SNS 109010200-DC0001-R01

Spallation Neutron Source Cabling Design Criteria

May 2002

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SPALLATION NEUTRON SOURCE
CABLING
DESIGN CRITERIA

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May 2001

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Accelerator Systems	P. Holik
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1.0 SCOPE AND PURPOSE

This document provides design criteria for cabling external to cabinets and equipment. Cabling within cabinets and on the technical equipment to these connection points are not in its scope.

Project requirements for cabling are provided in SNS 109010000-SR0001, Systems Requirements Document (SRD) for Cabling. This document provides additional information for use by designers to insure project SRD requirements are met and provide an appropriate degree of standardization.

The goal of this document is to aid designers in providing specifications and drawings in sufficient detail to have SNS technicians and/or Davis Bacon forces procure, install, terminate, and test cabling.

2.0 DELIVERABLES

1. Specifications needed for cable procurement
2. Drawings showing cable routing and termination information similar to those shown in Figure 1 and 2 of Appendix A.
3. Input of appropriate data to the project cabling database (an Excel spreadsheet to assist with this is on the cabling web page described in Section 5.1).

3.0 ELECTRICAL SAFETY & FLAMMABILITY REQUIREMENTS

The Electrical Safety Officers (ESO) listed below are members of the Electrical Safety Committee and will serve as the Authority Having Jurisdiction (AHJ) for their areas.

Paul Gibson – Ion Source
David Anderson – RF systems
Scott Fisher – Power Supplies
Don Richied - Cryogenics
John Crandall – Vacuum Systems
Bill Stone – Controls Systems
Ron Battle – Target Systems

Paul Holik is the chairman of the Electrical Safety Committee. Jim Eckroth jim@fireriskmgt.com) is responsible for project fire protection systems and serves as a subject matter expert for cabling flammability and fire protection issues.

All wiring in cable trays shall meet the requirement of ANSI/UL 1581 Vertical Tray Flame Test, IEEE 383, 70,000 BTU/hr Vertical Tray Flame Test, CSA FT 4 Vertical Flame Test, or IEC 332-3 “Test on Bunched Wire or Cables”.

Cables installed in air ducts, plenums, and other spaces used for environmental air shall be plenum cables that pass the NFPA 262/UL 910 Fire and Smoke Test. Cables installed in vertical runs in a shaft shall be riser cables that pass the UL 1666 Riser Cable Flammability Test.

Cabling approved for use in cable trays is shown on Table 1 in Appendix A. For additional guidance on plenum and riser cabling, contact the AHJ or Jim Eckroth.

4.0 CABLE AND PENETRATION NUMBERING

Cable numbering and block assignments for cables used in the accelerator are shown in Table 2 in Appendix A. Penetration (chase) numbers, locations, conduit assignments, services, and other data are included in the cabling database (available from the web page in Section 5.1).

From and to (Source and Destination) information to be included on labels for accelerator systems cables are included in Figure 3 of Appendix A.

Cable number block assignments for Target systems are as follows:

WBS	System	Cable Numbers
1.6.2	Moderator	6000000-6099999
1.6.5	Shutter Controls	6100000-6199999
1.6.7	Remote Handling	6200000-6299999
1.6.8	Controls	6500000-6999999

5.0 STANDARDIZATION

5.1 Web Page

A project web page that serves as a mechanism for distributing cabling information to all design team members is located at:

http://www.sns.gov/projectinfo/ics/191/1912/1912.html

The page contains this document, catalogs for cabling included in the Electrical Commodities Contract, a cabling and rack factory handbook, the cabling SRD, access to the cabling database, and other helpful information. If needed information is not found in this document, the next place to look is the cabling and rack factory web page at the above address.

5.2 Voltage Ratings

Basically, cable voltage ratings must provide compliance with the National Electric Code (NEC). The guidance given here is intended to help insure compliance.

Mixing cables with different voltage ratings in the same raceway (conduit or cable tray) can easily lead to non-compliance situations. For this and functional reasons, the cabling SRD requires that cable be separated into specific tray sections as shown in the table below. (Where AE drawings use a different designation, the AE designations are shown in parentheses.) To further reduce the likelihood that non-compliant mixtures of voltage ratings occur, the following methods should be used to greatest degree possible.

All cabling in tray sections HPRF, PWR, MAGPWR, and HV shall be rated at 600 Volts or greater.

Cable Tray Sections Required by Cabling SRD

Designation	Section Definition	Cables carried
TPS	Target Protection System (TPS)	TPS cabling (conduit only)
PPS	Personnel Protection System (PPS)	PPS cabling
MPS-PLC	PLC portion of MPS	MPS cabling in Front End building and carrying signals serving dump protection
FA	Fire Alarm	Fire Alarm
LLS (S-NLL)	Low Level Signal	Power with voltage < 50V, 4-20 ma, 0-10 VDC, 0/24VDC, fieldbus, Linac HPRF control cabling, etc.
COMM (COM)	Communication & Network cabling	Fiber optic cabling, communications (networks, data acquistion, ICS, DeviceNet, ControlNet, EPICS ethernet, CAT5, phone line) cabling, Public Address, Timing system, Equipment protection system (EPS)
MLS	Medium Level Signal	Control signals of <50V and <10 Amps. Stepper motors, low voltage DC motors, Cryo module heaters
VLLS (S-ELL)	Very Low Level Signal	Beam instrumentation/diagnostics, RF Control, Silicon diode temperatures, thermocouples, etc.
REF	RF Reference cable	Temperature controlled, Low Level RF Reference coax cable (in Linac tunel only)
HPRF	High Power RF	High power RF cabling (Expected only in Ring area)
PWR (PWR-DP, PWR-SWGR, PWR-SUPP)	Standard Power (AC and DC)	Power with voltage of 50 to 600V Magnet power (except for DC)
MAGPWR	DC Magnet power	DC power to magnets
HV	High voltage (>3kV)	High voltage vacuum and diagnostics cabling

Communications and remote control and signaling circuits must meet further requirements that are impacted by their circuit power sources. A detailed analysis of this situation is provided in a table on the cabling Web page. Project requirements implementing this requirement are as follows:

a) All cabling used in Normal Low Level Signal (S-NLL) and Medium Level Signal (MLS) raceways shall be 600V rated.
b) All cabling used in Very Low Level (S-ELL) or Communications (COM) raceways shall have 300V rated cable (Note: 600V and 150V rated cable is not allowed). Further, power sources for this cabling shall be listed as CL2 or CL3 circuits where commercially available or have AHJ agreement that they meet the intent of NEC Chapter 9 Table 11.
c) PPS or other raceways carrying a combination of communications and remote control and signal circuits shall either use all 600V cable or have all circuits driven by power sources that are either listed as CL2 or CL3 where commercially available or that have been approved by the AHJ as meeting the intent of NEC Chapter 9, Table 11.
d) 120VAC signals to solenoid valves, relays, etc. will be considered power circuits (not CL1 circuits) and run in the PWR tray for EMI reasons.

Coax cabling is sometimes not available with certified voltage ratings. When used for signal and communications functions, it should be installed only in the COMM, VLLS, or REF sections.

Where commercially available, coax cabling used for high voltage (greater than 600V) functions shall have a red jacket, and the rated voltage of the coaxial cable shall be greater than or equal to the operating voltage or it shall be Hi-Pot (voltage withstanding test, AC or DC) tested for the equivalent voltage levels. Otherwise, mark the cable ends with red heat shrinkable tubing or some other permanent means.

5.3 Color Coding

Where possible, conductor color coding shall be in accordance with Tables K-1 and K-2 of NEMA publication W30 as shown in Tables 3 and 4 in Appendix A. Where connectors are used, the preferred pinout configuration is also shown.

Grounding conductors shall be Green or bare copper. White or natural Grey shall always be used as the neutral conductor.

Where practical, low voltage AC and DC signal cabling (less than 10 VAC (rms) or 50 VDC), shall use red and black conductors. For DC, use red as (+) and black as (-).

Coax cabling used for high voltage (greater than 10 VAC (rms) or 50 VDC) shall have a red jacket.

For 120VAC, single phase, use Black for hot, White for neutral (and Green for ground).

For 208 volt, 3-phase, 4-wire use Black for Phase A, Red for Phase B, Blue for Phase C, White or Natural Grey for neutral. Use 3-pole breaker only.

For 120/208-volt single phase, use wire insulation color or tape to denote which two of the three "hot" phases are connected (Black for Phase A, Red for Phase B, Blue for Phase C). Use white or natural gray for the neutral. These shall use only a 2-pole breaker for the supply.

For 480 volt, single-phase, use wire insulation color or tape to denote which two of the three phases are connected (Brown for Phase A, Orange for Phase B, and Yellow for Phase C).

For 480 volt, three-phase, phase shall be identified by the use of 3 black wires marked A, B, C, or 1, 2, 3, or tape banded Brown for Phase A, Orange for Phase B, and Yellow for Phase C.

5.4 Procurement and Cable Selection

Procurement of bulk quantities and of cabling for multiple users will be facilitated by listing it on the Approved Cable Listing described in Section 5.6. This means that the cabling program will provide assistance in obtaining a procurement arrangement (contract, adding it to the commodities or other existing contract, BOA, etc) after the cabling parameters are included on the list as approved cables. It also means that if its not on this list, the cabling program is not working to procure it. Note: The cabling program does not provide funding for the cable – only a procurement contracting mechanism.

The most efficient way to procure cabling is to use that supplied by the project Electrical Commodities contract. (In fact, in many cases needed cabling will be supplied by adding it to this contract). Catalogs for cabling supplied by this contract and instructions for ordering cabling are on the cabling web page described in Section 5.1.

Thus, when selecting cabling, the first place to look is the Approved Cable Listing on the cabling web page. After that look in the commodities contract catalogs also on the web page. After that select the cable needed and provide the information listed on the Approved Cable Listing so that it can be added and procured.

5.5 Radiation Resistance

Table 5 in Appendix A shows radiation levels in various areas of the accelerator and target buildings. It also provides recommended cabling insulations for applicable Total Integrated Dose (TID) levels and recommended cable insulations for some systems. It is intended to expand this spreadsheet to show insulations to be used in other systems to the extent that this helpful

Cabling should function adequately (which may include planning to replace the cable when radiation damage occurs) in the radiation environments listed.

Consideration should be given to standardizing by using the same cabling in low radiation environments as that needed for higher radiation environments. This reduces the risk of installing

the wrong cable in the wrong location. Examples of this is magnet cabling having EPR insulation in nearly all areas and all controls cabling having PE or PVC insulation.

Cable insulation and jacket materials recommended by the CERN 89-12 report and the Plastics Design Forum for various Total Integrated Dose (TID) levels are shown below. For standardization purposes, Teflon and Nylon insulations should not be used in any cabling at any location.

Radiation Resistance of Cabling Materials

Insulation Material	TID (Mrad)
Teflon	0.1
Nylon	1
PE, PVC (XHHW)	100
ETFE (Tefzel)	200
EPR	300
PUR	1000
Vespel	5000
Kapton	5000

5.6 Approved Cable Listing

The cabling web page contains an Approved Cable List that lists cabling that has been approved by a committee of:

Paul Holik for accelerator systems and chairman of Electrical Safety Committee,
Ron Battle for target systems,
John Cleaves for conventional systems and administrative issues, and
Jim Eckroth (flammability subject matter expert)

Approval is for flammability, radiation resistance, code compliance, and other issues only for use under the conditions specified in the listing.

Cabling not shown on this list should not be used in SNS. If cabling not on this list is needed, contact the committee above and have it reviewed, approved, and added to the list. The list will be updated as needed to show all approved cables.

Note: The fact that cabling is available via the commodities contract does not constitute technical approval for use in SNS. Technical approval comes from the committee above.

Appendix A

Figures and Tables

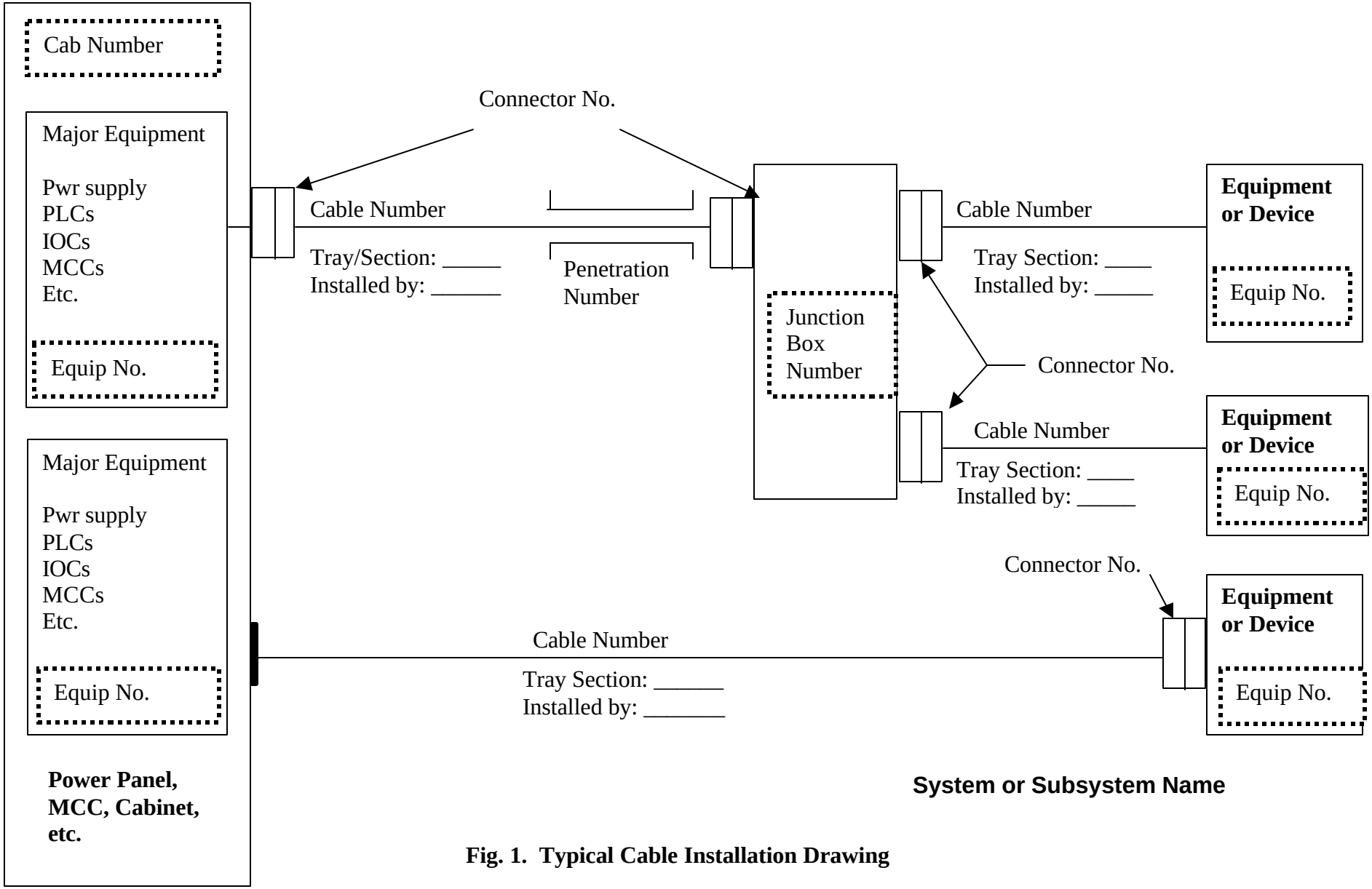

Fig. 1. Typical Cable Installation Drawing

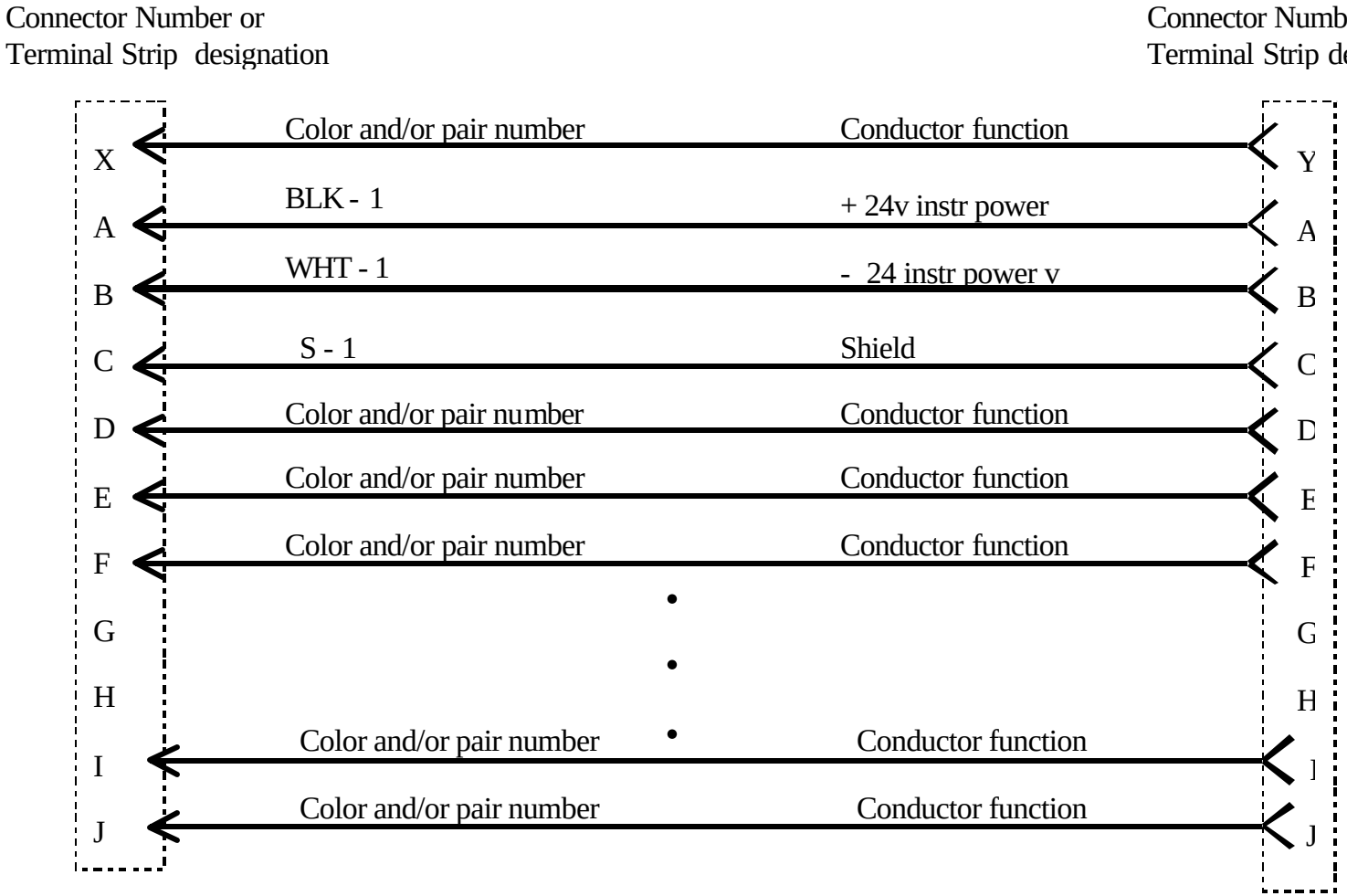

Figure 2 Cable Wiring Diagram

Figure 3 Cable labeling for Accelerator Systems
(LIMIT 28 CHARACTERS PER LINE)

CABLE# 7digits
FR:B8300:01D0101-TB01-01/10A (B,C,D, …S)

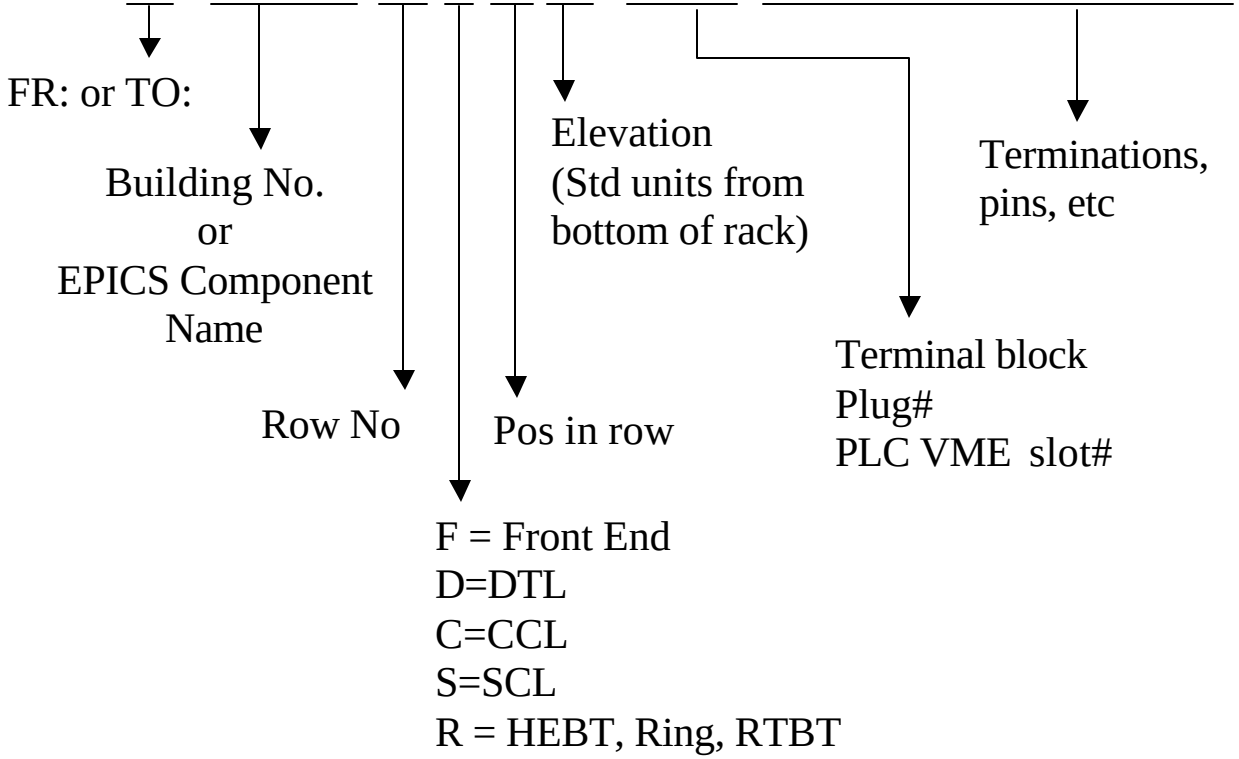

Table 1. Cables Acceptable for Use In Cable Trays

	Power Cable			**Control and Communications Cable**			**Optical Fiber Cable**
Conductor Type	**Single Conductor**		**Multi-Conductor**	**Coaxial**	**Multi-Conductor and Twisted Pair**	**Multi-Conductor**	
Minimum Conductor Size	AWG 1/0 (Equipment Grounding Conductor: AWG 4)		AWG 18	AWG 20	AWG 24	AWG 24	
Acceptable Cable Types	*NEC Cable Types:* MI, AC, MC, Welding Cable	*The following when marked "for CT use" and meeting the flammability test requirements of Section 3.0 of this document.* THW, THHN, THWN, XHHW, RHW, RHH, and Diesel Locomotive Cable or Transit Cable	TC, PLTC preferred NM, NMC, SNM, SE, USE, UF, MV acceptable	CM , CATV, PLTC preferred CL2, CL3 acceptable CL2X, CL3X or CATVX not acceptable	CM, PLTC, preferred MP acceptable CMX, MPX not acceptable	TC, PLTC, CM, preferred MP acceptable CMX, MPX not acceptable	OFN or OFC OFNP OFNR OFCR OFCP

Table 2. Accelerator Cable Numbering

1st Digit (per Cabling SRD)	
No.	
1	Unassigned
2	Personnel Protection System (PPS) & Target Protection System (TPS)
3	Front End Systems
4	Linac Systems (cold and warm)
5	Ring and Transfer Line Systems
6	Target Systems (including dumps)
7	Instruments
8	Conventional Facilities
9	Integrated Controls Systems

2nd Digit				
No.	**Front End and Linac**	**Ring & Transfer Lines**	**PPS/TPS**	**Integ Control Sys**
1	RF Power	RF Power and Controls	PPS	Ntwk backbone cabling
2	RF Controls	Extraction Kicker	PPS	Ntwk drops to IOCs
3	Cryogenics	Magnet HEBT	PPS	Ntwk drops to FE PLCs
4	Magnet Linac	Magnet Ring	PPS	Ntwk drops to Ring PLCs
5	Cooling water sys	Magnet RTBT	PPS	Ntwk drops to Linac PLCs
6	Diagnostics	Diagnostics	TPS	Ntwk drops to Tgt PLCs
7	Vacuum	Vacuum	TPS	Ntwk drops to Cryo PLCs
8	Miscellaneous	Miscellaneous	TPS	Ntwk drops to CF PLCs
9	Controls	Controls	TPS	Ntwk drops to PPS PLCs

2nd digit Definitions		
	RF	RF power for the Linac, RF power and controls for the Ring
	RF Controls	Low Level RF controls for the Linac
	Magnet Linac	Power & controls signals
	Magnet HEBT	Power & controls signals
	Magnet RTBT	Power & controls signals
	Magnet Ring	Power & controls signals
	Extraction Kicker	Extraction Kicker and PFN cabling
	Diagnostics	All cabling in beam diagnostics systems
	Vacuum	Power & controls signals
	Cooling water systems	Power & controls signals
	Cryogenics	Power & controls signals
	Miscellaneous	Unassigned numbers to be used as needed
	Controls	Controls signals not included in areas above

3rd Digit		
No.	**Front End and Linac**	**Ring & Transfer Lines (1)**
A	Ions Source	
B	RFQ	
C	LEBT	
D	MEBT	
E	DTL	
F	CCL	
G	MB SCL	
H	HB SCL	
J	SC warm sect's	
K	CHL	
L		HEBT
M		Ring
N		RTBT
1		VLLS - diagnostics and other very low level signals
2		LLS - low level signal and communications
3		120 - 480VAC Power
4		< 600 VDC magnet and other power
5		> 600 VDC pulse and other power
6		> 600 VAC Power
7		RF Power
8		Unassigned
9		Ground

(1) Anywhere voltages are designated, these numbers should be used.

Table 2 (cont'd). Cable Number Block Assignments

1st	2nd	3rd	System, Subsystem, or Area	Lab	Person
1			Not assigned		Les Ottinger
2			Personnel & Target Protection systems (PPS)/(TPS)	SNS	
	1-5		PPS		Paul Wright
	6-9		TPS		Ron Battle
3			Front End Systems (1)	LBNL	Bill Abraham
	1		RF	LBNL	Bill Abraham
	2		RF Controls	LBNL	Bill Abraham
	3		Cryogenics	LBNL	Bill Abraham
	4		Magnet Linac	LBNL	Bill Abraham
	5		Cooling water sys	LBNL	Bill Abraham, Steve Lewis
	6		Diagnostics	LBNL	Bill Abraham
	7		Vacuum	LBNL	Bill Abraham, Steve Lewis
	8		Miscellaneous	LBNL	Bill Abraham
	9		Controls	LBNL	Steve Lewis
4			Linac Systems (1)	LANL	Jack Gioia
	1		RF	LANL	Paul Tallerico
	2		RF Controls	LANL	Amy Reagan
	3		Cryogenics	LANL	
	4		Magnet Linac	LANL	Jack Gioia
	5		Cooling water sys		
		E,F	DTL & CCL	LANL	John Bernardin, Bob Dalesio
		G-K	MB, HB, CHL, & Warm Sections	JLAB	John Hogan, Herb Strong
	6		Diagnostics	LANL	Mike Plum
	7		Vacuum		
		E,F	DTL & CCL	LANL	John Bernardin, Bob Dalesio
		G-K	MB, HB, CHL, & Warm Sections	JLAB	John Hogan, Herb Strong
	8		Miscellaneous	LANL	Jack Gioia
	9		Controls		
		E,F	DTL & CCL	LANL	Bob Dalesio
		G-K	MB, HB, CHL, & Warm Sections	JLAB	Herb Strong
5			Ring and Transport Systems	BNL	PK Feng
	1		RF	BNL	Alex Zaltman
	2		Extraction Kicker	BNL	PK Feng
	3		Magnet HEBT	BNL	Ioannis Marneris
	4		Magnet Ring	BNL	PK Feng
	5		Magnet RTBT	BNL	Jian Lin Mi
	6		Diagnostics	BNL	Pete Cameron
	7		Vacuum	BNL	Lorilei Smart, John Smith
	8		Miscellaneous	BNL	PK Feng
	9		Controls	BNL	John Smith
6			Target Systems	ORNL	Ron Battle
			Controls	ORNL	Ron Battle
			Cold Source	ORNL	Allen Crabtree
			Remote Control	ORNL	Mark Renich
7			Experiment Systems	SNS	Rick Riedel
8			Conventional Facilities Systems	SNS	Les Ottinger
	1-8		Power, Fire Alarm, Security, Office Network, etc.	SNS	Les Ottinger
	9		CF Controls	SvT	Randall Steadmon
9			Integrated Control Systems		Bill DeVan

(1) 3rd digit exists for all accelerator areas, but is only shown where needed to assign blocks of numbers.

Table 2 (cont'd). Cable Number Block Assignments

1st	2nd	3rd	4th	System, Subsystem, or Area	Lab	Person
4				Linac Systems (1) (2)	LANL	Jack Gioia
	1			RF	LANL	Paul Tallerico
	2			RF Controls	LANL	Amy Reagan
	3			Cryogenics	JLAB	Jonathan Creel
	4			Magnet Linac	LANL	Jack Gioia
	5			Cooling water sys		
		E,F		DTL & CCL	LANL	John Bernardin, Bob Dalesio
		G-K	0-4	MB, HB, Warm Sections & CHL	JLAB	John Bernardin, Bob Dalesio
		G-K	5-8	MB, HB, Warm Sections & CHL	JLAB	John Hogan
		G-K	9	MB, HB, Warm Sections & CHL	SNS	Herb Strong
	6			Diagnostics	LANL	Mike Plum
	7			Vacuum		
		E,F		DTL & CCL	LANL	John Bernardin, Bob Dalesio
		G-J	0-5	MB, HB, Warm Sections	JLAB	Kevin Jordan
		G-J	6-7	MB, HB, Warm Sections	LANL	Bob Dalesio
		G-J	8-9	MB, HB, Warm Sections	SNS	Herb Strong
		K		CHL	JLAB	Jonathan Creel
	8			Miscellaneous	LANL	Jack Gioia
	9			Controls		
		E,F		DTL & CCL	LANL	Bob Dalesio
		G-J	0-7	MB, HB, Warm Sections	SNS	Herb Strong
		G-J	8-9	MB, HB, Warm Sections	LANL	Bob Dalesio
		K		CHL	SNS	Herb Strong
9				Integrated Control Systems		Bill DeVan

(1) 3rd digit exists for all accelerator areas, but is only shown where needed to assign blocks of numbers.

(2) 4th digit exists for SCL section to indicate responsibility for cable numbering of subsystems.

Examples

45G5234 Coupler Cooling water temperatures

- 4 Linac
- 5 Cooling Water System
- G MB cryomodule
- 5 Assigned by John Hogan

47J4123 Warm Section vacuum pump power

- 4 Linac
- 7 Vacuum
- J Warm Section of SC linac
- 4 Assigned by Kevin Jordan

49G0323 MB module silicon diode temperatures

- 4 Linac
- 9 Controls
- G MB Cryomodule
- 0 Assigned by Herb Strong

49G9032 MB module tuner cable, VME crate to drive

- 4 Linac
- 9 Vacuum
- G MB Cryomodule
- 9 Assigned by Bob Delasio

Table 3. Color Code (NEMA Pub. No. WC 30, Table K-1)

Multiconductor Cable Conductor No.	Wire Color Code*	Paired Cable Pair No.	Connector Pin
1	BLK	1	A
2	WHT	1	B
3	RED	2	C
4	GRN	2	D
5	ORN	3	E
6	BLU	3	F
7	WHT/BLK	4	G
8	RED/BLK	4	H
9	GRN/BLK	5	J
10	ORN/BLK	5	K
11	BLU/BLK	6	L
12	BLK/WHT	6	M
13	RED/WHT	7	N
14	GRN/WHT	7	P
15	BLU/WHT	8	R
16	BLK/RED	8	S
17	WHT/RED	9	T
18	ORN/RED	9	U
19	BLU/RED	10	V
20	RED/GRN	10	W
21	ORN/GRN	11	X
22	BLK/WHT/RED	11	Y
23	WHT/BLK/RED	12	Z
24	RED/BLK/WHT	12	a
25	GRN/BLK/WHT	13	b
26	ORN/BLK/WHT	13	c
27	BLU/BLK/WHT	14	d
28	BLK/RED/GRN	14	e
29	WHT/RED/GRN	15	f
30	RED/BLK/GRN	15	g
31	GRN/BLK/ORN	16	h
32	ORN/BLK/GRN	16	i
33	BLU/WHT/ORN	17	j
34	BLK/WHT/ORN	17	k
35	WHT/RED/ORN	18	m
36	ORN/WHT/BLU	18	n
37	WHT/RED/BLU	19	p
38	BLK/WHT/GRN	19	q
39	WHT/BLK/GRN	20	r
40	RED/WHT/GRN	20	s
41	GRN/WHT/BLU	21	t
42	ORN/RED/GRN	21	
43	BLU/RED/GRN	22	
44	BLK/WHT/BLU	22	
45	WHT/BLK/BLU	23	
46	RED/WHT/BLU	23	
47	GRN/ORN/RED	24	
48	ORN/RED/BLU	24	
49	ORN/RED/BLU	25	
50	BLK/ORN/RED	25	
51	WHT/BLK/ORN	26	
52	RED/ORN/BLK	26	

* First color is the base color of the insulation

Table 4. Color Code (NEMA Pub. No. WC 30, Table K-2)

Multiconductor Cable Cond. No.	Wire Color Code	Paired Cable Pair No.	Connector Pin
1	BLK	1	A
2	RED	1	B
3	BLU	2	C
4	ORN	2	D
5	YEL	3	E
6	BRN	3	F
7	RED/BLK	4	G
8	BLU/BLK	4	H
9	ORN/BLK	5	J
10	YEL/BLK	5	K
11	BRN/BLK	6	L
12	BLK/RED	6	M
13	BLU/RED	7	N
14	ORN/RED	7	P
15	YEL/RED	8	R
16	BRN/RED	8	S
17	BLK/BLU	9	T
18	RED/BLU	9	U
19	ORN/BLU	10	V
20	YEL/BLU	10	W
21	BRN/BLU	11	X
22	BLK/ORN	11	Y
23	RED/ORN	12	Z
24	BLU/ORN	12	a
25	YEL/ORN	13	b
26	BRN/ORN	13	c
27	BLK/YEL	14	d
28	RED/YEL	14	e
29	BLU/YEL	15	f
30	ORN/YEL	15	g
31	BRN/YEL	16	h
32	BLK/BRN	16	i
33	RED/BRN	17	j
34	BLU/BRN	17	k
35	ORN/BRN	18	m
36	YEL/BRN	18	N

* First color is the base color of the insulation

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)
Central Lab Office (CLO) Bldg	0	0	0	CF Power & Lighting	XHHW - Polyethylene (PE)
Klystron and Service Buildings				CF Controls	PVC or PE
Central Exhaust, He Compressor, Shop, etc bldgs & Comm backbone				CF Communications (2)	PVC or PE
				All Technical Systems	Standard, commercial grade
Front End Building	<1	<0.1	<0.2	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
FE Building near DTL tanks 1 and 2	2	0.2	0.4	CF Power & Lighting	XHHW - Polyethylene (PE)
Linac Tunnel - DTL				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
Lincac Tunnel - CCL	10	1	2	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
Linac Tunnel - SCL at Tunnel Wall	2	0.2	0.4	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
Linac Tunnel - SCL Near Beam Line	60	6	12	No CF Cables	NA
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
SCL no cryomodules - tunnel wall	20	2	4	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
SCL no cryomodules - Near beam	240	24	48	No CF Cables	NA
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
Beginning of HEBT dipole section	100	10	20	CF Power & Lighting	XHHW - Polyethylene (PE)
at tunnel wall				CF Controls - Tunnel Exhaust	PVC or PE
				CF Communications (2)	PVC or PE
Beginning of HEBT dipole section	1200	120	240	No CF Cables	NA
near beam line				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Transverse collimator - tunnel wall	80	8	16	CF Power & Lighting	XHHW - Polyethylene (PE)
from 10m toward SCL				CF Controls	PVC or PE
to 20m toward ring				CF Communications (2)	PVC or PE
Transverse collimator - near beam	1000	100	200	No CF Cables	NA
from 10m toward SCL				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
to 30m toward ring				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Longitudinal collimator - tunnel wall	1000	100	200	CF Power & Lighting	XHHW - Polyethylene (PE) (24)
				No CF Controls	NA
				CF Communications (2)	PVC or PE
Longitudinal collimator - near beam	2000	200	400	No CF Cables	NA
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
HEBT at Tunnel Wall	20	2	4	CF Power & Lighting	XHHW - Polyethylene (PE)
				No CF Controls	NA
				CF Communications (2)	PVC or PE
HEBT Near Beam Line	240	24	48	No CF Cables	NA
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	PVC, PE preferred, Std (4) acceptable
Injection Area - at tunnel wall	200	20	40	CF Power & Lighting	XHHW - Polyethylene (PE)
(entire quadrant of ring)				CF Controls - RTD	PVC or PE
				CF Communications (2)	PVC or PE
Injection Area - near beam line	2000	200	400	No CF Cables	NA
(entire quadrant of ring)				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Extraction Area - at tunnel wall	200	20	40	CF Power & Lighting	XHHW - Polyethylene (PE)
(entire quadrant of ring)				CF Controls - RTD	PVC or PE
(11)				CF Communications (2)	PVC or PE
Extraction Area - near beam	2000	200	400	No CF Cables	NA
(entire quadrant of ring)				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
(11)				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Collimator Area - at tunnel wall	6000	600	1200	CF Power & Lighting	XHHW - Polyethylene (PE) (24)
(entire quadrant of ring)				No CF Controls	NA
				No CF Communications (2)	NA
Collimator Area - near beam line	50,000	5,000	10,000	No CF Cables	NA

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)
(entire quadrant of ring)				Magnet cabling	Mineral Insulated (8)
				All Technical Systems	Kapton/Mineral Insulated
Ring RF Area - at tunnel wall	20	2	4	CF Power & Lighting	XHHW - Polyethylene (PE)
(entire quadrant)				No CF Controls	PVC or PE
(12)				CF Communications (2)	PVC or PE
Ring RF Area - near beam line	240	24	48	No CF Cables	NA
(entire quadrant)				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
(12)				All Technical Systems	PVC, PE preferred, Std (4) acceptable
RTBT Up to bend for tune dump	20	2	4	CF Power & Lighting	XHHW - Polyethylene (PE)
at tunnel wall				No CF Controls	NA
(12)				No CF Communications (2)	NA
RTBT Up to bend for tune dump	240	24	48	No CF Cables	
near beam line				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
(12)				All Technical Systems	PVC, PE preferred, Std (4) acceptable
RTBT Collimator - at tunnel wall	200	20	40	CF Power & Lighting	XHHW - Polyethylene (PE)
10m upstream				No CF Controls	NA
20m downstream				No CF Communications (2)	NA
RTBT Collimator - near collimator	2000	200	400	No CF Cables	
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
RTBT Downstream of collimator to proton beam window - at tunnel wall	20	2	4	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls - Tunnel Exhaust	NA
(12)				No CF Communications (2)	NA
near beam line	240	24	48	No CF Cables	
				Magnet cabling	Ethelene Propylene Rubber (EPR) (8)
(12)				All Technical Systems	PVC, PE preferred, Std (4) acceptable
Injection Dump Beam Stop Area	2,500,000	250,000	500,000	No CF Cables	NA
				TCs in beam stop	Kapton/Mineral Insulated
Inside Linac Dump	100,000	10,000	20,000	No CF Cables	NA
				TCs in beam stop	Kapton/Mineral Insulated
Inside Extraction Dump	100,000	10,000	20,000	No CF Cables	NA
				TCs in beam stop	Kapton/Mineral Insulated
Target Hot Cell Inside Pit	50,000	5,000	10,000	CF Power & Lighting	Merrick is specifying XLPE/CSPE. May need to be Kapton like rest of target

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)
				All Technical Systems	Kapton/Mineral Insulated
Delay tank cavity	25,000	2500	5000	No CF Cables	NA
				All Technical Systems	Kapton/Mineral Insulated
Inner inserts jumper	20,000	2,000	4,000	No CF Cables	NA
				All Technical Systems	Kapton/Mineral Insulated
LLLW pump & valve vault	20,000	2,000	4,000	CF Power & Lighting	Merrick is specifying XLPE/CSPE. May need to be Kapton like rest of target ??
				No CF Controls	NA
				No CF Communications (2)	NA
				All Technical Systems	Kapton/Mineral Insulated
Beamline enclosures				No CF Cables	NA
Curved Beamline (20)	20,000	2,000	4,000	All Technical Systems	Kapton/Mineral Insulated
Straight Beamline (21)	6,000	600	1,200	All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Target Vessel and Pan	20,000	2,000	4,000	No CF Cables	NA
				All Technical Systems	Kapton/Mineral Insulated
Chopper cavities				No CF Cables	NA
T0 (5 m from moderator face) (14)	10,000	1,000	2,000	All Technical Systems	Kapton/Mineral Insulated
E0 (10 m from moderator face) (15)	200	20	40		
Bandwidth (7.5 m from moderator face) (16)	2,000	200	400	All Technical Systems	Kapton/Mineral Insulated
Mercury Removal (23)	4,000	400	800	CF Power & Lighting	XHHW - Polyethylene (PE) - ???
				No CF Controls	NA
				No CF Communications (2)	NA
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Charcol Filter room (23)	2,000	200	400	CF Power & Lighting	XHHW - Polyethylene (PE) - ???
				No CF Controls	NA
				No CF Communications (2)	NA
				All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Bottom loading room				CF Power & Lighting	XHHW - Polyethylene (PE) - ???
				No CF Controls	NA
Next to Bottom Loading Port	2,000	200	400	No CF Communications (2)	NA

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)
Next to Room Walls (22)	<2	<2	<4	All Technical Systems	EPR, PUR preferred PVC, PE acceptable
Gas Liquid Separator Cavity	500	50	100	No CF Cables	NA
				All Technical Systems	PVC, PE preferred, otherwise EPR, PUR
Target Hot Cell Outside Pit	250	25	50	CF Power & Lighting	XHHW - Polyethylene (PE)
Transfer Cell (7)				No CF Controls	NA
				No CF Communications (2)	NA
				All Technical Systems	EPR, PUR preferred, otherwise PVC, PE
Target Utility Vaults 2,3, & 4	150	15	30	CF Power & Lighting	XHHW - Polyethylene (PE)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
				All Technical Systems	PVC or PE
Utility drain tanks	150	15	30	No CF Cables	NA
				All Technical Systems	EPR, PUR preferred, otherwise PVC, PE
Injection Dump Vault	<100	<10	<20	CF Power & Lighting	Standard, commercial grade (4)
				CF Controls	PVC or PE
				CF Communications (2)	PVC or PE
				All Technical Systems	EPR, PUR preferred, PVC, PE, Std (4) acceptable
Injection Dump Mech Equip Rm	<1	<1	<2	CF Power & Lighting	Standard, commercial grade (4)
Utility vault drain tank pits	5			CF Controls	PVC or PE
Bulk Shielding Liner drain lines (13)	<1			CF Communications (2)	PVC or PE
Instrument Enclosures (17)	<1			All Technical Systems	EPR, PUR preferred, PVC, PE, Std (4) acceptable
Target Utility Vault 1	<1				
Tritium Removal room (18)	<1				
Decay RCRA room (19)	<1				
Shutter Drive Equipment room	<1				
Target Bldg labs, offices, etc.	0	0	0	All	Standard, commercial grade (3)

Cable Radiation Resistance Requirements

Area	Dose Rate (Rad/hr)	Total Integrated Dose (1) 20 yrs (MRad)	Total Integrated Dose (1) 40 yrs (Mrad)	Cables	Insulation Requirements (10)

(1) Assumes 5000hrs/yr of operation
(2) Cat 5e, Telephone, Fire Alarm, DeviceNet, ControlNet, Comm Backbone, etc. Specs 16129, 16700, 16720
(3) Cabling meets service requirements and National Electric Code.
(4) Cabling meets service requirements and National Electric Code, but Teflon and Nylon should not be used.
(5) Specification 16120 & 16121. Spec does not specifically require PVC or state no Nylon jacket
(6) Radiation sufficiently high that the most radiation resistant cabling available should be used.
(7) Radiation levels will be higher for short periods of time when equipment to be removed passes through the hot cell
(8) Per Roy Cutler E-Mail of July 17, 2001
(9) Per the CERN 89-12 report and the Plastics Design Forum

Insulation Material	TID (Mrad)
Teflon	0.1
Nylon	1
PE, PVC (XHHW)	100
ETFE (Tefzel)	200
EPR	300
PUR	1000
Vespel	5000
Kapton	5000

The report also states that Nylon is not recommended in radiation areas and should be used with caution.
(10) For standardization purposes, requirements are greater than needed for radiation resistance in some areas.
(11) Assume the same as injection area
(12) Assume the same as the SCL area with no cryomodules

(14) Peak in the moter outside chopper housing. Higher doses in front of housing and inside the housing)
(15) Outside of beamline and chopper "blade" but inside of housing. Relevant to internal wiring. Peal outside of housing is ~40 Rad/hr.
(16) Outside of disc and housing. Approximate peak for a direct drive motor.
(17) Based on Instrument Hutch for Beamline 4B. Doses range from ~10 mRad/hr adjacent to the beam to <2 mRad/hr at the hutch wall. The calculation did not include the effect of scattering off of the sample and sample chamber.
(18) All radiation from tritium decay are betas, no gamma radiation.
(19) Radiation levels could be higher for short periods of time during operations on the equipment stored here, (e.g. slucing operations of the IX columns).
(20) Results based on Beamline 2 analysis. Dose rates ranged from 20,000 Rad/hr (7 m from moderator) to 10 Rad/hr (28 m from moderator) to <1 Rad/hr (30 m from the moderator).
(21) Results range from 6,000 Rad/hr at 7 m from the moderator to ~100 Rad/hr at 28 m from the moderator to ~40 rad/hr at 40 m from the moderator.
(22) Dose rates ranged from 1 to 2 Rad/hr at 3 meters from the cask to a few mrem/hr alogn the walls of the room.
(23) Dose rates are quoted for contact next to the equipment. Dose rates will be less on walls of the room due to geometric attenuation.
(24) XHHW for conventional facilities cabling in these areas has been deemed acceptable by March 27, 2002 E-Mail from Dan Stout/Paul Holik