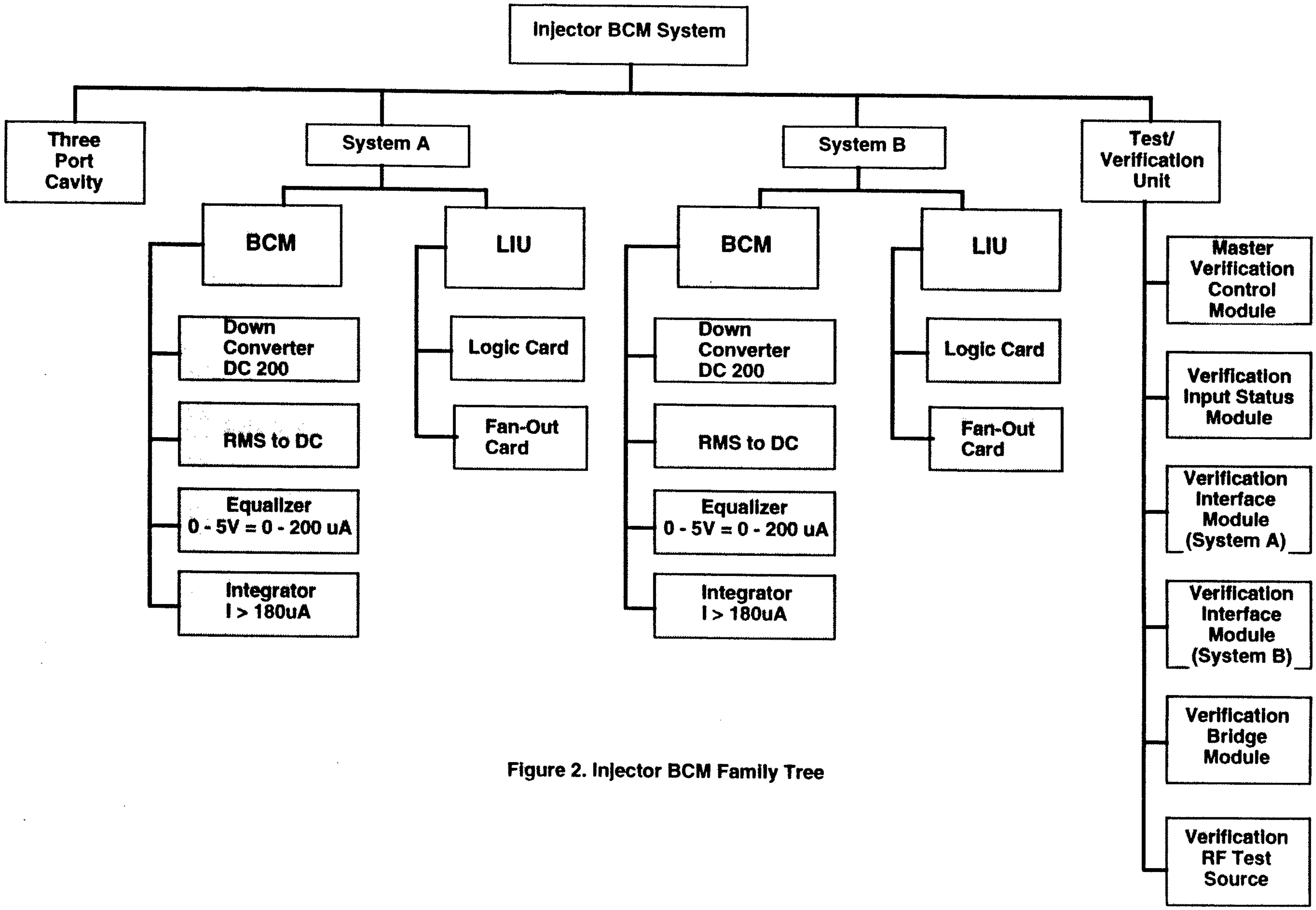


Figure 2. Injector BCM Family Tree

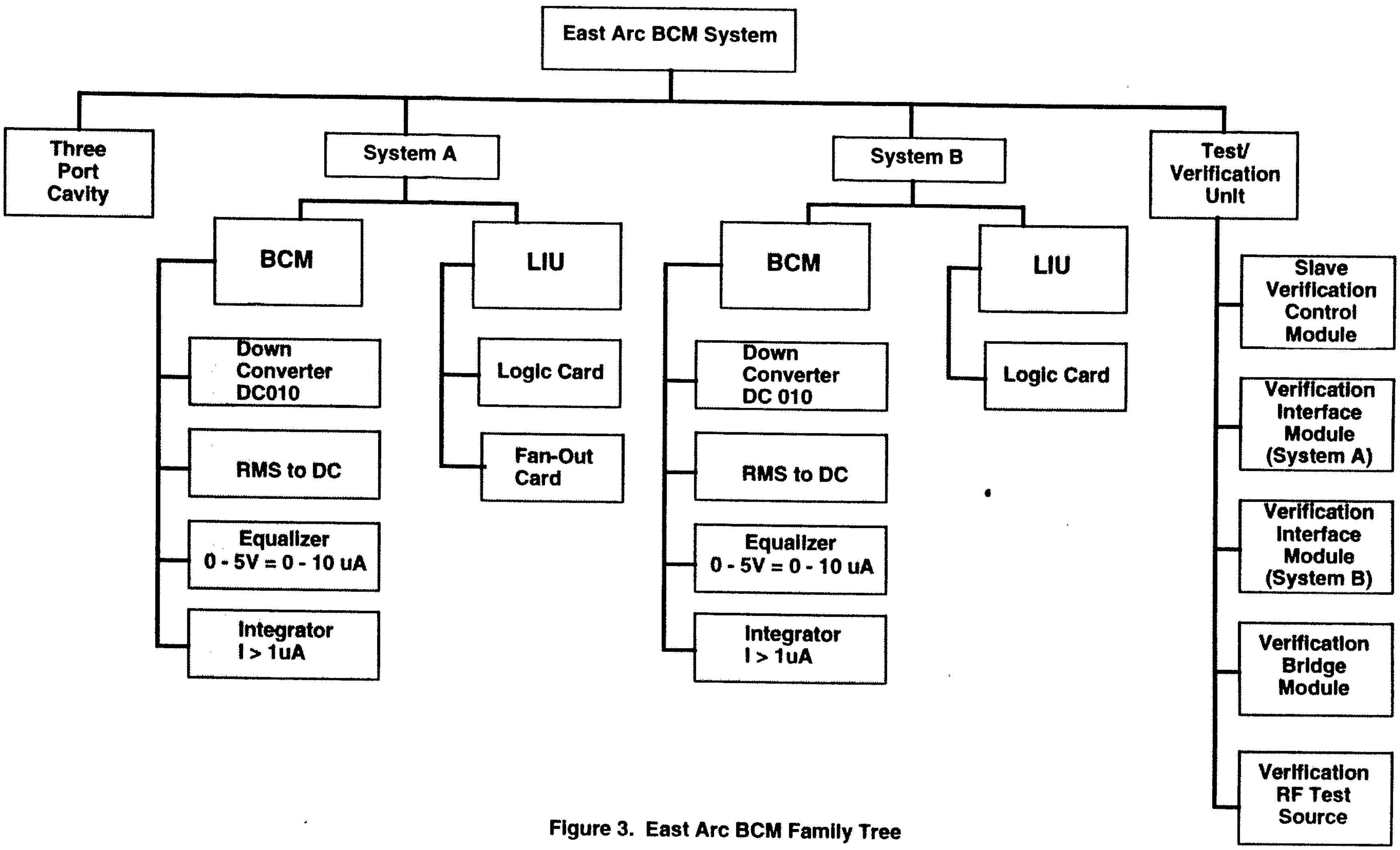


Figure 3. East Arc BCM Family Tree

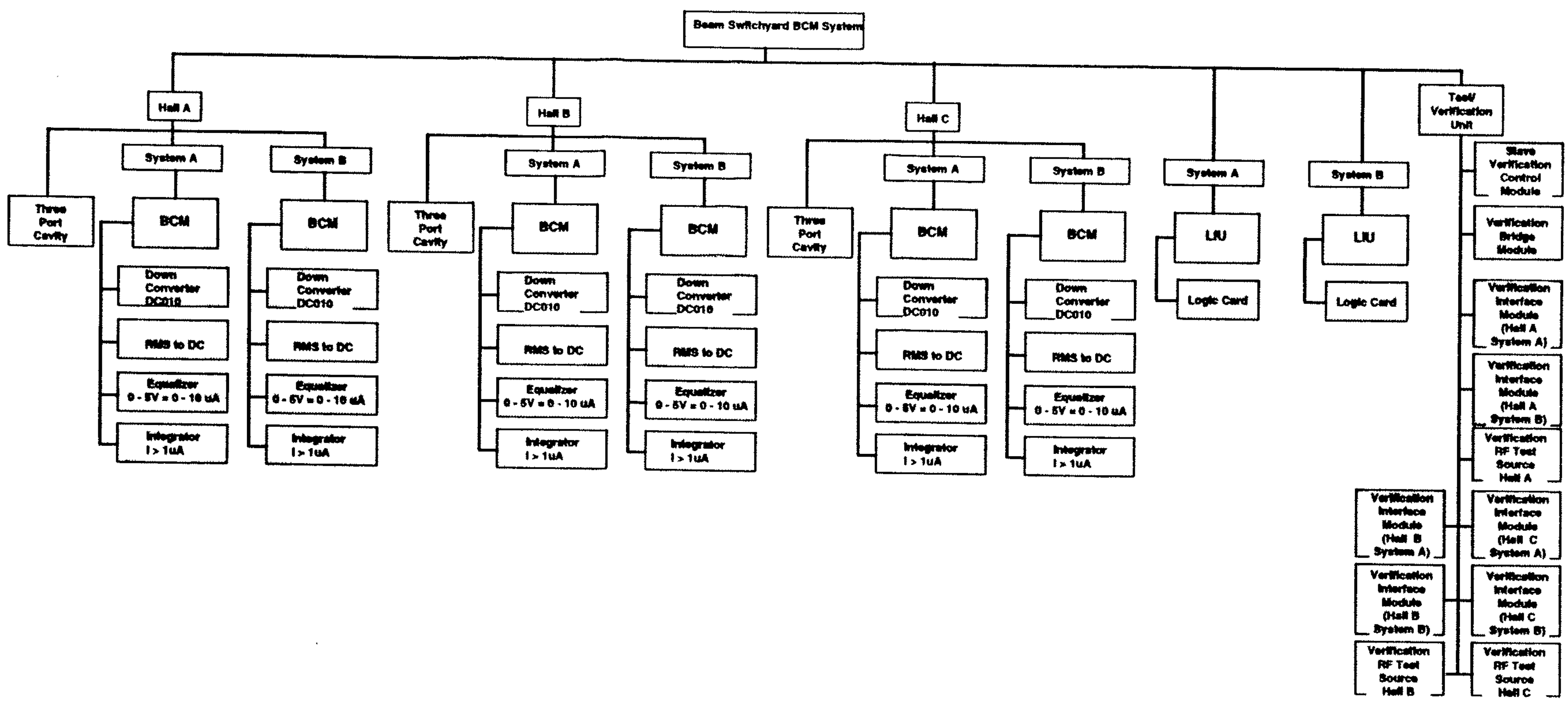


Figure 4. Beam Switchyard BCM Family Tree

Shut off time will be expressed as an integrated value - 200μA x 1ms = 200,000 μA-us

The Beam Current fault is generated by the integrator portion of the BCM. The minimum integration time is driven by the worst case time to fault minus the sum of the propagation times to the beam shut down devices.

Time Allocation:
The time that allotted the detection/integration is

$$T_{det} = T_{so} - T_{sb} - T_{rl} - T_{xmt} - T_{ll} - T_{bso}$$

T_{so} = Max Time to Shut off	1000 μs
T_{sb} = Stored Beam	21 μs
T_{rl} = Remote Logic Processing	100 μs
T_{xmt} = Fault Transmission time	10 μs
T_{ll} = Local Logic Processing	100 μs
T_{so} = Beam Shut Off Time	200 μs
Time left for integration =	569 μs

An Integration time of 500 μs will be used.

Integration time = 200 μA * 500 μs = 100,000 μA-μs

The integration time constant will be fixed on the BCM integrator card.

4.0 Subsystem Description:

Figure 6 shows the block diagram of the various subsystems. The major subsystems are the Beam Current Monitor, the Logic/Interface Unit, and the Test/Verification Unit. The PLC, control system, and fast beam shutdown systems are also shown.

4.1 BCM Cavity

The cavities used are a TE010 mode cavity tuned to 1497 GHz. Each cavity has 3 coupling loops (Fig. 5) Two opposing loops are used as separate beam current pickups for the system A and System B BCMs. The third port is used for calibration and test of the BCM systems. A signal simulating a beam current is injected into the cavity. Each BCM then compares the test level to an internal threshold. If the level is within a window the test is successful. If the level is outside the window then the test fails and BCM is taken off-line.

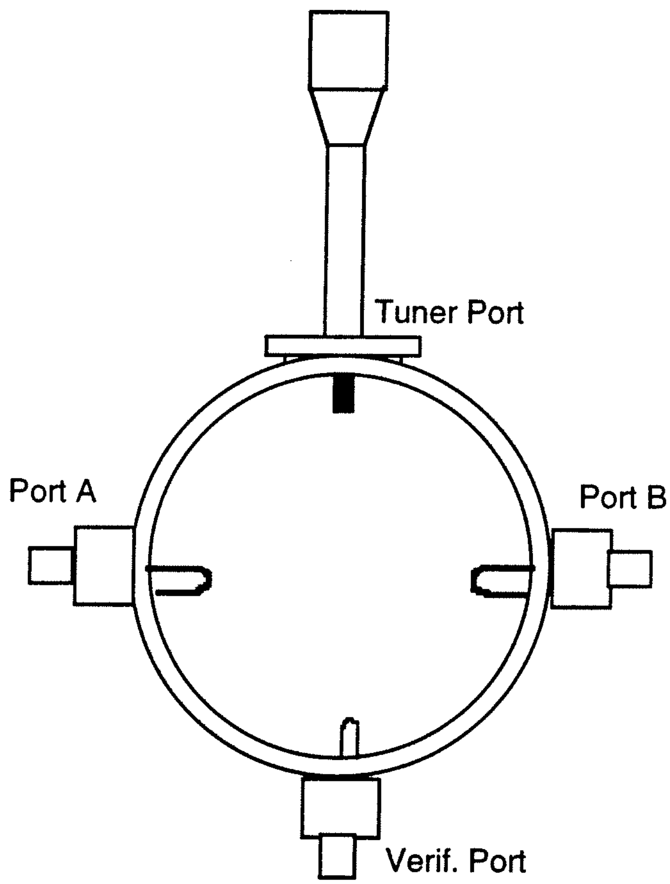
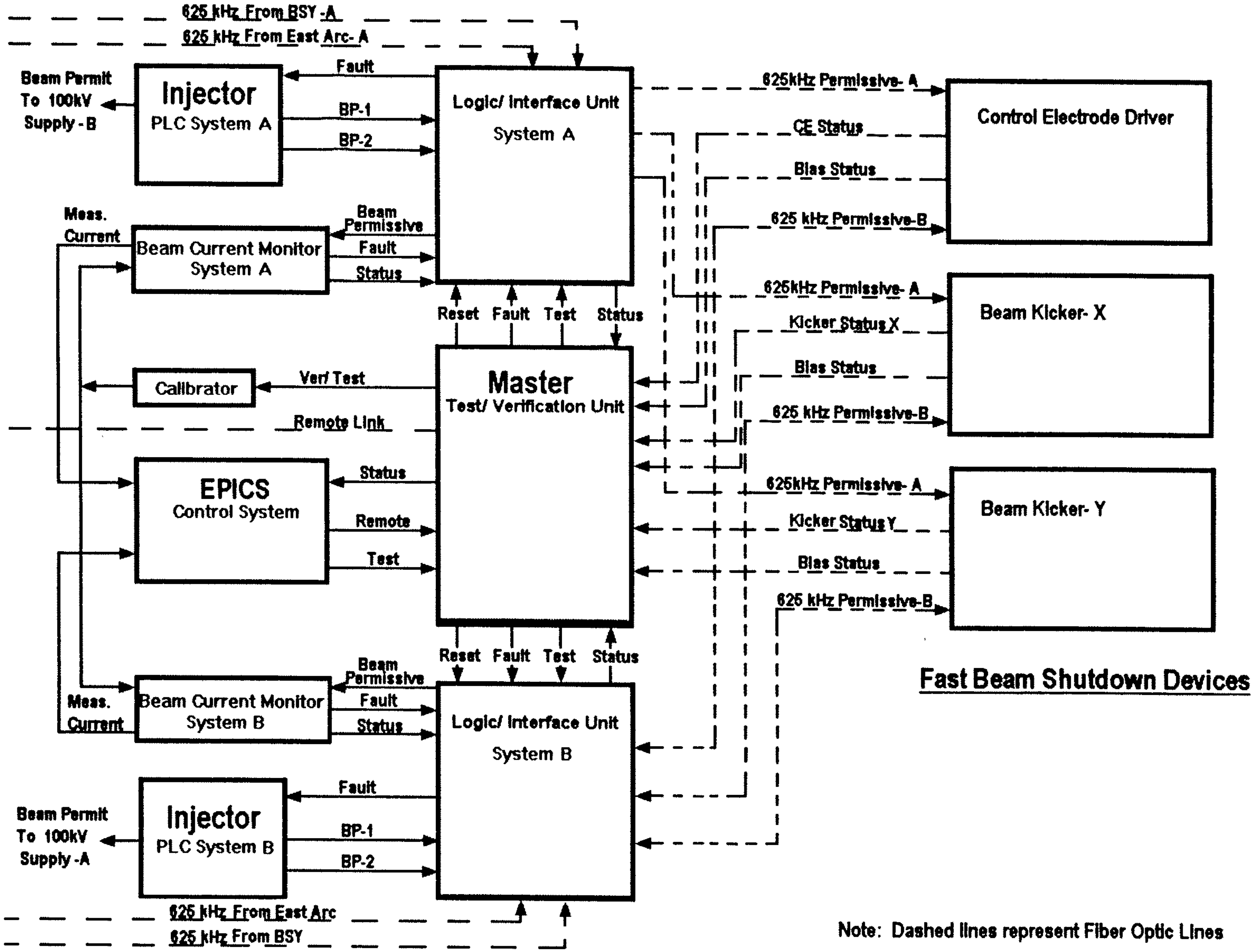


Figure 5. BCM 3-Port Cavity

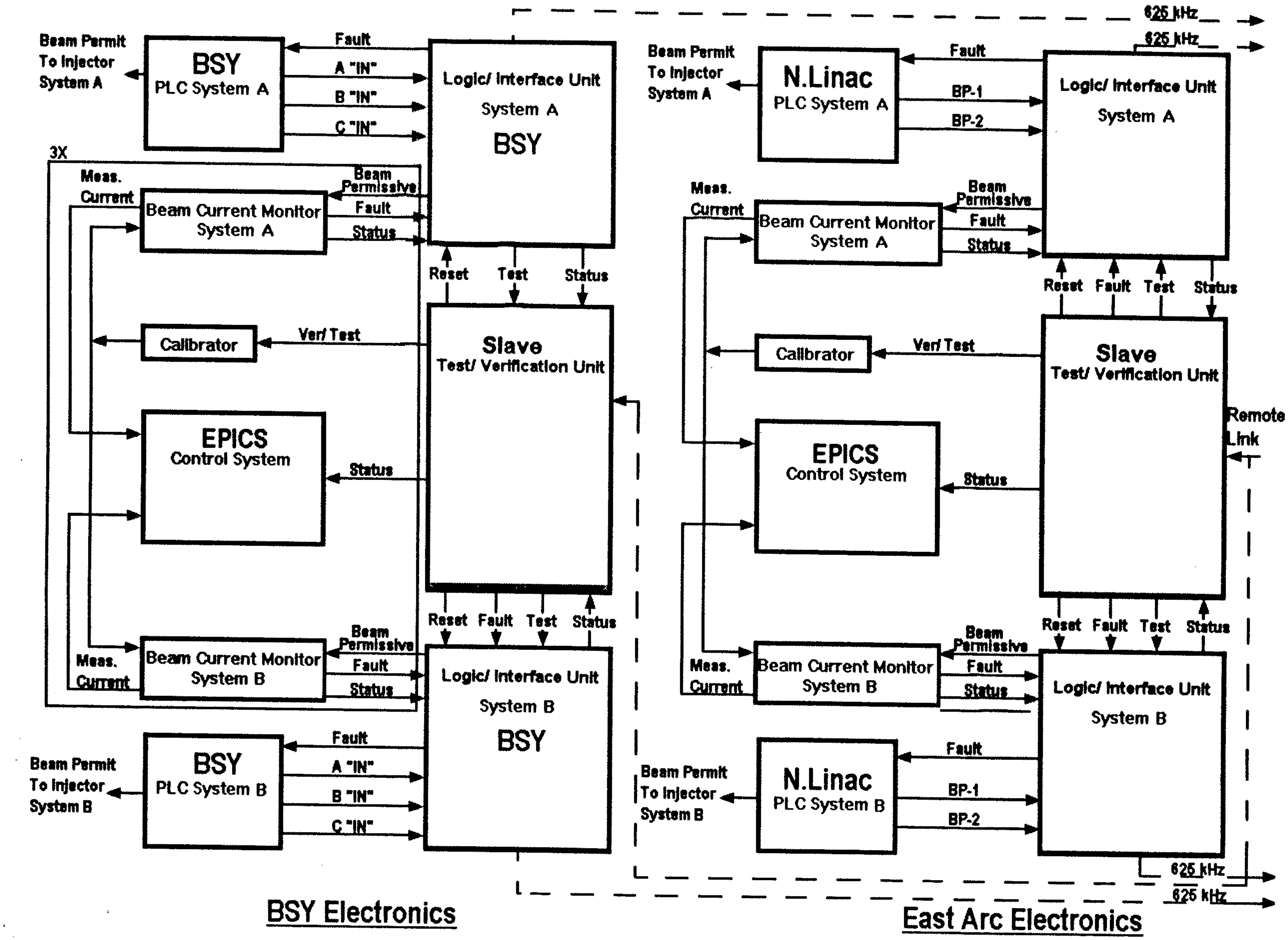
4.2 Beam Current Monitor:

The Beam Current Monitor includes a RF to IF downconverter, a RMS to DC converter, a gain adjustment, and integrator/fault detector electronics. All of the BCM electronics are the same design as used in the Machine protection system.



Injector Electronics Block Diagram

Fig. 6a.


Beam Permit
To Injector
System A
BSY
PLC System A
Fault
A "IN"
B "IN"
C "IN"
Logic/ Interface Unit
System A
BSY
3X
Meas.
Current
Beam Current Monitor
System A
Beam
Permissive
Fault
Status
Reset
Test
Status
Calibrator
Ver/ Test
Slave
Test/ Verification Unit
EPICS
Control System
Status
Reset
Fault
Test
Status
Beam Current Monitor
System B
Meas.
Current
Beam
Permissive
Fault
Status
Logic/ Interface Unit
System B
BSY
Beam Permit
To Injector
System B
BSY
PLC System B
Fault
A "IN"
B "IN"
C "IN"
BSY Electronics
625 kHz
625 kHz
Beam Permit
To Injector
System A
N.Linac
PLC System A
Fault
BP-1
BP-2
Logic/ Interface Unit
System A
Meas.
Current
Beam Current Monitor
System A
Beam
Permissive
Fault
Status
Reset
Fault
Test
Status
Calibrator
Ver/ Test
Slave
Test/ Verification Unit
Remote
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EPICS
Control System
Status
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Status
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Current
Beam Current Monitor
System B
Beam
Permissive
Fault
Status
Logic/ Interface Unit
System B
Beam Permit
To Injector
System B
N.Linac
PLC System B
Fault
BP-1
BP-2
625 kHz
625 kHz
East Arc Electronics

Fig. 6b.

4.2.1 Down Converter (fig. 7)
There are 2 models of downconverters. The DC200 is designed for a dynamic range of 0 - 200 μA. This will be used in the injector. The DC 010 is designed for a dynamic range of 0 - 10uA. This model will be used for beam stopper protection.

The I.F. output is 1 MHz for both models.

A summary fault output is included on each downconverter module. Faults include:

- Voltage out of regulation
- Local Oscillator +/- 1% out of tolerance
- RF input cable not connected to cavity

The fault signal goes to the Logic/Interface Unit. If a fault exists beam will be shut off.

4.2.2 RMS to DC Converter
The RMS to DC converter contains a differential input amplifier for noise rejection, a bandpass filter, and a commercial RMS to DC converter I.C. The input is 1MHz from the downconverter and the output is 0 to 5VDC, nominal.

Fault detection circuitry includes:

- Voltage out of regulation
- Down converter cable not attached

The fault signal goes to the Logic/Interface Unit. If a fault exists beam will be shut off.

4.2.3 Equalizer
The Equalizer board contains the gain adjustment for the DC current signal.
The gain is adjusted such that:

Injector BCM DC out	0 - 5V = 0 - 200 μA
Beam Stopper BCMs DC out	0 - 5V = 0 - 10 μA

Fault detection circuitry includes:

- Voltage out of regulation

The fault signal goes to the Logic/Interface Unit. If a fault exists beam will be shut off.

4.2.4 Integrator/Comparator Board
The Integrator/Comparator board contains circuitry that integrates the beam current and faults if the current -time product exceeds the threshold. Also contains window detector circuitry for verification self-test.
625kHz permissive signal from the Logic/Interface Unit is routed through a TTL gate controlled by the comparator output.

Fault detection circuitry includes:

- Voltage out of regulation
- Window Comparator Fault

Both faults go to the Logic/Interface Unit. A voltage regulation fault will shut off beam.
A Window fault is routed to the Test/Verification unit for the System self test.

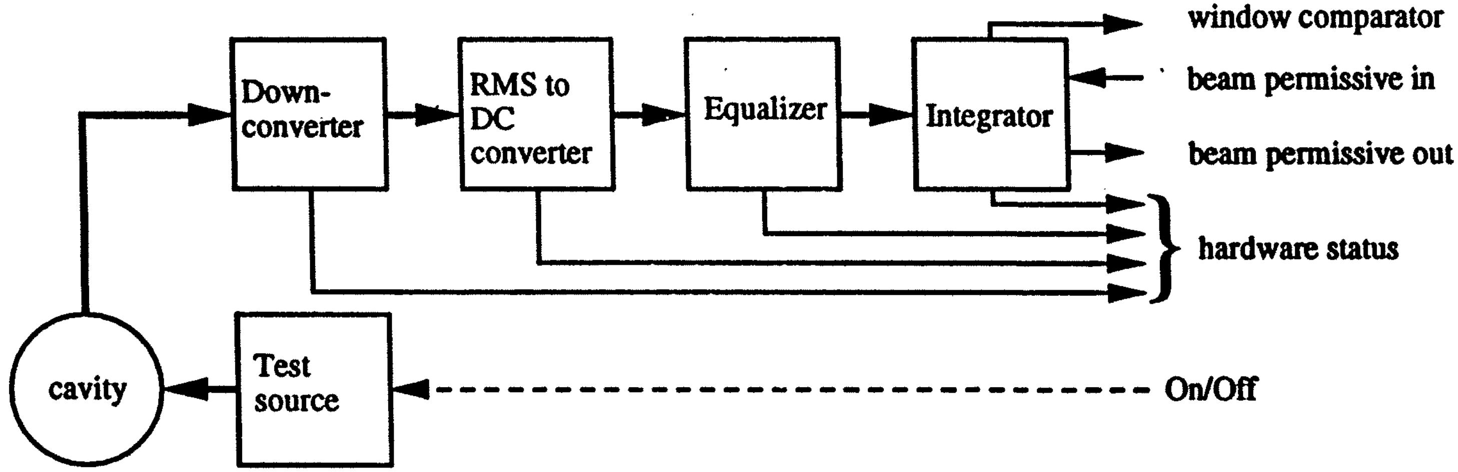

Figure 7
Downconverter Subsystem

STANDARD MODULES AND THEIR CONFIGURATION

4.3 Logic/Interface Unit

The Logic Interface Unit consists of a Logic card and a Fan-Out Card.

4.3.1 Logic Card.

There are two versions of the logic card. The first is used in the injector to route permissive signal from the BSY and East Arc to the beam shutdown devices. The BSY and East Arc cards contain 625 kHz clocks, Beam Stopper Logic, and permissive transmitters.
The Logic cards also interface to the Test/Verification Unit and the Beam Current Monitor. Each Card in the Beam Current Monitor sends a health status. If the health is bad the Logic card will remove the 625kHz permissive. The Test/Verification Unit sends a test status bit back to the Logic Card. If the test status is bad the Logic Card will remove the 625 kHz permissive.
The logic card also contains a latched relay output which is monitored by the local PLC. The contacts are open on fault. IF the local PLC senses a fault it will drop the area out of Beam Permit. By dropping an area out of beam Permit the 100 kV to the gun is turned off. All faults are latched. Faults can only be reset by either issuing a reset through the control system or manually resetting the latch through a front panel switch. The latch reset is AC coupled. If the latch is stuck it will not hold the system in an unsafe state. The status of each input is also latched on fault for diagnostics. All inputs and outputs to the Logic Card are optically isolated.

4.3.2 Fan-Out Card

The Fan-Out Card is used in the injector to distribute fiber-optic permissive signals to the fast beam shut off devices. There are 5 outputs:
Control Electrode Permissive
Polarized Source Permissive
Gun Modulator Permissive
X-Kicker Permissive
Y-Kicker Permissive

4.4 Test/Verification Unit

The purpose of the Test/Verification Unit (fig. 8) is to automatically sequence an end-to-end test of the entire BCM system. The Unit is also used to bridge the status of each LIU and beam shutdown device to the EPICs control system.

During a verification test the TVU will turn on the calibration source for each BCM cavity. The source will inject a signal into the BCM cavity. The resulting signal is sufficient to cause a beam current fault in each beam current monitor. The TVU monitors the status of each beam shut down device to ensure that it responded to the fault.
The level of the test signal is monitored by the window detector located on each BCM integrator card. If the signal level is too high or too low the window comparator will fault. The LIU receives a test status bit from the TVU. If the test fails the LIU will latch the fault and remove the 625 kHz permissive to the beam shutdown devices.
The test is sequenced such that each BCM is tested individually.

Verification/Self Tests can be initiated remotely from the control room or locally from the front panel of each Verification Control Module. Self test is automatically started on power up.

The Test/Verification Unit is composed of a combination of 4 cards.

4.4.1 Verification Control Module
The Verification Control Module contains the test sequence logic. The VCM can be configured to be either a master or slave module. The Master Module will be located in the injector. The Slave modules are located in the East arc and Beam Switch yard.

4.4.2 Verification Input Status Module
Buffers the fiber optic status lines from the beam shutdown devices. The device status lines (DEV_STAT) are then sent to the VCM and to the EPICs control system for control room readout.

4.4.3 Verification Interface Module
Optically isolates and buffers the signals between the VCM, LIU and the control system. For instance, the LIU status registers are sent to the VIM where they are buffered and sent to both the control system and to the VCM for use in the self test.

4.4.4 The Verification Bridge Module
The Verification Bridge Module is used to communicate status between the master and slave VCMs.

5.0 Operation

The BCM system automatically configures for which ever beam stopper is inserted. The decision of whether a beam stopper is "IN" or "OUT" is made by the PLCs systems local to the beam stopper. Figure 9 shows the routing of the 625 kHz permissive signals.

The injector Logic/Interface Unit decides whether to pass the East Arc or the BSY permissive signal to the beam shutdown devices. If both are passed it is a fault condition and neither is passed.

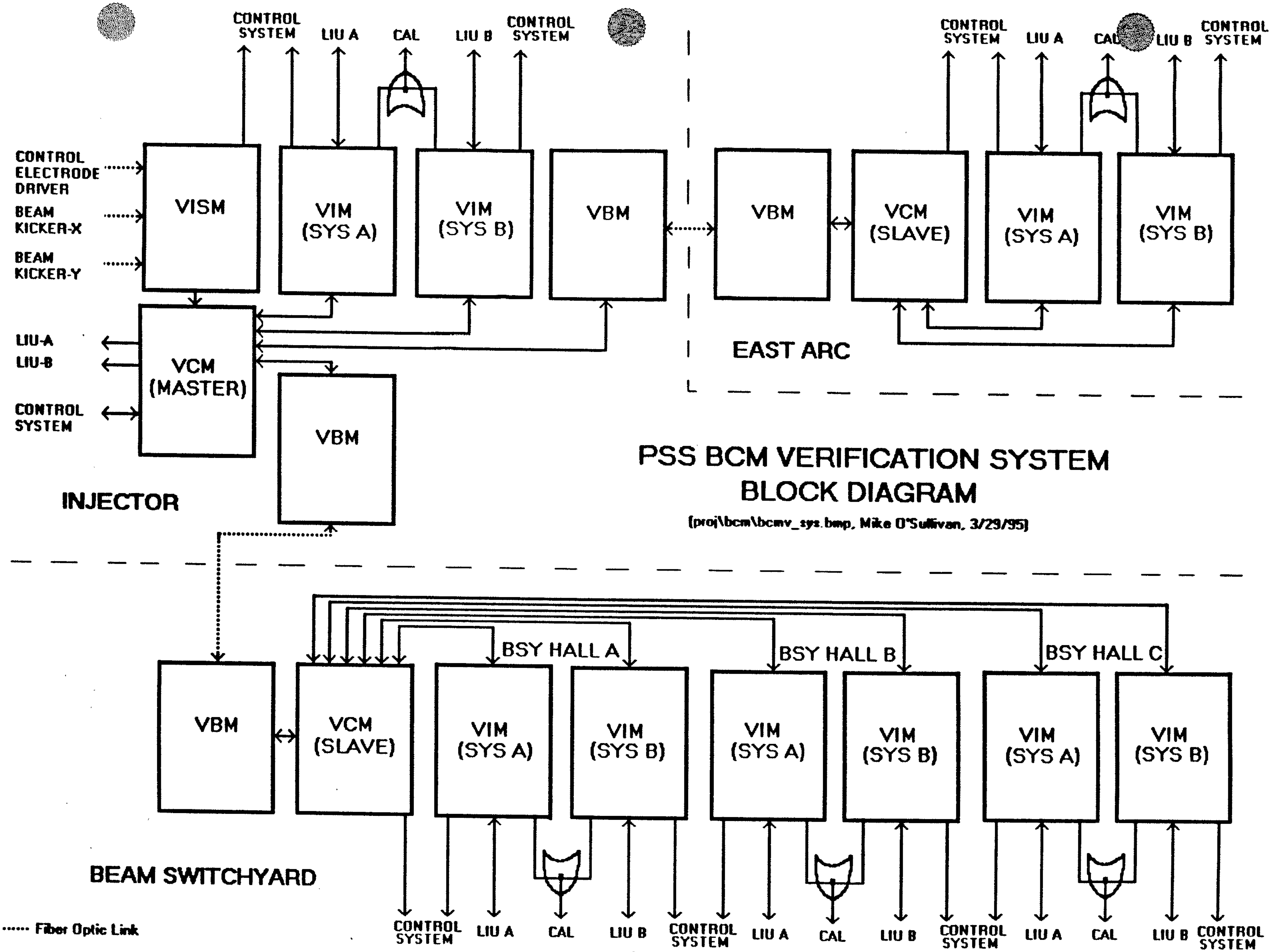
PSS BCM VERIFICATION SYSTEM
BLOCK DIAGRAM
[proj\bcm\bcmv_sys.bmp, Mike O'Sullivan, 3/29/95]
CONTROL ELECTRODE DRIVER
BEAM KICKER-X
BEAM KICKER-Y
VISM
VCM (MASTER)
LIU-A
LIU-B
CONTROL SYSTEM
VIM (SYS A)
VIM (SYS B)
VBM
CONTROL SYSTEM
LIU A
CAL
LIU B
INJECTOR
EAST ARC
VCM (SLAVE)
BEAM SWITCHYARD
BSY HALL A
BSY HALL B
BSY HALL C
Fiber Optic Link

Figure 8.

When the PSS is configured for operation to the North Stub dump the injector Logic/Interface Unit passes the permissive signal from the East arc and ignores the permissive signal from the BSY. As a condition for operation to the North Stub dump the east arc beam stopper MUST be inserted. This is in the PLC logic.

When the PSS is configured for operation to the BSY, or one or more of the endstations, the injector Logic/Interface Unit passes the permissive from the BSY and ignores the Permissive from the East Arc. The PLC logic is such that both of these conditions cannot be true.

East Arc Beam Stopper:
The injector Logic/Interface Unit receives a "Beam Permit Straight" from the injector PLC if:

The East Arch Transfer Switch is in the:
"Straight" (NL Beam Dump) AND "Not Recirculate" position.
The East Arc Magnet string has zero current
The East arc Beam Stopper is in the "IN" AND "Not OUT" position.

The injector Logic/Interface Unit receives a "Beam Permit Recirculate" from the injector PLC if:

The East Arc Transfer Switch is in the:
"Recirculate" AND "Not Straight" position.
The East Arc Beam Stopper is in the "OUT" AND "Not IN" position.
The South Linac and BSY are in "Beam Permit"

The East Arc Logic/Interface Unit receives never bypassed locally.

The BSY Logic/Interface Unit decides if the Hall A or C BCMs may be bypassed. The Hall B BCM is never bypassed. The Hall A and C BCM permissive signal may be bypassed if:

The endstation associated with a BCM is in "Beam Permit"

In turn, Beam Permit is received from the BSY PLC if:

The Endstation's Beam Stopper is in the "OUT" AND "Not IN" position
The Beam Stopper pressure is OK.

If any BSY BCM Permissive is both Bypassed AND Active the system will fault and neither will be passed to the injector.

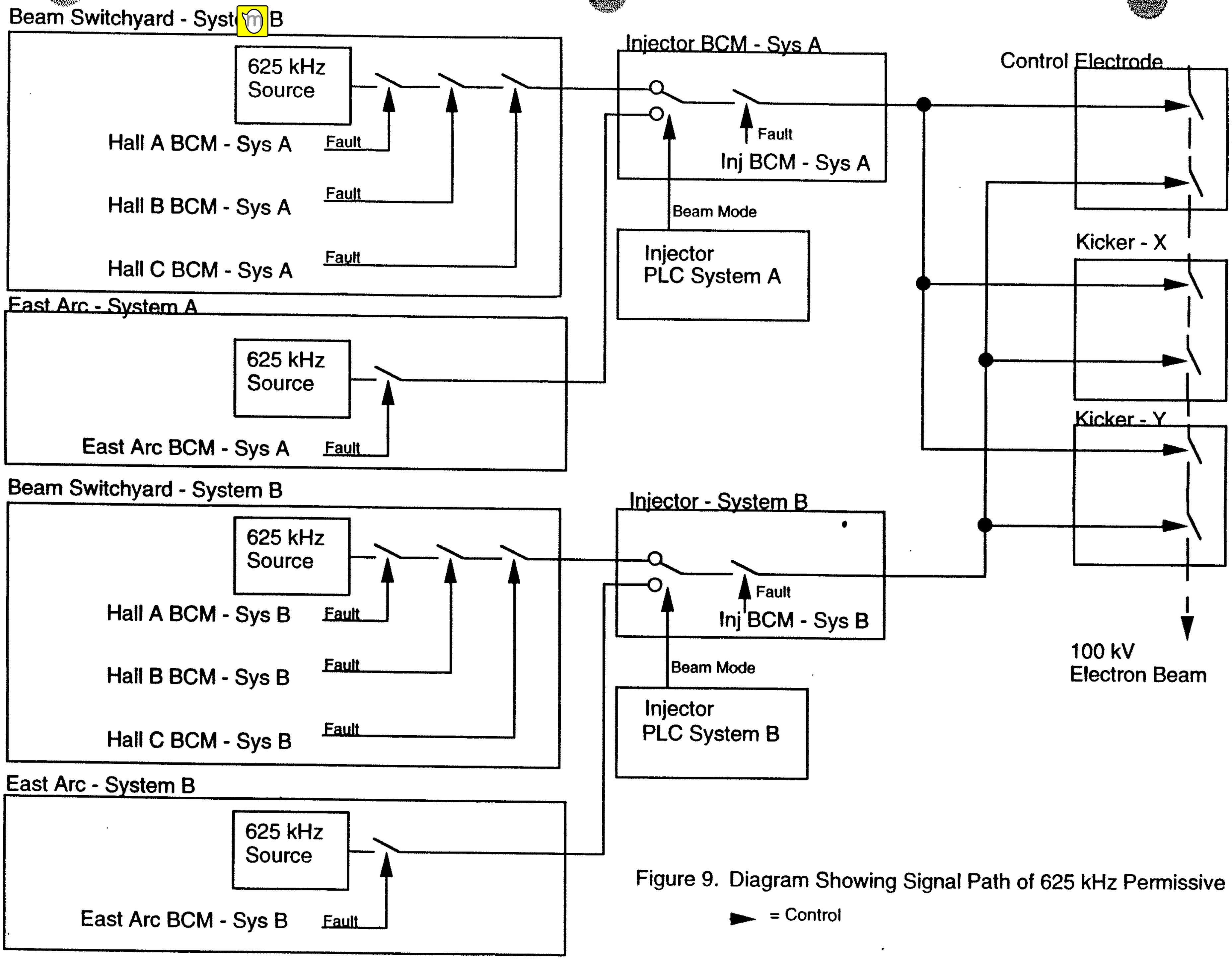

Figure 9. Diagram Showing Signal Path of 625 kHz Permissive