Fermilab

BEAMS DIVISION
RADIATION SAFETY GROUP

10 October 2003

To: Radiation Safety Files

From: William S. Higgins /WSH/

Subject: Linac-Mucool Shielding Wall

The replacement of the Lambertson magnet at the downstream end of the Linac gallery required removal of the shield wall between Linac and Mucool.

The blocks in the shield wall have now been replaced in a new configuration, detailed in the attached drawings and photos.

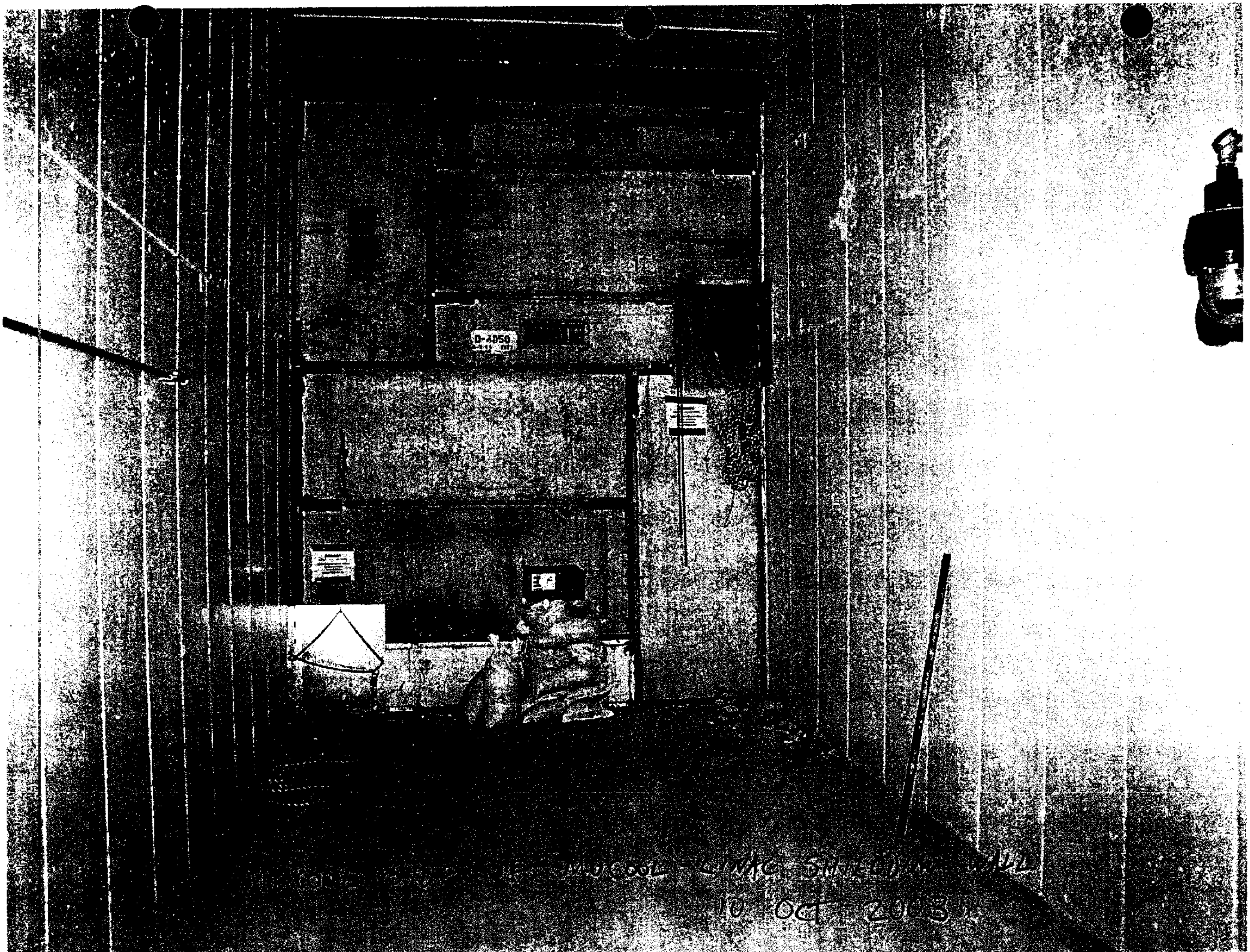
This configuration meets or exceeds the shielding provided by the previous shield wall. Thus it should suffice for the operation of the Linac.

There are two new penetrations in this wall. These have been filled with sandbags. Ropes on the sandbags extend into the Linac and Mucool enclosures to enable removal when necessary.

The sandbags are covered with aluminum plates which should prevent removal or accidental slippage. On the Mucool side of the wall, these plates have been chained and padlocked in place.

On the Linac side, the plates will not be locked. The rollup door is locked on both a Radiation Safety PAD-118 and a Linac enclosure key.

The old Lambertson magnet has been placed between the rollup door and the shielding blocks, and its more active end covered with lead blankets. These reduce its maximum dose rate from 250 mrem/hour at one foot to 50 mrem/hour.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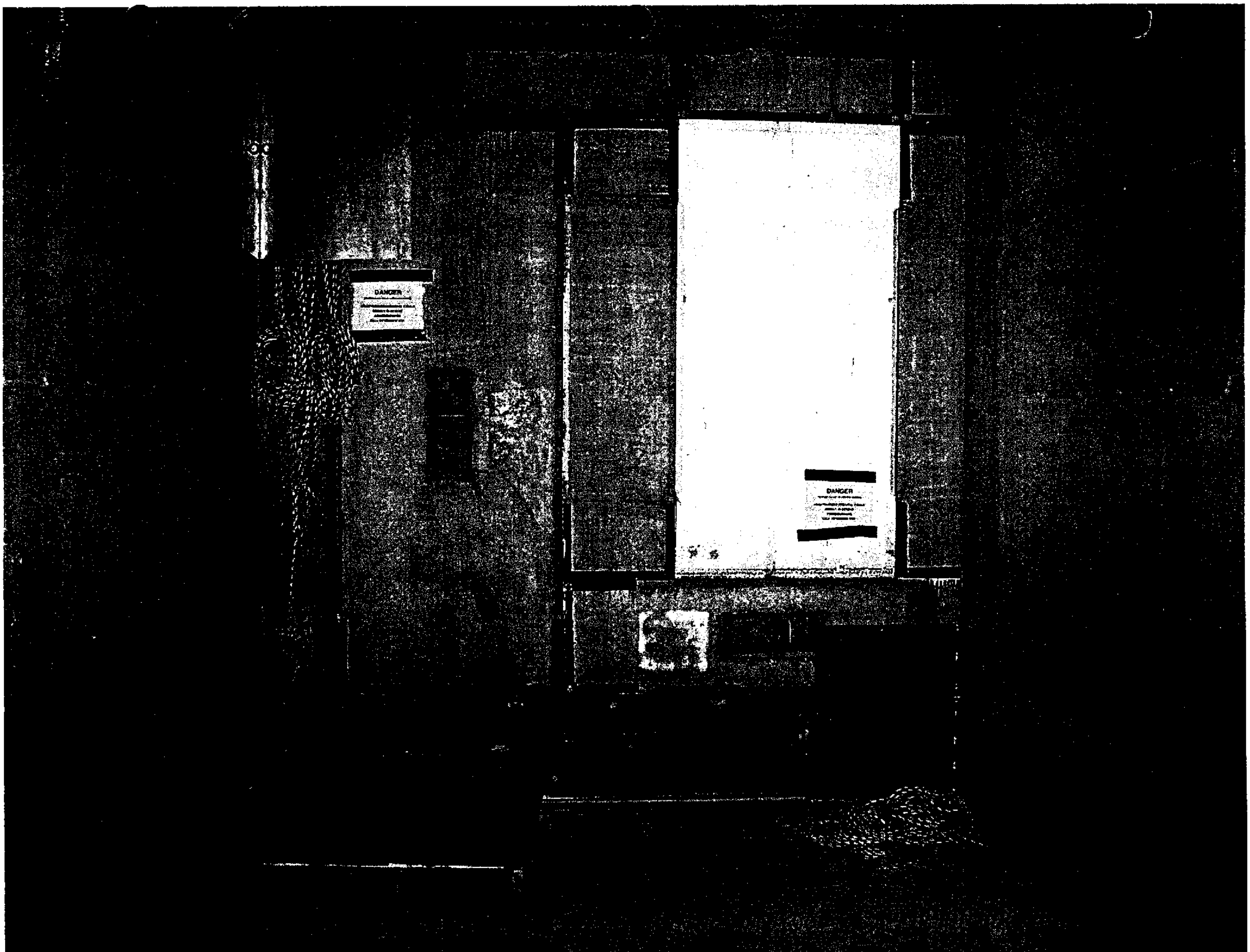
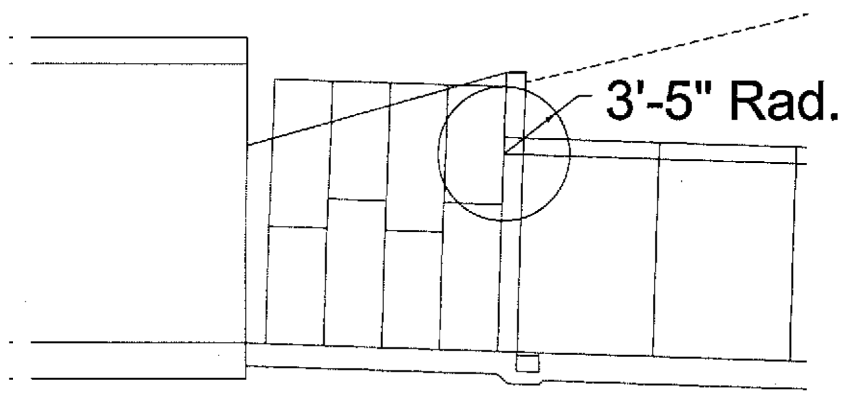
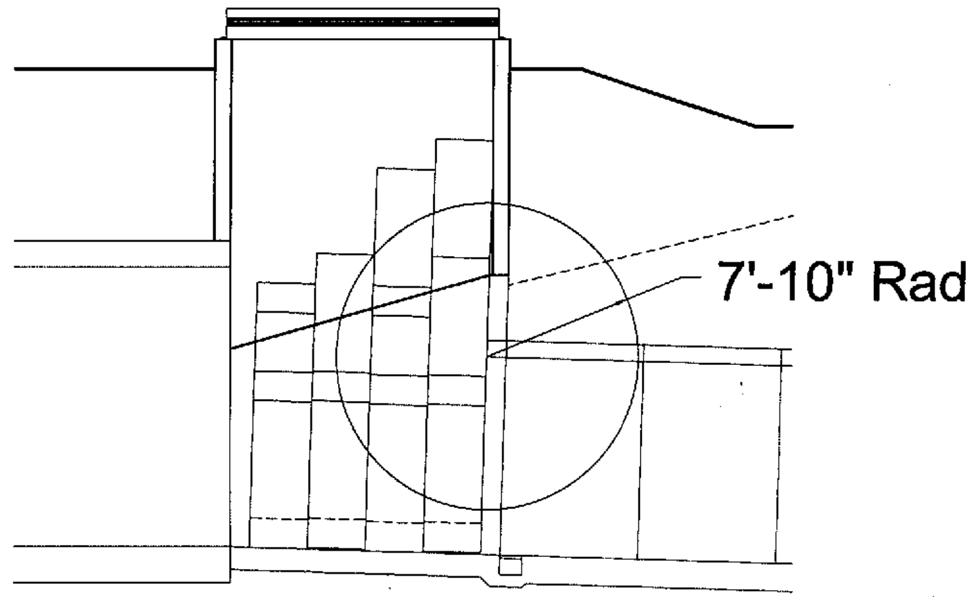


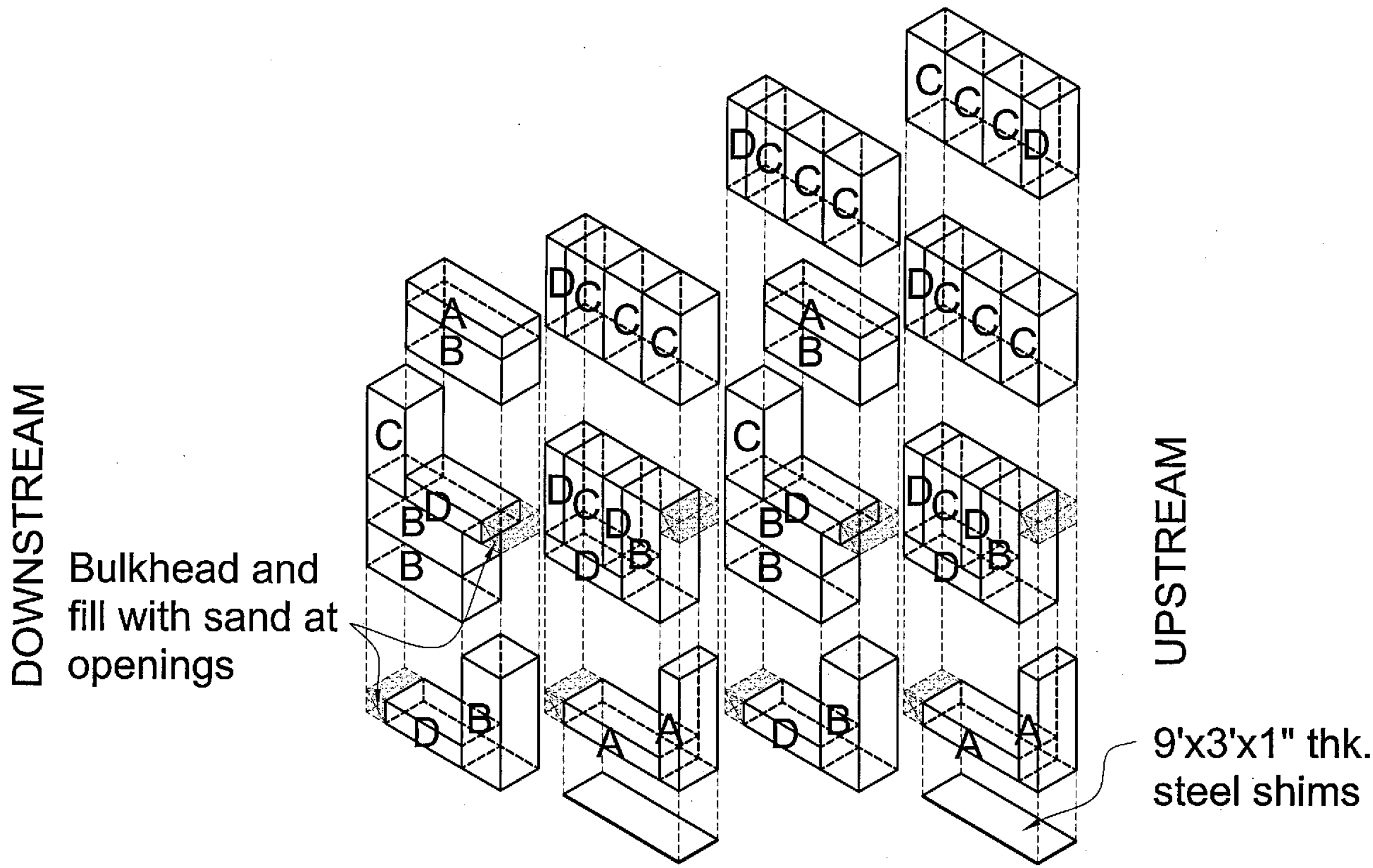
10 OCT 2003



OLD CONFIGURATION

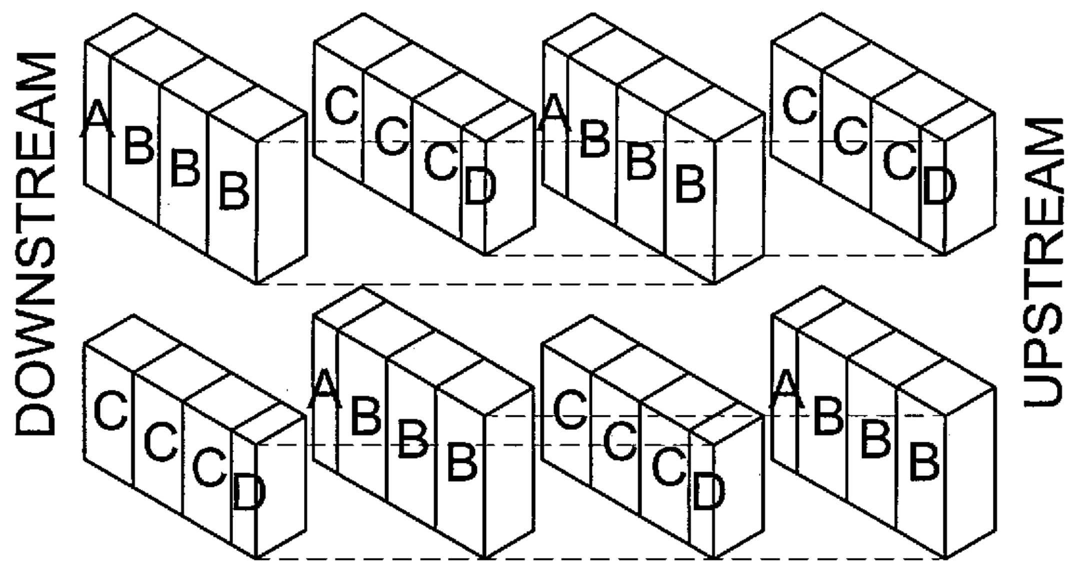


NEW CONFIGURATION

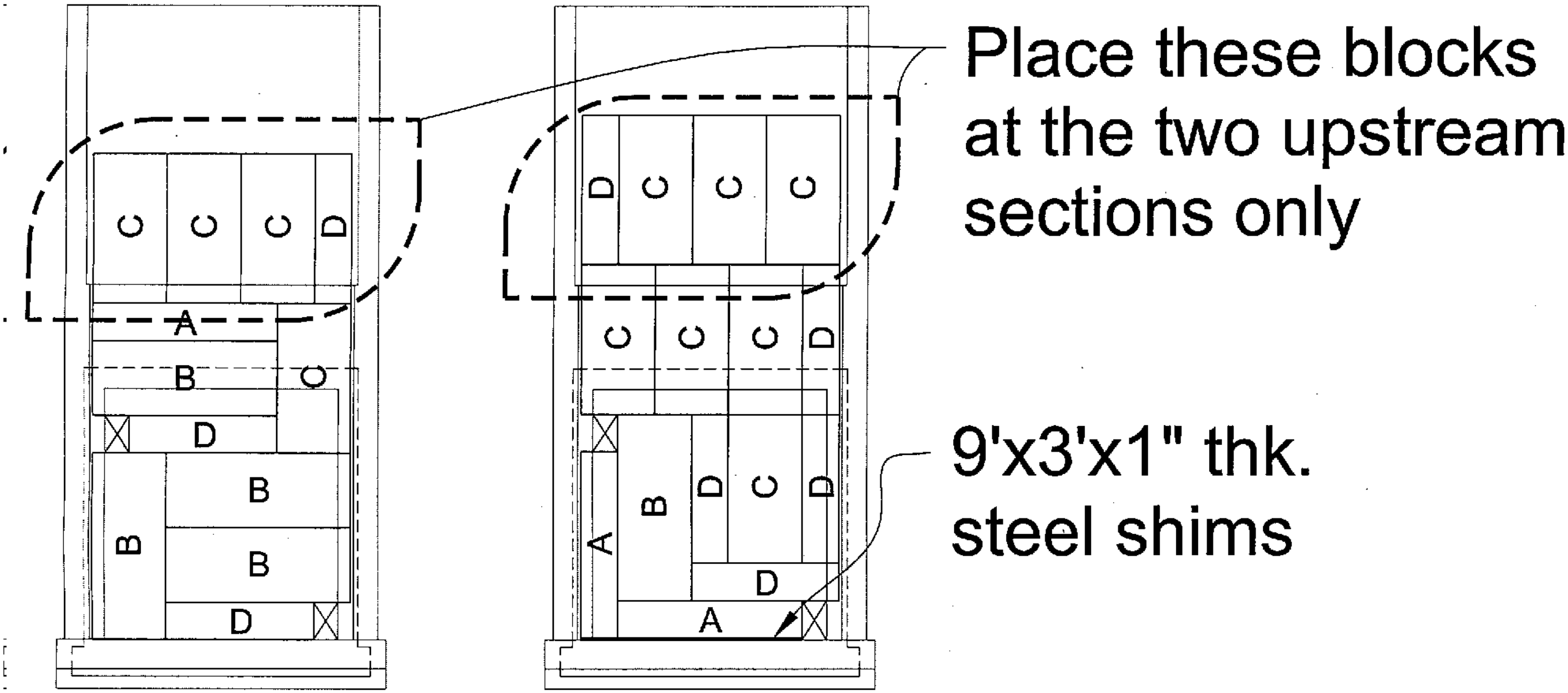


NEW CONFIGURATION

A BLOCK 7.5' HIGH 3.0'x1.5'
B BLOCK 7.5' HIGH 3.0'x3.0'
C BLOCK 6.0' HIGH 3.0'x3.0'
D BLOCK 6.0' HIGH 1.5'x3.0'



EXISTING CONFIGURATION



NEW CONFIGURATION

(Looking Downstream)

Fermilab
Linac

March 20, 2000

TO: M. Gerardi
FROM: C. Schmidt C.S.
SUBJECT: Ropes and Signs Along Linac Lower Utility Gallery

As you recently pointed out, the Linac lower utility gallery is divided into two areas by a rope and radiation signs separating the aisle area from the utility equipment area. The equipment utility area is beside the Linac shielding wall while the aisle is away from the Linac. This division makes the aisle a limited occupancy non-radiation area so no radiation precaution is needed, while the equipment area is a limited occupancy radiation area requiring personal radiation protection.

This distinction has been in effect for a long time and was instituted to identify the utility area as a potential radiation area when radiation requirements were different and little or no other protection or monitoring existed along the Linac shielding wall. Since that time the shielding requirements have changed greatly so that now, and since the shielding assessment, the shielding of the penetrations has improved and active radiation monitors have been placed along the shielding wall. These monitors are controlled and tested by the safety group and interlocked to the radiation safety system to quickly inhibit beam if inappropriate radiation levels are detected beyond the Linac enclosure; i.e., in the equipment utility area.

During the Linac Shielding Assessment of 1991 removal of the rope and signs was considered in view of the fact that shielding was increased in the penetrations and interlocked radiation monitors were install. The rope and signs remained because it was easier to keep them than to argue their removal. One regulation that weighed strongly in this decision was the requirement that the shielding must satisfy a worst case accident from the accelerator assuming that such an accident would persist for one hour.

Several factors each make this time limit (one hour) and a radiation exposure a highly unlikely possibility:

1. Radiation monitors located along the shielding wall are interlocked to inhibit beam at a dose of 10 mrem/hr.
2. A worse case or significant beam loss accident would be very detrimental to the Linac and could not be sustained for a few minutes let alone an hour. An accident where significant or total beam hits the accelerator in a small region would quickly deposit sufficient energy into the spot such that melting would occur causing RF sparking and mistuning or a vacuum or water leak, any of which would shutdown the accelerator. This type of damage has only occurred for objects that could enter the beam path. It occurred once when a vacuum gate valve, Tank 5 I believe, remained closed and in the beam path when beam was started. The tank vacuum failed immediately and shutdown the accelerator. Discovery of the failure showed a hole melted through the plate of the vacuum valve. This damage had occurred in a few seconds and inhibited beam immediately. The interlock for this valve had been jumpered for NTF operation during downstream cavity maintenance and failed to be restored on startup.
3. The control system monitors all Linac beam dependent devices and on the next 15-Hz cycle inhibits beam if any critical (beam sensitive) device goes out of tolerance. This prevents damage to the accelerator and serious radiation accidents.
4. Since the Linac Shielding Assessment of 1991 the lower utility gallery has been constantly monitored and, I believe, the radiation levels recorded. A review of this data could show the radiation levels that typically occur along this gallery and whether large events have occurred. I am aware that during normal operation these levels are very low.
5. Beam is only accelerated in the Linac for a reason - HEP, NTF or tuning and studies. For these purposes someone is aware that beam should occur and if it doesn't begins to investigate. A condition causing excessive beam loss and radiation would be noted by operations, Linac or NTF personnel and questioned.

It is very difficult to image an operation or accident scenario that would produce high radiation levels in the Linear accelerator for an extended period of time. The Linac Shielding Assessment retained the rope and signs for this purpose. If conditions have changed or these arguments reduce the need for the rope and signs then perhaps they can be removed. An addendum to the Linac Shielding Assessment would probably be needed.

Fermilab
Beams Division ES&H

3/15/00

To: Mike Gerardi

From: Matt Ferguson

Subject: Justification for De-posting the Linac Lower Level Gallery Radiation Area

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Art. 236 of the Fermilab Radiological Control Manual (FRCM) states that accelerator/beamline areas shall be posted and controlled for the normal operating conditions in accordance with Table 2-6 of the FRCM when the safety analysis documents the unlikelihood of delivering the maximum dose equivalent to an individual.

Page 1 of the 1991 Linac Shielding Assessment states the Linac Lower Level Gallery interlocked detector setpoints of 50 mR/hr and the Radiation Area posting within the lower level gallery are for a fault condition the could exist in the Linac. The setpoint of 50 mR/hr was based on not exceeding the limit of 100 mR delivered in one hour **during a fault condition**.

Page 7 of the 1993 Linac Shielding Assessment states that the Linac Lower Level Gallery interlocked detectors from Transmission Line Penetration #6 through #9 had their set points reduced from 50 mR/hr to 10 mR/hr. This is to protect the Linac Upper Level waveguide penetrations, as this area is a non-posted minimal occupancy area (limit stated 10 mR/hr for one hour). Since these detectors would provide the same level of protection in the Lower Level Gallery as the Upper Level Gallery, it would stand to reason that the Lower Level Gallery could be considered a non-posted minimal occupancy area as well at least from Tanks #6 through #9. Page 7 of the 1993 Linac Shielding Assessment also states that the radiation levels in the upper level waveguide penetrations are approximately the same as those of the lower level penetrations.

Page 3 of the 1993 Linac Shielding Assessment states that all measurements taken during the shielding assessment were extrapolated to maximum possible beam intensity (35 mA x 30 microsec, continuous operation at 15 Hz). With regards to the Lower Level Utility Penetrations, the 1993 Linac Shielding Assessment only re-evaluated the penetrations corresponding to the old Linac Tanks #6, 7, 8 and 9. This is the highest energy end of the Linac Lower Level Gallery, and represents the worst case for all lower level penetrations (ref. Pg. 7 of the 1993 Linac Shielding Assessment).

Fermilab
Beams Division ES&H

3/15/00

I believe we can de-post the Linac Lower Level Gallery based on the following reasons:

1) Page 6 of the 1993 Linac Shielding Assessment describes the conditions that had to be met in order to cause a loss in the area. Specifically the first full paragraph under the heading "Lower Linac Utility Penetrations" states that module 7 continuously tripped off whenever beam was initiated and lost in that module. When a module trips, beam is inhibited. It further states that all commissioning studies have so far shown all modules to spark and trip with significant beam loss. Due to this fact, in order to accomplish the studies, the rf had to be mistimed, and the beam inhibits had to be disabled on module 7 and the rf had to be inhibited on all modules downstream of module 7. This in itself is not a normal condition, but with regards to the modules tripping off, continuous operation at 15 Hz or any other repetition rate allowed by the Beam Permit is not likely, if not impossible.

2) There are (9) permanent, interlocked detectors installed at every "center" penetration. This correlates to every third penetration. The downstream detectors (penetrations #6-9) are set to trip at 10 mR/hr, the upstream detectors (Transmission Lines #1-5) are set to trip at 50 mR/hr. Note that the TL#1 detector is physically located inside the enclosure on the east wall toward the downstream end of Tank #1(10 MeV end). This detector is partially shielded with lead sheet to attenuate x-rays coming from the cavities when the gradients are energized.

   In addition to the interlocked detectors mentioned above, there are (2) interlocked chipmunks located above the straight ahead dump on the berm, there are (2) interlocked chipmunks inside the Booster Enclosure (1) near the Booster Chute and (1) near the Straight Ahead Dump. There is also a scarecrow in the second leg of the 400 MeV labyrinth, and another at the end of Tank #3 near the east wall of the enclosure. All of these detectors provide some level of protection against various loss scenarios.

   Attached are some calculations I performed in order to estimate the dose delivered in various accident conditions. The values are extrapolated from the 1991 and 1993 Linac Shielding Assessments studies. The values were extrapolated to the Linac Safety Envelope values of 3.54 E17 protons per hour, and they assume a 15 Hz repetition rate. This should provide the worst case values. It should be noted that normal Linac operation during HEP and NTF has an overall duty factor much less than the 15 Hz used in all these calculation (by a factor of 3 to 30 during an hour).

Reference can be made to a memo from C. Schmidt entitled " Linac Radiation Reduction", dated 7/10/91.

The response time values for the interlocked detector rad cards are based on the dose rates derived from integrated values. I chose 1 second as the response time of the safety system after the trip has occurred arbitrarily. This value is probably close enough to the true value and the margin of error here is negligible.

3) I performed a review of the Interlocked detector trips for the entire Collider Run 1B and for the entire Fixed Target Run of 1996. To summarize, only two interlocked chipmunk detectors, placed to protect the Linac Lower Level Gallery, ever tripped in a four year period for reasons associated with increased radiation levels. All but one of these radiation induced trips occurred at Tank #1. The other trip occurred at the Lower Level Gallery #8 penetration. The resultant dose delivered for this trip was calculated to be .11 mR. The highest dose delivered to the Tank #1 interlocked detector during this time period was 13.8 mR. Again, this detector is located inside the enclosure and has 3 foot of concrete shielding between it and the Lower Level Gallery.

4) I performed a review of the dose rates seen by the interlocked detectors located in the Linac Lower Level Gallery over the last year. Specifically, I looked at the responses logged on the control systems Lumberjack data logging system for every month in 1999. To summarize, I found that dose rates seen on these detectors during normal operation are routinely well below the limits established in the FRCM for requiring the posting of a Radiation Area. Other periods of operation considered "non-normal" such as NTF dosimetry studies, Linac studies, tuning, etc., may require temporary posting, and should be evaluated on a case by case basis.

Based on the information provided above and in the attachments, I see no reason why we cannot remove the Radiation Area postings in the Linac Lower Level Gallery. A memo from the Linac Department stating the unlikelihood of sustaining an accident condition, at maximum intensity, continuously for one hour has been recently generated and is on file.

Evaluation of the 1991 Linac Shielding Assessment. Low Energy End Only

Loss Point	1991 Linac Shielding Assessment Extrapolated Dose rate (mR/hr) @ 1.8E16 pph	Extrapolated Values (mR/hr) to Safety Envelope 3.54E17 pph	Dose Delivered per pulse(microrem) @ 54000 pulses/hr	Detector Location for Shielding Study	Interlocked Detector Location(x)	Highest Reading(x)	Comment	Time Required to trip interlocked detector in seconds at Extrapolated Dose Rate(column E)	Dose Delivered in time to trip(mR)	Dose Delivered in Safety System Response time(1 sec)
93 MeV	51.2	1006.93333	18.64691358	NTF in Room by Gate			Interlocked detector at	Tank 1 Interlocked	0.02746781	0.30717151
93 MeV	7.1	139.633333	2.585802469	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0.00380901	0.04259605
93 MeV	0.8	15.7333333	0.291358025	Outside Poly Door			Penetration set to trip		0.00042918	0.00479955
93 MeV	36.8	723.733333	13.40246914	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 1		0.01974249	0.22077953
93 MeV	1.1	21.6333333	0.400617284	Wall by Tank 4			interlocked detector will		0.00059013	0.00659939
93 MeV	44.5	875.166667	16.20679012	Tank 4 DS Penetration			trip first here		0.02387339	0.26697524
93 MeV	0	0	0	By NTF Rolling Stone					0	0
93 MeV	498	9794	181.3703704	Tank 5 US Penetration		x			0.26716738	2.98772294
93 MeV	2.6	51.1333333	0.94691358	Tank 1 DS Penetration					0.00139485	0.01559855
93 MeV	46.6	916.466667	16.97160494	Tunnel Wall at Tank 1 end	x				0.025	0.27957407
93 MeV	1.8	35.4	0.655555556	Tank 2 US Penetration					0.00096567	0.010799
93 MeV	1.7	33.4333333	0.619135802	Below former Entrance					0.00091202	0.01019905
93 MeV	3.3	64.9	1.201851852	Wall Step					0.00177039	0.01979816
93 MeV	4.1	80.6333333	1.493209877	Tank 3 US Penetration				0.098203244	0.00219957	0.02459772

93 MeV	46	904.666667	16.75308642	NTF in Room by Gate		x	Interlocked detector at	Tank 4 Interlocked	0.03484848	0.28614478
93 MeV	4.9	96.3666667	1.784567901	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0.00371212	0.03048064
93 MeV	1.3	25.5666667	0.47345679	Outside Poly Door			Penetration set to trip		0.00098485	0.0080867
93 MeV	33	649	12.01851852	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 4		0.025	0.20527778
93 MeV	0.5	9.83333333	0.182098765	Wall by Tank 4			interlocked detector will		0.00037879	0.00311027
93 MeV	39.5	776.833333	14.38580247	Tank 4 DS Penetration			trip first here		0.02992424	0.24571128
93 MeV	0.7	13.7666667	0.254938272	By NTF Rolling Stone					0.0005303	0.00435438
93 MeV				Tank 5 US Penetration		x	saturated		0	0
93 MeV	1.2	23.6	0.437037037	Tank 1 DS Penetration					0.00090909	0.00746465
93 MeV	28.6	562.466667	10.41604938	Tunnel Wall at Tank 1 end	x				0.02166667	0.17790741
93 MeV	1.8	35.4	0.655555556	Tank 2 US Penetration					0.00136364	0.01119697
93 MeV	1.1	21.6333333	0.400617284	Below former Entrance					0.00083333	0.00684259
93 MeV	1.2	23.6	0.437037037	Wall Step					0.00090909	0.00746465
93 MeV	2.2	43.2666667	0.801234568	Tank 3 US Penetration				0.138674884	0.00166667	0.01368519

Evaluation of the 1991 Linac Shielding Assessment. Low Energy End Only

Loss Point	1991 Linac Shielding Assessment Extrapolated Dose rate (mR/hr) @ 1.8E16 pph	Extrapolated Values (mR/hr) to Safety Envelope 3.54E17 pph	Dose Delivered per pulse(microrem) @ 54000 pulses/hr	Detector Location for Shielding Study	Interlocked Detector Location(x)	Highest Reading(x)	Comment	Time Required to trip interlocked detector in seconds at Extrapolated Dose Rate(column E)	Dose Delivered in time to trip(mR)	Dose Delivered in Safety System Response time(1 sec)
93 MeV	13.3	261.566667	4.84382716	NTF in Room by Gate		x	Interlocked detector at	Tank 4 Interlocked	0.00484383	0.07750123
93 MeV	4.3	84.5666667	1.566049383	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0.00156605	0.02505679
93 MeV	0.3	5.9	0.109259259	Outside Poly Door			Penetration set to trip		0.00010926	0.00174815
93 MeV	94.6	1860.46667	34.45308642	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 4	(1) Single Pulse	0.03445309	0.55124938
93 MeV	2.8	55.0666667	1.019753086	Wall by Tank 4			interlocked detector will	will be delivered	0.00101975	0.01631605
93 MeV	34.8	684.4	12.67407407	Tank 4 DS Penetration			trip first here		0.01267407	0.20278519
93 MeV	0.3	5.9	0.109259259	By NTF Rolling Stone					0.00010926	0.00174815
93 MeV	149.7	2944.1	54.52037037	Tank 5 US Penetration		x			0.05452037	0.87232593
93 MeV	1	19.6666667	0.364197531	Tank 1 DS Penetration					0.0003642	0.00582716
93 MeV	46.4	912.533333	16.89876543	Tunnel Wall at Tank 1 end	x				0.01689877	0.27038025
93 MeV	2.5	49.1666667	0.910493827	Tank 2 US Penetration					0.00091049	0.0145679
93 MeV	0.5	9.83333333	0.182098765	Below former Entrance					0.0001821	0.00291358
93 MeV	1.7	33.4333333	0.619135802	Wall Step					0.00061914	0.00990617
93 MeV	3.3	64.9	1.201851852	Tank 3 US Penetration				0.04837496	0.00120185	0.01922963

ween Tanks 3 & 4	14.3	281.233333	5.208024691	NTF in Room by Gate		x	Interlocked detector at	Tank 4 Interlocked	0.00520802	0.0833284
ween Tanks 3 & 4	1.2	23.6	0.437037037	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0.00043704	0.00699259
ween Tanks 3 & 4	0.4	7.86666667	0.145679012	Outside Poly Door			Penetration set to trip		0.00014568	0.00233086
ween Tanks 3 & 4	93.7	1842.76667	34.12530864	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 4	(1) Single Pulse	0.03412531	0.54600494
ween Tanks 3 & 4	1.5	29.5	0.546296296	Wall by Tank 4			interlocked detector will	will be delivered	0.0005463	0.00874074
ween Tanks 3 & 4	33.5	658.833333	12.20061728	Tank 4 DS Penetration			trip first here		0.01220062	0.19520988
ween Tanks 3 & 4	0.6	11.8	0.218518519	By NTF Rolling Stone					0.00021852	0.0034963
ween Tanks 3 & 4	148.8	2926.4	54.19259259	Tank 5 US Penetration		x			0.05419259	0.86708148
ween Tanks 3 & 4	1.1	21.6333333	0.400617284	Tank 1 DS Penetration					0.00040062	0.00640988
ween Tanks 3 & 4	29.1	572.3	10.59814815	Tunnel Wall at Tank 1 end	x				0.01059815	0.16957037
ween Tanks 3 & 4	2	39.3333333	0.728395062	Tank 2 US Penetration					0.0007284	0.01165432
ween Tanks 3 & 4	1.5	29.5	0.546296296	Below former Entrance					0.0005463	0.00874074
ween Tanks 3 & 4	2	39.3333333	0.728395062	Wall Step					0.0007284	0.01165432
ween Tanks 3 & 4	2.6	51.1333333	0.94691358	Tank 3 US Penetration				0.048839607	0.00094691	0.01515062

Evaluation of the 1991 Linac Shielding Assessment. Low Energy End Only

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37.5 MeV	0.7	13.7666667	0.254938272	NTF in Room by Gate			Interlocked detector at Tanks 1 & 4 Middle Penetration set to trip at 50 mR/hr. Tank 1 interlocked detector will trip first here	Tank 1 Interlocked Detector	0.00036383	0.0041879
37.5 MeV	1.4	27.5333333	0.509876543	Front of Tank 5 Door					0.00072765	0.0083758
37.5 MeV	0	0	0	Outside Poly Door					0	0
37.5 MeV	12	236	4.37037037	Tank 4 Middle Penetration	x	x			0.00623701	0.07179256
37.5 MeV	0	0	0	Wall by Tank 4					0	0
37.5 MeV	3.4	66.8666667	1.238271605	Tank 4 DS Penetration					0.00176715	0.02034123
37.5 MeV	0	0	0	By NTF Rolling Stone					0	0
37.5 MeV	0.3	5.9	0.109259259	Tank 5 US Penetration					0.00015593	0.00179481
37.5 MeV	1.4	27.5333333	0.509876543	Tank 1 DS Penetration					0.00072765	0.0083758
37.5 MeV	48.1	945.966667	17.51790123	Tunnel Wall at Tank 1 end	x	x			0.025	0.28776852
37.5 MeV	6.2	121.933333	2.258024691	Tank 2 US Penetration					0.00322245	0.03709282
37.5 MeV	11.3	222.233333	4.115432099	Below former Entrance					0.00587318	0.06760466
37.5 MeV	8.6	169.133333	3.132098765	Wall Step					0.00446985	0.05145134
37.5 MeV	4.8	94.4	1.748148148	Tank 3 US Penetration				0.095140773	0.0024948	0.02871702

37.5 MeV	0.3	5.9	0.109259259	NTF in Room by Gate			Interlocked detector at Tanks 1 & 4 Middle Penetration set to trip at 50 mR/hr. Tank 1 interlocked detector will trip first here	Tank 1 Interlocked Detector	0.00016741	0.0018063
37.5 MeV	0.2	3.93333333	0.072839506	Front of Tank 5 Door					0.00011161	0.0012042
37.5 MeV	0	0	0	Outside Poly Door					0	0
37.5 MeV	10.4	204.533333	3.787654321	Tank 4 Middle Penetration	x	x			0.00580357	0.06261839
37.5 MeV	0.6	11.8	0.218518519	Wall by Tank 4					0.00033482	0.0036126
37.5 MeV	3.3	64.9	1.201851852	Tank 4 DS Penetration					0.00184152	0.0198693
37.5 MeV	0	0	0	By NTF Rolling Stone					0	0
37.5 MeV	0.8	15.7333333	0.291358025	Tank 5 US Penetration					0.00044643	0.0048168
37.5 MeV	1.2	23.6	0.437037037	Tank 1 DS Penetration					0.00066964	0.0072252
37.5 MeV	44.8	881.066667	16.31604938	Tunnel Wall at Tank 1 end	x	x			0.025	0.26974074
37.5 MeV	4.5	88.5	1.638888889	Tank 2 US Penetration					0.00251116	0.02709449
37.5 MeV	10.4	204.533333	3.787654321	Below former Entrance		x			0.00580357	0.06261839
37.5 MeV	6.3	123.9	2.294444444	Wall Step					0.00351563	0.03793229
37.5 MeV	4.3	84.5666667	1.566049383	Tank 3 US Penetration				0.10214891	0.00239955	0.02589029

Evaluation of the 1991 Linac Shielding Assessment. Low Energy End Only

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10 MeV	0	0	0	NTF in Room by Gate			Interlocked detector at	Tank 1 Interlocked	0	0
10 MeV	0	0	0	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0	0
10 MeV	0	0	0	Outside Poly Door			Penetration set to trip		0	0
10 MeV	0	0	0	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 1	(1) Single Pulse	0	0
10 MeV	0	0	0	Wall by Tank 4			interlocked detector will	will be delivered	0	0
10 MeV	0	0	0	Tank 4 DS Penetration			trip first here		0	0
10 MeV	0	0	0	By NTF Rolling Stone					0	0
10 MeV	0	0	0	Tank 5 US Penetration					0	0
10 MeV :	3.3	64.9	1.201851852	Tank 1 DS Penetration		x			0.00120185	0.01922963
10 MeV)	96.3	1893.9	35.07222222	Tunnel Wall at Tank 1 end	x	x			0.03507222	0.56115556
10 MeV (	0.7	13.7666667	0.254938272	Tank 2 US Penetration					0.00025494	0.00407901
10 MeV	0	0	0	Below former Entrance					0	0
10 MeV	0	0	0	Wall Step					0	0
10 MeV	0	0	0	Tank 3 US Penetration				0.047520988	0	0

10 MeV	0	0	0	NTF in Room by Gate			Interlocked detector at	Tank 1 Interlocked	0	0
10 MeV	0	0	0	Front of Tank 5 Door			Tanks 1 & 4 Middle	Detector	0	0
10 MeV	0	0	0	Outside Poly Door			Penetration set to trip		0	0
10 MeV	0	0	0	Tank 4 Middle Penetration	x		at 50 mR/hr. Tank 1	(1) Single Pulse	0	0
10 MeV	0	0	0	Wall by Tank 4			interlocked detector will	will be delivered	0	0
10 MeV	0	0	0	Tank 4 DS Penetration			trip first here		0	0
10 MeV	0	0	0	By NTF Rolling Stone					0	0
10 MeV	0	0	0	Tank 5 US Penetration					0	0
10 MeV :	3.4	66.8666667	1.238271605	Tank 1 DS Penetration		x			0.00123827	0.01981235
10 MeV (	108.7	2137.76667	39.5882716	Tunnel Wall at Tank 1 end	x	x			0.03958827	0.63341235
10 MeV (	0.8	15.7333333	0.291358025	Tank 2 US Penetration					0.00029136	0.00466173
10 MeV	0	0	0	Below former Entrance					0	0
10 MeV	0	0	0	Wall Step					0	0
10 MeV	0	0	0	Tank 3 US Penetration				0.042100011	0	0

that the Tank 4 Downstream and the Tank 5 Upstream penetration are within fenced Radiation Areas in the Lower Level Gallery. The access to these areas are normally locked during operation.

are given throught these calculations. It should be noted that even though rad levels were not significantly greater than background at the operating conditions used during these shielding studies, e rad levels would not be significantly different at full operating intensity.

Evaluation of the 1991 Linac Shielding Assessment. Low Energy End Only

as not considered in these calculations.

that there are several interlocked detectors associated with the Linac Safety System. They all provide some level of protection, but all were not included in these calculations.

n extrapolated to the Linac Safety Envelope Limits (3.54E17 protons per hour), and a 15 Hz repitition rate is assumed to be used. It should be understood that this mode of operation provides t case) numbers.

Evaluation of the 1993 Linac Shielding Assessment. High Energy End Only

Loss Point	Shielding Assessment Extrapolated Dose Rate (mR/hr) @ 3.54E17 pph	Dose Delivered per Pulse(microrem) @ 54000 pulses/hr	Detector Location for Shielding Study	Interlocked Detector Location(x)	Highest Reading in Run(x)	Comment	Time required to trip interlocked detector in seconds at given dose rate	Dose Delived in time to trip(mR)	Dose Delivered in Safety System Response Time(1 sec)
lomentum dump	0.14	0.002592593	Tank 9 center penetration	x		The berm above the straight dump	Linac Berm detector will be	9.11458E-05	0.00013003
lomentum dump	1.03	0.019074074	Between Tank 9C and Tank 9D			has an interlocked detector set to	the only detector to trip	0.000670573	0.00095668
lomentum dump	5.93	0.109814815	Tank 9 Downstream Penetration			trip at 2.5 mR/hr.		0.003860677	0.0055079
lomentum dump	38.4	0.711111111	Berm above straight dump	x	x		2.34375	0.025	0.03566667
Above Chute	2.63	0.048703704	Tank 9 center penetration	x		The berm above the straight dump	Linac Berm detector will be	0.000411684	0.00114224
Above Chute	1.99	0.036851852	Between Tank 9C and Tank 9D			has an interlocked detector set to	the only detector to trip	0.000311502	0.00086428
Above Chute	9.21	0.170555556	Tank 9 Downstream Penetration			trip at 2.5 mR/hr.		0.001441676	0.00400001
Above Chute	159.71	2.957592593	Berm above straight dump	x	x		0.563521383	0.025	0.06936389
ctrometer Magnet	0.3	0.005555556	Tank 9 center penetration	x		The berm above the straight dump	Linac Berm detector will be	0.0001055	0.00018883
ctrometer Magnet	1.96	0.036296296	Between Tank 9C and Tank 9D			has an interlocked detector set to	the only detector to trip	0.000689267	0.00123371
ctrometer Magnet	6.33	0.117222222	Tank 9 Downstream Penetration			trip at 2.5 mR/hr.		0.002226051	0.00398438
ctrometer Magnet	71.09	1.316481481	Berm above straight dump	x	x		1.266000844	0.025	0.04474722
Straight Dump	2.48	0.045925926	Tank 9 center Penetration	x		The berm above the straight dump	Linac Berm detector will be	0.001676129	0.00236502
Straight Dump	3.08	0.057037037	Between Tank 9C and Tank 9D			has an interlocked detector set to	the only detector to trip	0.002081644	0.0029372
Straight Dump	4.95	0.091666667	Tank 9 Downstream Penetration			trip at 2.5 mR/hr.		0.003345499	0.0047205
Straight Dump	36.99	0.685	Berm above straight dump	x	x		2.433090024	0.025	0.035275
nbertson Entrance	9.61	0.177962963	Tank 9 center penetration	x		The berm above the straight dump	Linac Berm detector will be	0.000952239	0.00362168
nbertson Entrance	30.42	0.563333333	Between Tank 9C and Tank 9D			has an interlocked detector set to	the only detector to trip	0.003014269	0.01146427
nbertson Entrance	79.53	1.472777778	Tank 9 Downstream Penetration			trip at 2.5 mR/hr.		0.007880499	0.02997217
nbertson Entrance	252.3	4.672222222	Berm above straight dump	x	x		0.356718193	0.025	0.09508333
nbertson Entrance	18.1	0.335185185	Tank 7 Center Penetration	x		All interlocked detectors indicated	Tank 8 Center Interlocked	0.00846744	0.01349522
nbertson Entrance	53.44	0.98962963	Tank 8 Center Penetration	x		Have a trip level set to 10 mR/hr.	detector is the detector	0.025	0.03984444
nbertson Entrance	54.91	1.016851852	Tank 8 Downstream Penetration				most likely to trip for this	0.025687687	0.04094046
nbertson Entrance	77.34	1.432222222	Between Tank 9U and Tank 8D		x		scenario.	0.036180763	0.0576641
nbertson Entrance	17.41	0.322407407	Tank 9 Upstream Penetration					0.008144648	0.01298076
nbertson Entrance	4.23	0.078333333	Tank 9 Center Penetration	x				0.001978855	0.00315385
nbertson Entrance	8.27	0.153148148	Between Tank 9C and Tank 9 D					0.003868825	0.00616605
nbertson Entrance	75.78	1.403333333	Tank 9 Downstream Penetration				1.684131737	0.035450973	0.05650097

Evaluation of the 1993 Linac Shielding Assessment. High Energy End Only

Loss Point	Shielding Assessment Extrapolated Dose Rate(mR/hr) (35 mA, 30	Dose delivered per Pulse(microrem) (column D*1000/54000 pulses/hr)	Detector Location for Shielding Study	Interlocked Detector Location(x)	Highest Reading in Run(x)	Comment	Time required to trip interlocked detector in seconds at given dose rate	Dose Delived in time to trip(mR)	Dose Delivered in Safety System Response Time(1 sec)
ntrance Module 7	18.02	0.333703704	Tank 7 Center Penetration	x		All interlocked detectors indicated	Tank 8 Center Interlocked	0.000956212	0.00596177
ntrance Module 7	471.13	8.72462963	Tank 8 Center Penetration	x		Have a trip level set to 10 mR/hr.	detector is the detector	0.025	0.15586944
ntrance Module 7	420.23	7.782037037	Tank 8 Downstream Penetration				most likely to trip for this	0.022299047	0.1390296
ntrance Module 7	343.65	6.363888889	Between Tank 9U and Tank 8D				scenario.	0.018235413	0.11369375
ntrance Module 7	140.66	2.604814815	Tank 9 Upstream Penetration					0.00746397	0.04653619
ntrance Module 7	209.64	3.882222222	Tank 9 Center Penetration	x				0.011124318	0.06935765
ntrance Module 7	133.88	2.479259259	Between Tank 9C and Tank 9 D					0.007104196	0.04429309
ntrance Module 7	562.11	10.40944444	Tank 9 Downstream Penetration		x		0.191030077	0.029827755	0.18596942
ntrance Module 6	8.59	0.159074074	Tank 7 Center Penetration	x		All interlocked detectors indicated	Tank 8 Center Interlocked	0.001449055	0.00383517
ntrance Module 6	148.2	2.744444444	Tank 8 Center Penetration	x		Have a trip level set to 10 mR/hr.	detector is the detector	0.025	0.06616667
ntrance Module 6	187.97	3.480925926	Tank 8 Downstream Penetration				most likely to trip for this	0.031708839	0.08392273
ntrance Module 6	141.47	2.619814815	Between Tank 9U and Tank 8D				scenario.	0.02386471	0.06316193
ntrance Module 6	286.14	5.298888889	Tank 9 Upstream Penetration		x			0.048269231	0.12775256
ntrance Module 6	17.51	0.324259259	Tank 9 Center Penetration	x				0.002953779	0.00781767
ntrance Module 6	8.4	0.155555556	Between Tank 9C and Tank 9 D					0.001417004	0.00375034
ntrance Module 6	49.69	0.920185185	Tank 9 Downstream Penetration				0.607287449	0.008382254	0.02218503
ntrance Module 5	0.25	0.00462963	Tank 7 Center Penetration	x		All interlocked detectors indicated	Tank 8 Center Interlocked	5.10121E-05	0.00012046
ntrance Module 5	122.52	2.268888889	Tank 8 Center Penetration	x		Have a trip level set to 10 mR/hr.	detector is the detector	0.025	0.05903333
ntrance Module 5	309.17	5.72537037	Tank 8 Downstream Penetration		x		most likely to trip for this	0.063085619	0.14896617
ntrance Module 5	41.64	0.771111111	Between Tank 9U and Tank 8D				scenario.	0.008496572	0.02006324
ntrance Module 5	70.75	1.310185185	Tank 9 Upstream Penetration					0.014436419	0.0340892
ntrance Module 5	72.88	1.34962963	Between Tank 8U and Tank 8C					0.014871041	0.03511549
ntrance Module 5	154.95	2.869444444	Tank 8 Upstream Penetration					0.031617287	0.07465895
ntrance Module 5	5.48	0.101481481	Between Tank 8U and Tank 7D				0.734573947	0.001118185	0.00264041

ated as negative numbers in the shielding assessment. This is explained in a memo by C. Schmidt entitled "Re: ES&H Review of the Linac Shielding Assessment", dated 11/4/93.

t considered in these calculations.

ere are several interlocked detectors associated with the Linac Safety System. They all provide some level of protection, but all were not included in these calculations.

rapolated to the Linac Safety Envelope Limits (3.54E17 protons per hour), and a 15 Hz repitition rate is assumed to be used. It should be understood that this mode of operation provides
e) numbers.

ven throught these calculations. It should be noted that even though rad levels were not significantly greater than background at the operating conditions used during these shielding studies,
levels would not be significantly different at full operating intensity.

Subject: Detectors
Date: Wed, 06 Nov 2002 13:35:24 -0600
From: Michael A Gerardi <gerardi@fnal.gov>
Organization: Fermi National Accelerator Lab
To: mccrory@fnal.gov
CC: "glauten@fnal.gov" <glauten@fnal.gov>, "jea@fnal.gov" <jea@fnal.gov>, tomlin@fnal.gov, "vaziri@fnal.gov" <vaziri@fnal.gov>, "Mau, Robert" <mau@fnal.gov>, d_johnson@fnal.gov, tsullivan@fnal.gov, "Webber, Robert" <webber@fnal.gov>, "higgins@fnal.gov" <higgins@fnal.gov>, "zimmermann@fnal.gov" <zimmermann@fnal.gov>

Hi Elliott,
In response to your memo to me dated November 4, 2002 regarding the "Trip point for the radiation detectors at the Chute", your review concurs with the analysis that we completed in September 2002. The trip settings chosen at the time of initial installation were based on the operational characteristics at that time, and can now be adjusted to more efficiently operate Linac during Booster access without compromising the level of protection in our current configuration. To that end I have had the trip levels changed from 10 mrem/hr to 50 mrem/hr on both the Booster Chute Detector (G:RD2044), and the Booster Dump #1 detector (G:RD2053). These detectors are basically protecting individuals on access in the Booster Tunnel when Linac is operating. Booster is a posted "Radiation Area" indicating typical rates of 100 mrem/hr. Setting these two detectors at 50 mrem/hr continues our spirit of ALARA while providing additional flexibility to our operating environment. I will add your document and my response to the Linac and Booster shielding assessments as Post Assessment Documents to provide for future clarity.
Thanks,
Mike

Fermilab

Proton Source Department/Beams Division

Monday, November 04, 2002

To: Mike Gerardi
From: Elliott McCrory
Subject: Trip point for the radiation detectors at the Chute

Two interlocked radiation monitors have been installed at the end of the Linac/Booster chute to insure that Linac can operate safely when there are people in the Booster tunnel. These detectors were installed with a trip level of 10 mRem/hour in keeping with ALARA even though 100 mRem/hr is an acceptable accident condition for a minimal occupancy area. Since then, the Booster total beam and the induced tunnel radiation levels have increased significantly so that now Booster operation induces a background level that exceeds the trip point and holds off the Linac beam when a Booster access is made. Presently it takes more than two hours for this area to decay sufficiently for Linac operation to resume. I suggest that the trip level for these detectors be increased to improve this situation and am proposing setting the detectors to 50 mRem/hr. Attached is what background information I could obtain regarding this situation.

During a recent shutdown when Booster was in access and Linac was open, the key detector that held Linac off, referenced in the ACNET control systems as G:RD2053, was below 15 mRem/hr immediately when the enclosure opened at 06:00, see attached figure #1. It took an additional 2.5 hours for it to drop below the 10-mRem/hr trip level to allow Linac beam to run. The other detector, G:RD2044, was below 10 mRem/hr immediately.

I have consulted the original Linac Shielding Assessment documents from 1991-1992. In the version dated April 26, 1991 (Attachment #1), it is stated:

> "With the shielding in place [at the top of the chute] and full beam striking the Spectrometer the loss at the bottom of the chute is 3 mR/hr. With full Linac beam striking the momentum line pipe immediately in front of the chute, the measured radiation at the bottom of the chute is 41 mR/hr. The additional shielding blocks has made the chute attenuation > 10^6. Since 100 mR/hr is an acceptable accident condition for minimal occupancy [of a radiation enclosure], even wide open, there is no problem."

In 1992, there was an access, whose exact purpose I have not been able to determine, in which shielding in the chute was disturbed. In a supplement [Attachment #2] to the 1991 document, it states:

> "Measurements of the radiation through the Booster chute indicate that the background in the Booster tunnel, due to significant missterring of the Linac beam at the 200-MeV momentum line, could exceed radiation standards for this area [*100 mR/hr*]. It would be difficult to overcome this problem by additional shielding, especially since it is likely that the chute will be uncovered occasionally and would require retesting each time. Therefore, an interlocked

> radiation detector has been permanently installed at the bottom of the chute [set at] 10 mR/hr [when Booster is open and Linac is closed]."

To clarify this somewhat, I also attach a memo, dated April 2, 1992, from Dixon Bogert (Attachment #3), which states:

> "4) An evaluation of the results of the studies was made, and one weakness was identified. The 'chute' from the Linac to the Booster was measured to have an increased transmission under loss conditions as compared with measurements in the previous assessment. The increased radiation measured in the Booster is quite probably associated with a (relatively) slight (and unintentional) change in the shielding stacked in and around the chute. Consistent with past practices, remediation in the form of an additional interlocked detector is proposed."

In conversations with Chuck Schmidt about his recollections from this period, he recalls discussing the trip point on this detector with Tony Leveling. He recalls, specifically, that he and Tony set this detector to as low a trip point as possible, even though the level of 10 mR/hr is well below the levels required for the Booster tunnel during access.

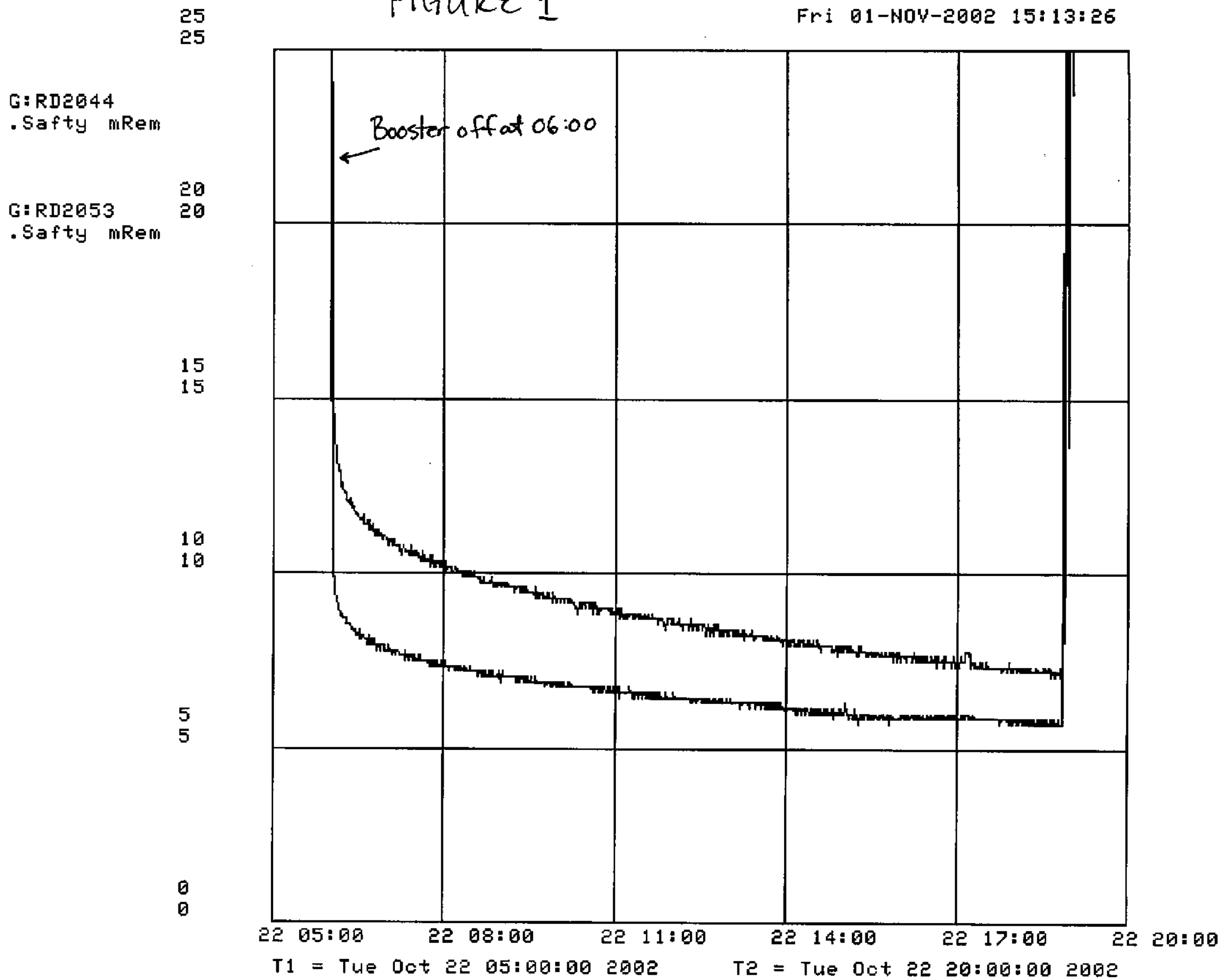
These measurements, especially the first one in 1991, show that it would take a worst-case accident in the Linac to put the radiation levels in the Booster above the acceptable levels. Rather than relying on the shielding in the chute for the rare case when Linac is running while Booster is open, my predecessors decided to put the interlocked detectors at the bottom of the chute and rely on that. It is clear that the trip point set for these detectors was arbitrarily low, especially considering present conditions.

As I see this situation the detector is only one system preventing Linac beam or radiation from getting down the chute and causing an unacceptable incident. The Booster critical devices inhibit beam to the Booster line and the chute shielding will attenuate radiation induced accidentally in the 400 MeV area. In any event the detector will still be there providing protection at an acceptable level.

Please review this proposal to see if something can be done.

CC: C. Schmidt

FIGURE 1



Console Location 235,
Booster Chute Rad Monitors

1-NOV-2002 15:13

to trip at 3.5 R/hr was installed on the tunnel wall across from this lab. This will limit the radiation in the lab due to a fault condition to 1 mR/hr.

The Tank 5, NTF Shielding Door

For the purpose of NTF, the Linac shielding door at Tank 5 is not closed completely. Closing it too far causes excessive neutron losses from NTF operation into the Linac aisle. However, not closing the door leaves a gap (about six inches) between the door and the Linac wall through which neutrons can pass from the linac tunnel into the NTF cave. From the Feb. 22, Test 5A, Run 2, measurements it was found that the radiation in the NTF cave from a nearby fault in the Linac could exceed 1 R/hr. To decrease the losses from the Linac, the entrance in the Linac wall was filled with solid concrete blocks about three feet thick. From the recent April measurements, the radiation due to a full Linac fault is 15 mR/hr. The attenuation of the door has increased from 1240 in February, to ~50,000 now. Since this is a limited access area, posted for radiation this condition is acceptable.

The 200-MeV Labyrinth

From the Feb. 21, Test 2, Run 3B,C, the losses at our normalized intensity at the gallery door to the 200-MeV labyrinth was 12.4 mR/hr. At the full Linac rate of 15 Hz this could be 372 mR/hr. To limit the maximum radiation at the door, a detector was placed in the second leg of the 200-MeV labyrinth where the radiation measured 2750 mR/hr when the door was 12.4 mR/hr. This detector will have a trip level of 200 mR/hr, so the maximum radiation at the door will be 1 mR/hr. During the April tests this detector tripped a few times while adjusting quads in Tank 9 and producing small losses in the early part of the 200-MeV line. This detector is very effective for preventing high losses in the early 200-MeV area.

The 200-MeV Chute

From the Feb. 21, Test 2 and 3, (beam striking the Booster septum and the Spectrometer) the level achievable at the bottom (Booster side) of the chute was 4.5 mR/hr for operation at 1800 pulses/hr. This could go to 135 mR/hr for 15 Hz operation. Since then, three feet of solid block shielding has been added to the front (beam direction) and 1 to 2 feet to the side of the chute opening at the top (Linac side). With the shielding in place and full beam striking the Spectrometer the loss at the bottom of the chute is <3 mR/hr. With full Linac beam striking the momentum line pipe immediately in front of the chute, the measured radiation at the bottom of the chute in the booster is 41 mR/hr. The additional shielding blocks has made the chute attenuation $>10^6$. Since 100 mR/hr is an acceptable accident condition for the minimal occupancy of the Booster tunnel, even when open, there is no problem.

The 200-MeV Dumps

Using data from the Feb. 21, Test 4A and 4B, for the straight dump and the momentum dump, neither dumps show a problem either in the Booster or on the berm. At high Linac intensity the straight dump, which is over the Booster tunnel, produced 0.4 mR/hr in the Booster tunnel, At 15 Hz continuous Linac operation this could increase by 30 to 12 mR/hr. If this were to occur for an hour this would be extraordinary and a fault condition. Since it is below 100 mR/hr, it is acceptable. The momentum dump produced no detectable radiation in the Booster tunnel.

On the 200-MeV berm above the dumps there was essentially no detectable radiation during the Feb. 21 runs. The highest observed reading (Feb 21, Test 4A, Run 2 detector 2G) above dump 1 gave a reading of 0.1 mR/hr, which is 3 mR/hr for 15 Hz operation. These runs were done at high intensities and have significantly meaningful statistics to claim the radiation to be 3 mR/hr or less on the berm above the dumps.

The 200-MeV Berm

The remainder of the 200-MeV Linac berm has similar low levels or is protected by the detector located in the 200 MeV labyrinth. Feb. 21, Test 2, Run 3B and 3C, show that levels up to 4.7 mR/hr (detector 8F) or 141 mR/hr for 15 Hz running could be reached on the berm by total loss of beam on the Booster septum. Under this condition the losses in the second leg of the labyrinth (detector 6G) are 2750 mR/hr or 82,500 mR/hr for 15 Hz operation. This location has a detector set for 200 mR/hr and will limit the losses on the berm to ~0.3 mR/hr. Similar, losses from the upstream end of the 200-MeV area are seen in the Labyrinth and prevent high levels on the berm.

From memo dated April 2, 1992 titled "Addendum to the Radiation Shielding Assessment of the Linac Enclosure of April 26, 1991" April 2, 1992 (ATTACHMENT #2)

Measurements

The Booster Chute

Measurements of radiation through the Booster chute indicate that the background in the Booster tunnel, due to a significant missteering of the Linac beam at the 200-Mev momentum line, could exceed radiation standards for this area. It would be difficult to overcome this problem by additional shielding, especially since it is likely that the chute will be uncovered occasionally and would require retesting each time. Therefore, an interlocked radiation detector has been permanently installed at the bottom of the chute in the Booster tunnel to inhibit beam if the Booster does not have a Radiation Safety System permit and the radiation exceeds 10 mrem/hr. Since this is a radiation area, the permissible fault level is 100 mrem/hr for one hour under accident conditions. Data from this assessment shows that during normal operation of the Linac the radiation in the Booster chute area to be 0.007 mrem/hr.

The lower Linac utility penetrations

Measurements of radiation through the lower Linac utility penetrations at Tank 9 show that the upstream penetration is ~7 times better shielded than the middle penetration. The downstream penetration is ~14 times better shielded than the middle penetration. (The middle penetration allows the coaxial power line to enter the Linac tunnel, and therefore there is a necessary 10" hole in the shielding.) The radiation detector at the middle penetration trips at 50 mrem/hr therefore the radiation at the side penetrations cannot exceed 7 mrem/hr (upstream) and 4 mrem/hr (downstream). The permissible level outside these penetrations for an accident condition is 100 mrem/hr for one hour. During normal operation of the Linac, the radiation level at the upstream and downstream penetrations is less than 0.01 mrem/hr while at the middle penetration the radiation level is about 0.03 mrem/hr. These are well below the radiation limit for an unlimited occupancy area under normal conditions.

The penetrations at Tanks 6, 7, and 8 have the same geometry as at Tank 9. We have inspected these penetrations and have verified that the shielding there is greater than or equal to the shielding in the Tank 9 penetrations. Since Tank 9 is the highest energy and thus the worst case, the existing protection in these areas (Tanks 6, 7, and 8) is adequate.

To: File

From: Dixon Bogert

April 2, 1992

(ATTACMENT #3)

Subject: Review of the Linac Assessment with the Linac Upgrade Access Enclosure Constructed Jan.-Mar. 1992

1) As was the case last year, the Linac Assessment is largely dependent on actual measurements of beam loss conditions because of the absence of reliable calculational tools in the energy regions 200MeV and below.

2) Last year an appropriate complete review to find and categorize all potential 'weakest' shielding points was conducted. The operational energy of the Linac is unchanged at this time. Therefore, it is possible to restrict our attention to the changes made since the last assessment, and/or to the areas where shielding was removed and nominally restored.

The assessment document correctly enumerates all the changes and/or shielding removal/restorations.

3) An appropriate study plan was designed, and the now existing conditions were studied, and all losses appropriately normalized.

4) An evaluation of the results of the studies was made, and one weakness was identified. The 'chute' from the Linac to the Booster was measured to have an increased transmission under loss conditions as compared with the previous assessment. The increased radiation measured in the Booster is quite probably associated with a (relatively) slight (and unintentional) change in the shielding stacked in and around the chute. Consistent with past practices, remediation in the form of an additional interlocked detector is proposed.

5) Since no additional shielding was found to be necessary as a result of the assessment study period, no verification study period is required. The interlocked detector will need to be set at the correct trip level, however, at the foot of the 'chute'. The assessment shows that the correct level of protection has now been achieved for all areas according to their utilization. This protection has been actively demonstrated.

(The Linac can be physically operated above the administrative guidelines for normal operation and so it is relatively straightforward to demonstrate the protection and the action of the interlocks.)

6) Except for the installation of the additional detector at the bottom of the 'chute', the locations of all other detectors required are unaltered from the previous assessment.

7) The assessment was not done for the future 400MeV Linac operating conditions and is explicitly not appropriate

previous assessment.

LINAC

1993 SHIELDING ASSESSMENT

Fermilab
ES&H Section

RECEIVED
DEC 13 1993
ACCELERATOR DIVISION
HEADQUARTERS

December 10, 1993

TO: Steve Holmes

FROM: Don Cossairt DC

SUBJECT: ES&H Section Review of Upgraded Linac Shielding Assessment Supplement dated 11/17/93

Members of the ES&H Section Staff and I have reviewed this document. We concur that it demonstrates that the upgraded Linac may be operated in accord with the requirements of the Fermilab Radiological Control Manual and addresses our comments of October 19, 1993. This document should, as you have suggested, be appended to the Linac shielding assessment.

cc: J. Peoples
K. Stanfield
R. Stefanski
D. Boehnlein
T. Miller
Shielding Assessment File

To: Pat Lesiak
Please send copies to
Chuck Schmidt
Vinod Bharadwaj
Dixon Bogert
Bob Ducar
and incorporate into Linac Shielding Assessment file. Thanks. Steve

12-14-93 copies sent

To: Pat Lesiak
Please file with the Linac Shielding Assessment.
Thanks,
Steve

Fermilab
Linac

September 21, 1993

TO: Dixon Bogert, Chairman
Shielding Assessment Committee

FROM: C. Schmidt, C. Schmidt
Linac Department

SUBJECT: Low Intensity Shielding Assessment of the Linac Upgrade

Attached is the complete Linac Report summarizing the Upgrade Shielding Assessment conducted on September 8 and 20, 1993.

A previous report, dated September 13, 1993, has serious errors. It should be ignored and hopefully discarded. The revised report of September 15, 1993 is replaced in its entirety by the present report.

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Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning

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Introduction

During the 1993 shutdown, the side-coupled cavities for the Linac Upgrade project were installed in the beam line in the Linac enclosure. These cavities have an output energy of 400 MeV, twice the energy of the previous Linac cavities (200 MeV). Since the energy has been increased the shielding of the affected area must be re-assessed. The Upgrade Commissioning Plan requires a shielding assessment following the attainment of low intensity beam operation of 2.0 mA-sec/hr and 16 mA maximum (down a factor of ~25 from the normal 53.5 mA-sec/hr) before going to higher intensities.

The shielding areas affected by this change are:

1. The momentum dump and straight dump which must be measured for full beam radiation at accessible places outside the enclosure, that is on the berm and in the Booster. This is a normal operating condition so the maximum allowable radiation, for a non-posted minimal occupancy area, is 2.5 mrem/hr for one hour, as on top of the berm and 10 mrem/hr for a posted minimal occupancy area, as in the Booster.

2. Elsewhere in the 400 MeV area where beam losses may occur from accident situations, such as at the momentum line pipe just above the Booster chute, and the spectrometer or the Booster Lambertson magnet. These devices are distributed through the area, are representative of all devices in the 400 MeV area, and are the largest and most likely sources of beam induced radiation in this

area. The radiation they might produce must be measured for full beam loss at accessible places outside the enclosure; that is, on the berm, in the Booster tunnel and gallery, and at and around the high energy (labyrinth) entrance. The loss from these devices is an accident condition and the maximum allowable radiation, for non-posted minimal occupancy, is 10 mrem/hr for one hour, as on the berm and at the labyrinth door, or 100 mrem/hr for one hour for a posted minimal occupancy area, as in the Booster tunnel.

3. The Booster chute and tunnel must be protected for 400 MeV Linac operation. The chute has had the shielding modified for higher energy but needs to be checked with beam for losses in the Booster tunnel. Presently, the Booster tunnel is protected from radiation through the chute by a permanent interlocked detector located in the Booster tunnel at the bottom of the chute, which is set to trip at 10 mrem/hr (rate measure). The permissible level in this area for an accident condition is 100 mrem/hr for one hour and 10 mrem/hr for an hour (integrated dose) for normal operating conditions.

4. The shielding of the Linac tunnel equipment access must be measured for beam loss occurring anywhere in the 400 MeV area or the Upgrade accelerator. The concrete blocks covering the entrance and the soil berm over the access must be checked. The maximum allowable radiation for this non-posted minimal occupancy areas is 10 mrem/hr for one hour for an accident, or 2.5 mrem/hr for an hour for normal conditions. If it requires a higher rating it must be posted.

5. The lower 30 inch diameter Linac utility penetrations for the old Linac which are along side the new cavities have been modified with concrete inserts, filling completely the 12 foot length of these penetrations except for some 4 inch utility holes in the concrete. As was determined for the old Linac, every third penetration is monitored by a permanent interlocked detector set to trip at 50 mrem/hr but now lowered to 10 mrem/hr. The permissible level outside these penetrations for an accident condition is 100 mrem/hr for one hour because of ropes and signs.

6. The upper penetrations for the Linac Upgrade waveguides must be measured under conditions of 400 MeV beam loss. The maximum allowable radiation for non-posted minimal occupancy, as on top of the berm of the Linac enclosure, is 10 mrem/hr for one hour for the accident condition and 2.5 mrem/hr for normal conditions

Measurements

Since the geometry of these areas are difficult to characterize the Linac shielding assessment relies on beam measurements to assess the shielding. The effectiveness of the shielding is measured by producing beam loss at known points of measured beam dose. These points were at or in devices most likely to produce radiation from beam loss or representative of conditions that could occur in the local area. The detection outside the shielding was done using calibrated chipmunk detectors at the spots most likely to have the least or an unknown shielding as determined by drawings or past shielding studies. The detector measurements, in counts, each corresponding to 2.5 microrem, were integrated for the time the beam was on, recorded by the control system and saved on paper copies, converted to a dose rate, and then extrapolated to the maximum possible beam intensity (35 mA x 30 microsec at 15 Hz rate) representative of the worse case accident condition.

Since these measurements had to be taken with low intensity beam (1 to 6 mA x 1 to 7 microsec) as compared to normal operation (35 mA x 30 microsec) and could not exceed the previously determined shielding requirements, the extrapolation to full loss conditions is between 35 and 1300. At the same time an attempt was made to keep the integrated beam loss low so as not to severely irradiate the new equipment and make the working conditions on the accelerator more hazardous. In all significant cases however, the extrapolated radiation is sufficiently low or high that it is not questionable. Where questions may arise additional measurements will be made at higher intensities or with better detection.

The measurements were divided into two major segments. Those around the 400 MeV area (Figure 1, and Runs 1 - 5 of the spreadsheets) and those related to the upper and lower penetrations (Figures 2 and 3, and Runs 6 - 9).

Results

The results of the measurements, their significance and solutions are presented. All given radiation dose rates are extrapolated to a worse case condition, i.e., 35 mA in 30 microseconds pulses for continuous operation at 15 Hz, unless stated otherwise. This is the Linac Beam Safety Envelope.

The Linac Berm above the 400 MeV Area

This area was measured by dumping as much of the low intensity beam into each dump as presently possible. The maximum beam achievable into each dump was, 2.4 mA to the momentum dump and 4.1 mA to the straight dump with a 7 microsec pulse length at 15 Hz rate for 10 minutes. In addition, similar beam was dumped into the spectrometer, the spectrometer arm beam pipe and the Booster Lambertson magnet. These devices are representative of other devices in close proximity in the 400 MeV area.

These conditions are represented by Runs 1 - 4 of the data spreadsheets, detectors SSTUDA through SSTUDD. In all cases the soil shielding above the straight dump is inadequate. In the worse case the radiation may be 250 mrem/hr. Prior to beam commissioning an interlocked detector, set to trip at 5 mrem/hr, was placed at this location and presently provides the required protection. Since this condition can be caused by normal operation the maximum limit is 2.5 mrem/hr for one hour and the detector has been lowered to trip at 2.5 mrem/hr.

At the request of the Shielding Assessment Committee a second set of runs was done for the straight dump with cleaner beam conditions (~100% transmission through the Linac and to the dump. See the toroid printout, Fig. 5) and more detectors to convincingly determine the peak of the radiation from the straight dump. Runs A (1 -3) give the results. Eight detectors were place two feet apart along the beam line from before to after the straight dump (Run 1 A, SSTUD0 - 7). At the maximum point the detectors were moved to traverse the beam line in two foot spacings (Run 2 A). Having found the expected peak the detectors were placed around this point in one foot spacings (Run 3 A, SSTUD0 - 7). With some satisfaction the maximum position was at the place the interlocked detector had previously been placed. As a comparison the previous and present measured levels were in good agreement and with the Radiation MUX readings (Run 4, SSTUDC, Runs A (1 - 3), and the MUX readings for the Berm Dump #1 DS). The peak distribution was surprisingly narrow with a half width of approximately four feet (Fig. 4).

The immediate solution for this area is to leave the interlocked detector in place set to a trip level of 2.5 mrem/hr. A more permanent and passive solution would be to add sufficient soil to the area to absorb the radiation. Until this can be done, re-measured and certified the interlocked detector will remain in place and be considered permanent.

The Booster Chute, Tunnel and Gallery

Measurement of radiation through the Booster chute indicates that the background in the Booster tunnel, due to a significant error of the Linac beam at the 400 MeV momentum line, could be 333 mrem/hr (see Run 2, SSTUD7). An interlocked radiation detector is permanently installed at the bottom of the chute in the Booster tunnel to inhibit beam if the radiation exceeds 10 mrem/hr and the Booster is not secure with a permit. Since this is a posted radiation area the permissible fault level is 100 mrem/hr for one hour while the level due to normal operation is 10 mrem/hr. The detector provides the necessary level of protection required for both cases.

The highest area in the Booster was upstream of the chute. This area is the spot below the end of the straight dump where the soil between the dump and Booster tunnel is the thinnest. High extrapolated levels (483 mrem/hr maximum) were detected in this area with beam loss in the 400 MeV area (see Runs 1 - 5, SSTUD5). An interlocked detectors is necessary and has been installed in this area with a trip level of 10 mrem/hr as at the Booster chute.

These first results also gave concern as to the extent of radiation in the Booster tunnel. During the second measurements two additional detectors were placed in the Booster tunnel upstream and downstream of the interlocked detectors (Fig. 6). These detectors were a factor of 50 or more below the interlocked detectors indicating the radiation is limited to the area of the interlocked detectors (Runs A, 1 - 3, SSTUD8 - B).

The Booster gallery near the dumps had a maximum extrapolated level of 3.5 mrem/hr (see Runs 1 - 5, SSTUD6). This would be limited to <0.05 mrem/hr by the tripping of the Booster chute detector and even more by the new tunnel detector. The Booster gallery is fine.

The 400 MeV Equipment Access

This area was examined at two locations. One behind the 12 foot concrete blocks that form the shielding door and a second on the berm just in front and above this door. The permissible level for an accident condition is 10 mrem/hr for one hour or 2.5 mrem/hr for normal operation. These detectors extrapolate to a maximum of ~4 mrem/hr respectively for loss produced in the 400 MeV area (see Runs 1 - 4, SSTUDE and F). In all cases the Booster tunnel detector would trip beam before levels of 0.2 mrad/hr were reached. For the other high case of 125 mrem/hr due to losses in the Lambertson (Run 5, SSTUDE) the area would be protected by the Linac high energy labyrinth entrance detector. During the run the Lambertson losses were adjusted so the labyrinth detector (200SCA), with its internal background, read 240 mrem/hr (228 mrem/hr on the MUX monitor), very close to tripping. It is set to trip beam at 200 mrem/hr. At this point the actual radiation above the access door was 0.1 mrem/hr and would not have gone much higher before a trip. The same could be said for everything in Run 5 since the Lambertson is just adjacent to the labyrinth tunnel opening to which the labyrinth detector is highly sensitive.

Although the gallery door of the labyrinth and the 400 MeV cable penetrations behind the labyrinth (Run 2, 3 and 5, SSTUD3 and 4) had high levels when extrapolated to full beam loss, their actual maximum levels were 2.15 and 2.0 mrem/hr when the labyrinth was near tripping. They would not exceed the permissible 10 mrem/hr before the labyrinth detector caused a trip.

The Lower Linac Utility Penetrations

In Run 7, losses were produced in module 7 (the highest energy module of the Upgrade Linac, 357 to 401 MeV), mostly at the beginning of the module. Unfortunately because of the loss the module constantly tripped off whenever beam was initiated and inhibited beam. This in itself would prevent excessive loss and radiation if it could be counted on. In order to take data the module rf had to be mistimed and the beam inhibit for this station disabled. Thus only 357 MeV could be achieved but this is the condition at the entrance to this module. It was also necessary to inhibit rf on all other modules downstream of where beam was being lost. Commissioning studies have so far shown all modules to spark and trip with significant beam loss.

For the lower utility penetrations there are permanent interlocked detectors at each "center" penetration for the old Linac (tanks 6, 7, 8 and 9 center) which previously tripped at 50 mrem/hr but are now set to 10 mrem/hr. The permissible level outside these penetrations for an accident condition is 100 mrem/hr for one hour due to posting and limited occupancy. For the losses produced in module 7 the highest radiation was observed at the tank 8 center penetration. All other penetrations and wall surfaces between the penetrations was less than tank 8 center and therefore would not exceed 10 mrem/hr (see Run 7, SSTUD0 - 7). Similarly, excessive losses in module 6 (313 MeV in) would have been prevented by the tank 8 center detector. The tank 9 upstream penetration would have been near 15 mrem/hr at this point but still well within its limit (see Run 8, SSTUD0 - 7). For the last case (see Run 9, SSTUD0 - 7) with losses in module 5 (271 MeV in), the tank 8 downstream penetration would have been at 25 mrem/hr, well below its limit, when a trip of 10 mrem/hr occurred at tank 8 center (see Run 9, SSTUD1 and 2). It should also be noted that the labyrinth detector (200SCA) was near its trip limit when the actual maximum dose was 5.15 mrem/hr (Run 9, SSTUD2) and would have prevented excessive radiation in all these cases except that this may be due to additional losses in or near the Lambertson magnet. Since these are the highest energy modules and the worse cases, the same protection would be true for the other penetrations further upstream which have the same geometry and protection.

The Upper Waveguide Penetrations

The same argument as given for the lower utility penetrations applies to the upper waveguide penetrations (Runs 7, 8 and 9, SSTUD8 - A). The waveguide penetrations have approximately the same level of radiation as the lower penetrations and can thus be protected by the lower detectors. The waveguide penetrations are presently a non-posted minimal occupancy area and have a permissible limit of 10 mrem/hr for one hour. This is achieved with the lower utility penetrations set to trip at 10 mrem/hr.

Conclusion

The areas of the Linac shielding that apply to upgrading the Linac to 400 MeV have been examined and some corrections have been made. The conclusions, necessary changes and possible future changes are:

1. Two interlocked detectors have been placed on the berm, one above and one downstream of the straight dump position to trip at

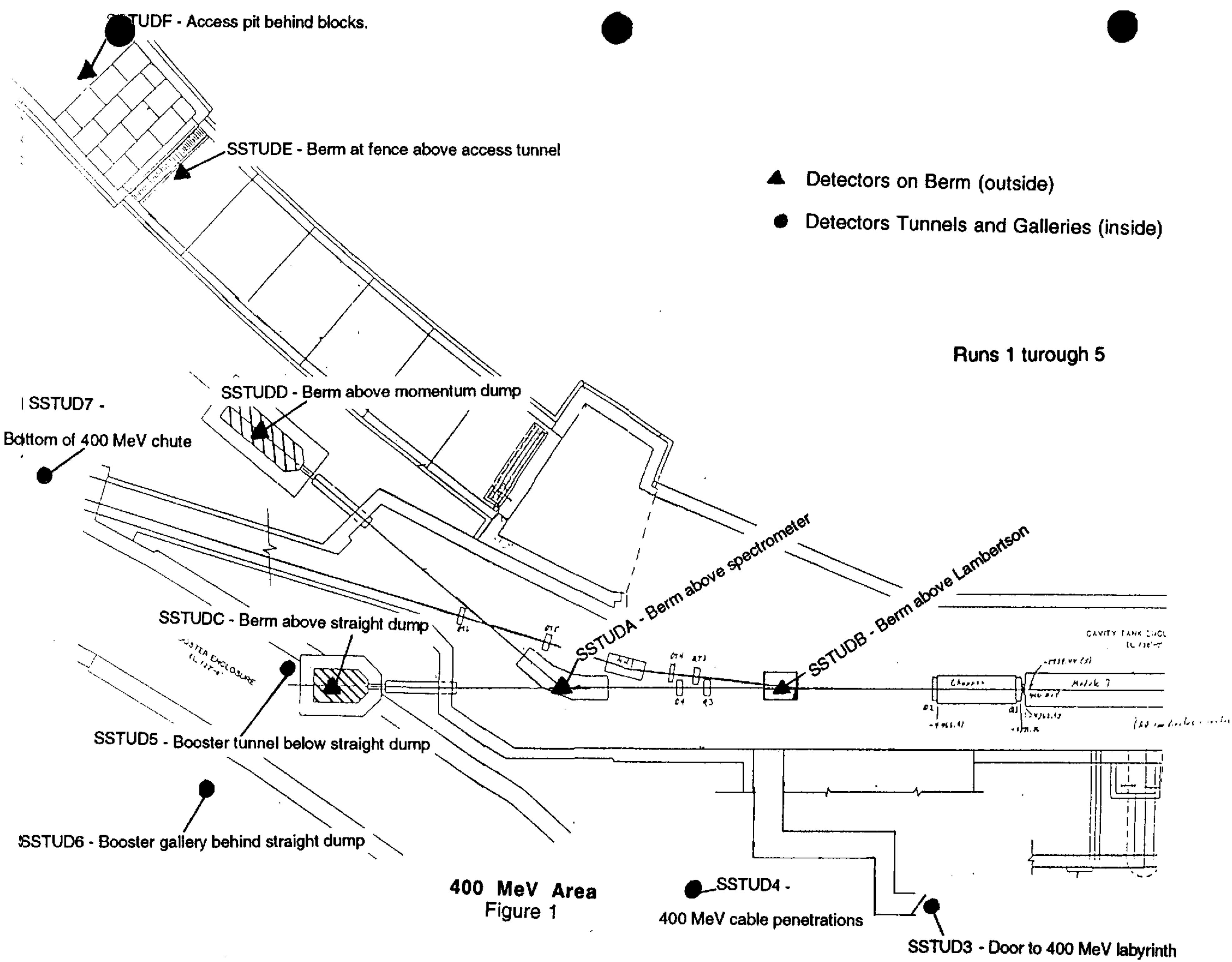
2.5 mrem/hr. This is where the soil slopes down and is the thinnest. Additional soil should be considered for over the straight dump area and re-tested. The interlocked detector on the berm over the straight dump must remain and be permanent until other measures are shown to be effective and approved.

2. An interlocked detector has been placed at the Booster tunnel position closest to the Linac straight dump set to trip at 10 mrem/hr. It is interlocked to Booster operation as is the Booster chute detector to be active whenever the Booster tunnel is accessed.

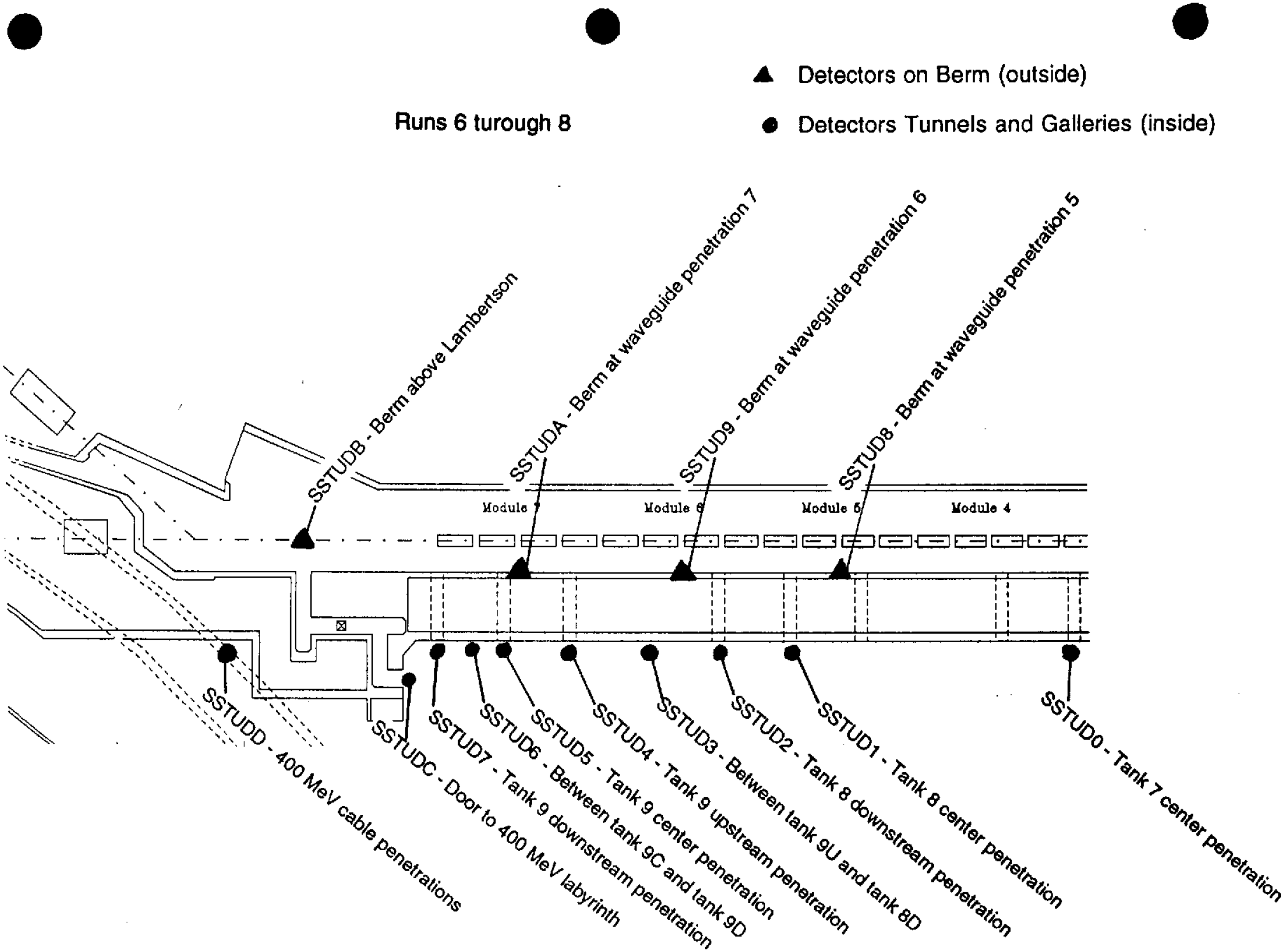
3. The trip level of tanks 6 to 9 lower utility penetration interlocked detectors have been lowered to 10 mrem/hr. They also protect the upper waveguide penetrations.

4. A "temporary" interlocked detector presently located behind the 12 feet of shielding blocks for the Linac equipment access can be removed.

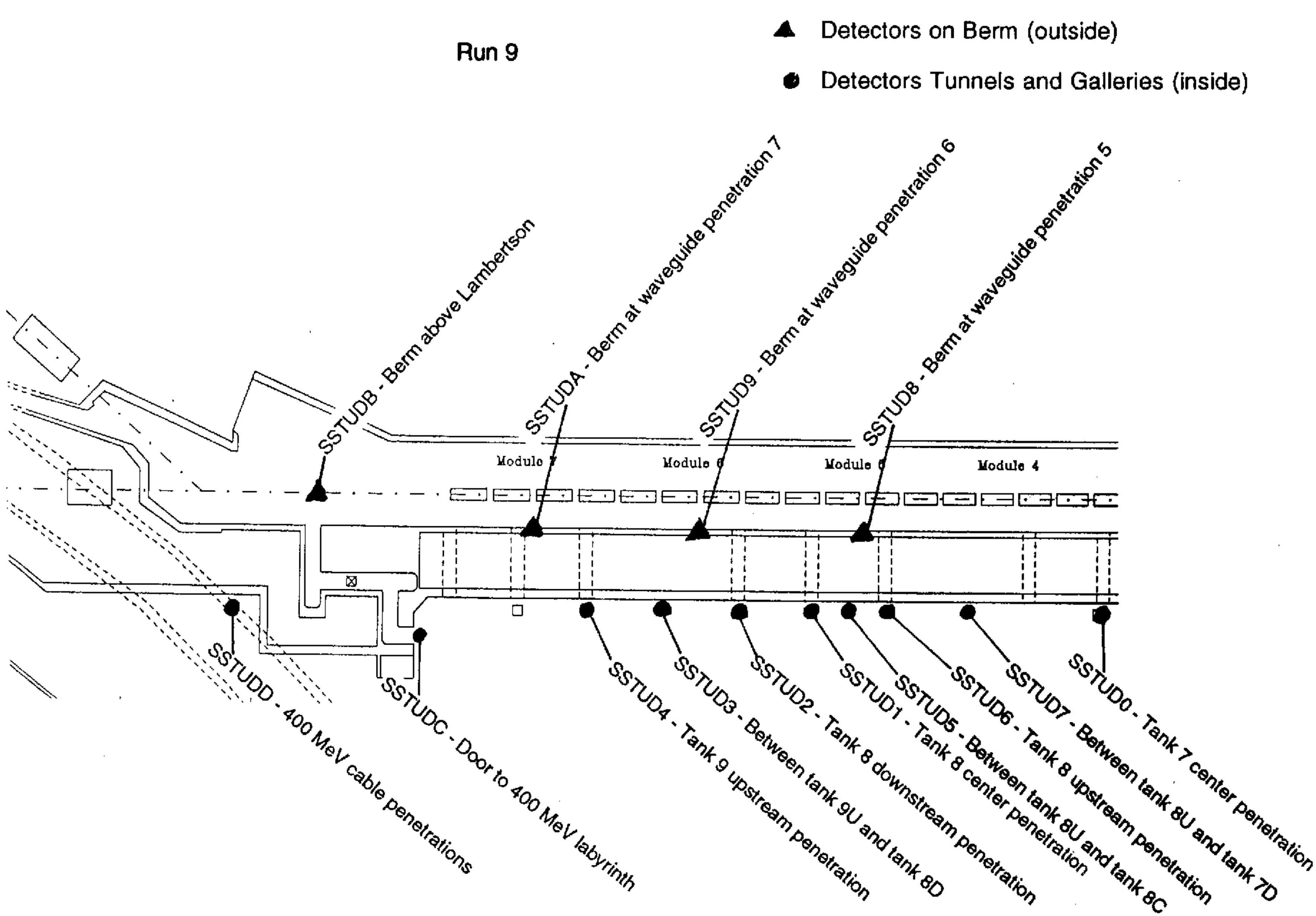
The other areas of the Linac, the low energy end to Tank 5, are not required to be reevaluated and have not. They were found to be appropriate during the original assessment and have not been modified.



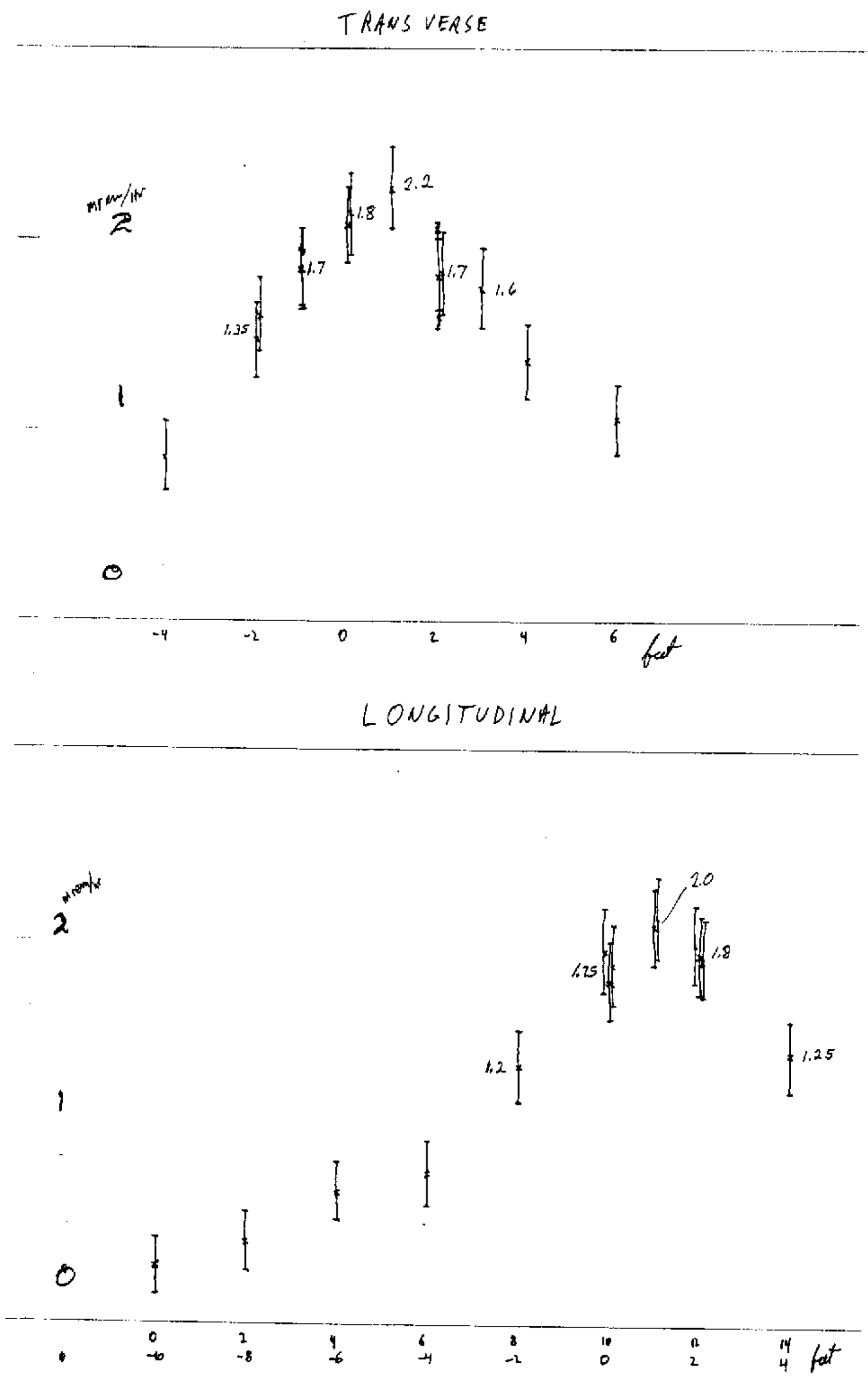
400 MeV Area
Figure 1



Linac Tunnel Area
Figure 2



Linac Tunnel Area
Figure 3



Longitudinal and Transverse Radiation Profiles above Straight Dump

Figure 4

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Console Location 4,          20-SEP-1993 [illegible]:55
PA:L49  H- SOURCE PARAMS

L49  TOROIDS                             SET     D/A    A/D   Eng-U ♦COPIES♦
-<FTP>+ *SA♦ X-A/D  X=TIME     Y=L:GR2MID,M SE28F ,L        ,L
COMMAND ---- Eng-U  I= 0       I= 0       ,-10       ,-10      ,-10
-< 1>+  One+ AUTO   F= 400     F= 1.2     , 10       , 10      , 10
source  750 kev timers  misc    750 2   TOROIDS spect   reset
 L:HTOR4       H  TOROID  4                         * 50.89  MA
 L:HTOR7       H  TOROID  7                         * 51.83  MA
 L:IHTOR2      BUNCHER IN TOROID                    *-49.73  MA
 L:TO1IN       T1 TOROID IN                         *-50.74  MA
 L:TO4IN       T4 TOROID IN                         *-6.805  MA
 L:TO4OUT      T4 TOROID OUT                        *-6.744  MA
 L:TO5OUT      T5 TOROID OUT                        * 6.726  MA  ← Beam From DT Linac
 L:D0TOR       TRN SECT OUT TORD                    * 6.604   MA
 L:D1TOR       MODULE 1 OUT TORD                    * 6.427   MA
 L:D2TOR       MODULE 2 OUT TORD                    * 6.299   MA
 L:D3TOR       MODULE 3 OUT TORD                    * 6.244   MA
 L:D4TOR       MODULE 4 OUT TORD                    * 6.36    MA
 L:D5TOR       MODULE 5 OUT TORD                    * 6.198   MA
 L:D6TOR       MODULE 6 OUT TORD                    * 6.015   MA
 L:D73TOR      M7 TOROID LINACEND                   * 6.189   MA
 L:D7TOR       MODULE 7 OUT TORO                    * 6.284   MA ← Beam From SCS Linac
 L:TORSI       E TOR SPECT IN                       * 6.204  MA
 L:TORSD       E TOR ST DUMP                        *-6.226  MA ← Beam To Straight
                                                                    Dump
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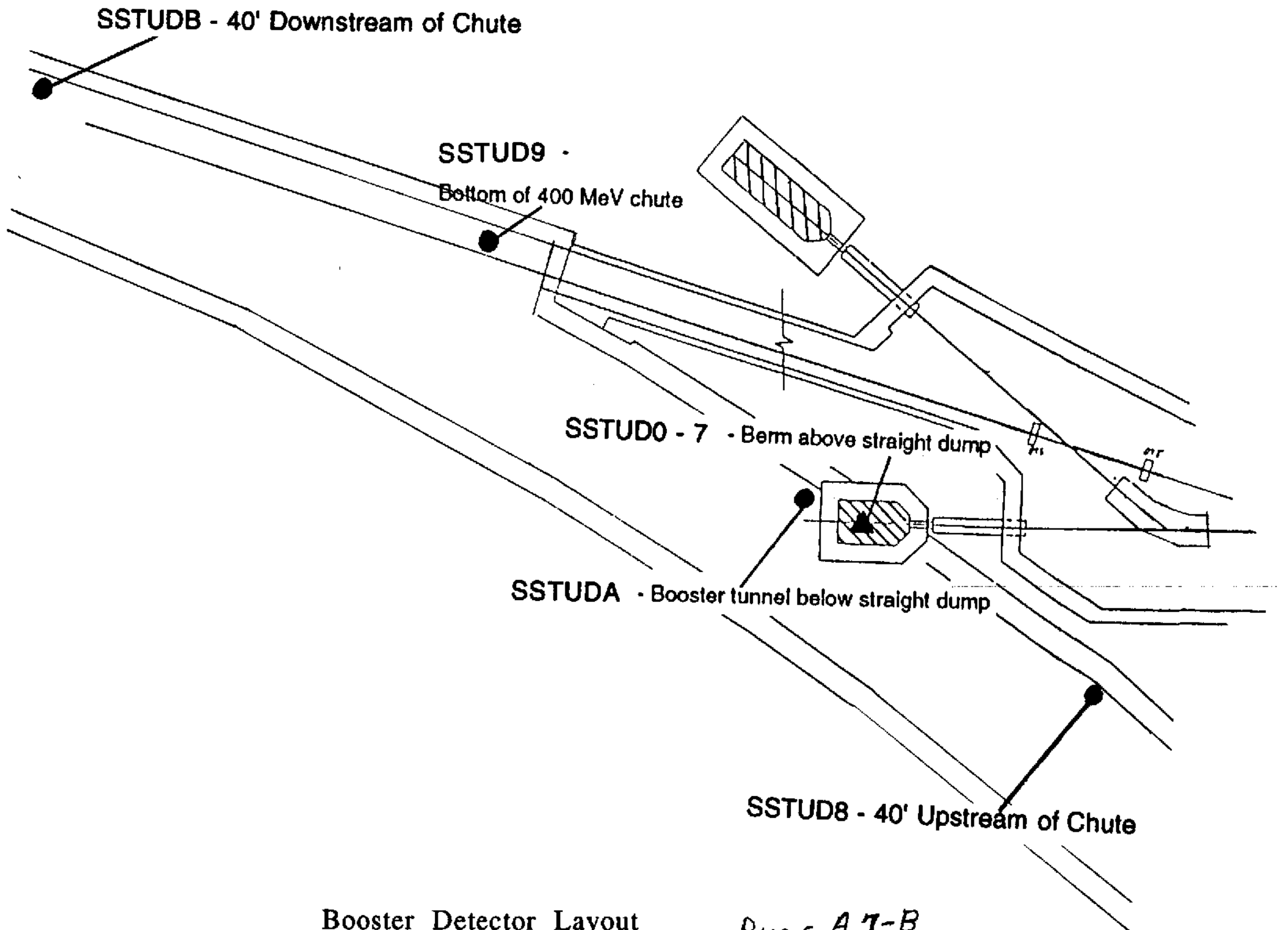
~ 100% Transmission To
Straight Dump

Toroid Readings for Runs A, 1 - 3

Figure 5



Booster Detector Layout

Runs A 7-B

Figure 6

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3											
4	Background	For losses in 400 MeV Area									
5			1 count equal	2.50E-06	rem						
6		Counts	Multipier	Time (sec)		rem/sec	error				
7	SSTUD0	44.09	1.00	600.00		1.84E-07	2.77E-08		Tank 9 center penetration		
8	SSTUD1	40.91	1.00	600.00		1.70E-07	2.67E-08		Between Tank 9 C and Tank 9 D		
9	SSTUD2	47.16	1.00	600.00		1.97E-07	2.86E-08		Tank 9 Down stream penetration		
10	SSTUD3	40.06	1.00	600.00		1.67E-07	2.64E-08		Door to 400 MeV Labyrinth		
11	SSTUD4	46.22	1.00	600.00		1.93E-07	2.83E-08		400 MeV cable penetrations		
12	SSTUD5	88.06	1.00	600.00		3.67E-07	3.91E-08		Booster tunnel below st. dump		
13	SSTUD6	43.06	1.00	600.00		1.79E-07	2.73E-08		Booster gallery behind st. dump		
14	SSTUD7	47.22	1.00	600.00		1.97E-07	2.86E-08		Bottom of 400 MeV Chute		
15	SSTUD8	35.34	1.00	600.00		1.47E-07	2.48E-08		Berm at Waveguide pen. 6		
16	SSTUD9	39.25	1.00	600.00		1.64E-07	2.61E-08		Berm at Waveguide pen. 7		
17	SSTUDA	33.06	1.00	600.00		1.38E-07	2.40E-08		Berm above spectrometer		
18	SSTUDB	36.88	1.00	600.00		1.54E-07	2.53E-08		Berm above lambertson		
19	SSTUDC	40.03	1.00	600.00		1.67E-07	2.64E-08		Berm above straight dump		
20	SSTUDD	34.41	1.00	600.00		1.43E-07	2.44E-08		Berm above momentum dump		
21	SSTUDE	42.78	1.00	600.00		1.78E-07	2.73E-08		Berm at fence above access tunnel		
22	SSTUDF	48.63	1.00	600.00		2.03E-07	2.91E-08		Access pit behind blocks		
23											
24											
25											
26											
27											
28											

	A	B	C	D	E	F	G	H	I	J	K
29											
30					Current lost =		Pulse length =		Rep Rate =		
31	Run 1	Beam to Momentum Dump			2.40	mA	7.00	microsec	15.00	Hz	
32											
33						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
34		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
35	SSTUD0	57.47	1.00	600.00	780.00	0.00	0.17	0.14	Tank 9 center penetration		
36	SSTUD1	54.28	1.00	600.00	780.00	0.02	0.17	1.03	Between Tank 9 C and Tank 9 D		
37	SSTUD2	67.63	1.00	600.00	780.00	0.09	0.18	5.93	Tank 9 Down stream penetration		
38	SSTUD3	127.10	1.00	600.00	780.00	1.13	0.21	70.33	Door to 400 MeV Labyrinth		
39	SSTUD4	149.70	1.00	600.00	780.00	1.34	0.23	84.01	400 MeV cable penetrations		
40	SSTUD5	408.40	1.00	600.00	780.00	4.41	0.35	275.55	Booster tunnel below st. dump		
41	SSTUD6	56.44	1.00	600.00	780.00	0.01	0.17	0.43	Booster gallery behind st. dump		
42	SSTUD7	72.69	1.00	600.00	780.00	0.17	0.19	10.60	Bottom of 400 MeV Chute		
43	SSTUD8	45.94	1.00	600.00	780.00	0.00	0.15	0.00	Berm at Waveguide pen. 6		
44	SSTUD9	54.47	1.00	600.00	780.00	0.05	0.16	3.23	Berm at Waveguide pen. 7		
45	SSTUDA	55.25	1.00	600.00	780.00	0.18	0.16	11.51	Berm above spectrometer		
46	SSTUDB	53.59	1.00	600.00	780.00	0.08	0.16	5.29	Berm above lambertson		
47	SSTUDC	93.00	1.00	600.00	780.00	0.61	0.19	38.40	Berm above straight dump		
48	SSTUDD	44.75	1.00	600.00	780.00	0.00	0.15	0.02	Berm above momentum dump		
49	SSTUDE	59.00	1.00	600.00	780.00	0.05	0.17	3.17	Berm at fence above access tunnel		
50	SSTUDF	66.72	1.00	600.00	780.00	0.05	0.18	3.28	Access pit behind blocks		
51											
52											
53											
54											
55											
56											

	A	B	C	D	E	F	G	H	I	J	K
57											
58					Current lost =		Pulse length=		Rep Rate =		
59	Run 2	Beam lost above chute			1.92	mA	7.00	microsec	15.00	Hz	
60											
61						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
62		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
63	SSTUD0	41.03	1.00	360.00	540.00	0.03	0.22	2.63	Tank 9 center penetration		
64	SSTUD1	37.84	1.00	360.00	540.00	0.03	0.21	1.99	Between Tank 9 C and Tank 9 D		
65	SSTUD2	47.16	1.00	360.00	540.00	0.12	0.23	9.21	Tank 9 Down stream penetration		
66	SSTUD3	92.34	1.00	360.00	540.00	1.41	0.28	109.93	Door to 400 MeV Labyrinth		
67	SSTUD4	106.60	1.00	360.00	540.00	1.63	0.30	126.96	400 MeV cable penetrations		
68	SSTUD5	326.60	1.00	360.00	540.00	6.18	0.50	483.10	Booster tunnel below st. dump		
69	SSTUD6	39.59	1.00	360.00	540.00	0.02	0.22	1.63	Booster gallery behind st. dump		
70	SSTUD7	213.20	1.00	360.00	540.00	4.27	0.40	333.40	Bottom of 400 MeV Chute		
71	SSTUD8	34.41	1.00	360.00	540.00	0.07	0.20	5.09	Berm at Waveguide pen. 6		
72	SSTUD9	35.03	1.00	360.00	540.00	-0.01	0.20	-0.58	Berm at Waveguide pen. 7		
73	SSTUDA	59.22	1.00	360.00	540.00	0.74	0.23	57.55	Berm above spectrometer		
74	SSTUDB	37.00	1.00	360.00	540.00	0.10	0.20	7.44	Berm above lambertson		
75	SSTUDC	117.80	1.00	360.00	540.00	2.04	0.31	159.71	Berm above straight dump		
76	SSTUDD	49.88	1.00	360.00	540.00	0.47	0.22	36.94	Berm above momentum dump		
77	SSTUDE	40.50	1.00	360.00	540.00	0.05	0.22	3.90	Berm at fence above access tunnel		
78	SSTUDF	45.34	1.00	360.00	540.00	0.04	0.23	3.07	Access pit behind blocks		
79											
80		200SCA read 191 mr/hr									
81											
82											
83											
84											

	A	B	C	D	E	F	G	H	I	J	K
85											
86					Current lost =		Pulse length =		Rep Rate =		
87	Run 3	Beam lost in Spectrometer			4.05	mA	7.00	microsec	15.00	Hz	
88											
89						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
90		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
91	SSTUD0	40.00	1.00	360.00	540.00	0.01	0.22	0.30	Tank 9 center penetration		
92	SSTUD1	38.94	1.00	360.00	540.00	0.05	0.21	1.96	Between Tank 9 C and Tank 9 D		
93	SSTUD2	49.28	1.00	360.00	540.00	0.17	0.23	6.33	Tank 9 Down stream penetration		
94	SSTUD3	115.90	1.00	360.00	540.00	2.00	0.30	73.93	Door to 400 MeV Labyrinth		
95	SSTUD4	120.80	1.00	360.00	540.00	1.98	0.31	73.34	400 MeV cable penetrations		
96	SSTUD5	439.20	1.00	360.00	540.00	9.00	0.56	333.28	Booster tunnel below st. dump		
97	SSTUD6	39.28	1.00	360.00	540.00	0.01	0.22	0.49	Booster gallery behind st. dump		
98	SSTUD7	48.19	1.00	360.00	540.00	0.14	0.23	5.27	Bottom of 400 MeV Chute		
99	SSTUD8	35.97	1.00	360.00	540.00	0.10	0.20	3.86	Berm at Waveguide pen. 6		
100	SSTUD9	40.47	1.00	360.00	540.00	0.13	0.21	4.76	Berm at Waveguide pen. 7		
101	SSTUDA	60.50	1.00	360.00	540.00	0.77	0.23	28.47	Berm above spectrometer		
102	SSTUDB	37.34	1.00	360.00	540.00	0.10	0.20	3.84	Berm above lambertson		
103	SSTUDC	112.80	1.00	360.00	540.00	1.92	0.30	71.09	Berm above straight dump		
104	SSTUDD	40.06	1.00	360.00	540.00	0.23	0.21	8.42	Berm above momentum dump		
105	SSTUDE	40.06	1.00	360.00	540.00	0.04	0.22	1.44	Berm at fence above access tunnel		
106	SSTUDF	44.69	1.00	360.00	540.00	0.02	0.23	0.85	Access pit behind blocks		
107											
108		200SCA read 220 mr/hr									
109											
110											
111											
112											

	A	B	C	D	E	F	G	H	I	J	K
113											
114					Current lost =		Pulse length =		Rep Rate =		
115	Run 4	Beam to Straight Dump			4.11	mA	7.00	microsec	15.00	Hz	
116											
117						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
118		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
119	SSTUD0	57.44	1.00	600.00	720.00	0.07	0.16	2.48	Tank 9 center penetration		
120	SSTUD1	54.72	1.00	600.00	720.00	0.08	0.16	3.08	Between Tank 9 C and Tank 9 D		
121	SSTUD2	65.63	1.00	600.00	720.00	0.14	0.17	4.95	Tank 9 Down stream penetration		
122	SSTUD3	68.66	1.00	600.00	720.00	0.31	0.17	11.27	Door to 400 MeV Labyrinth		
123	SSTUD4	66.63	1.00	600.00	720.00	0.17	0.17	6.11	400 MeV cable penetrations		
124	SSTUD5	655.30	1.00	600.00	720.00	8.24	0.42	300.89	Booster tunnel below st. dump		
125	SSTUD6	55.38	1.00	600.00	720.00	0.06	0.16	2.03	Booster gallery behind st. dump		
126	SSTUD7	64.66	1.00	600.00	720.00	0.12	0.17	4.38	Bottom of 400 MeV Chute		
127	SSTUD8	49.69	1.00	600.00	720.00	0.11	0.15	3.99	Berm at Waveguide pen. 6		
128	SSTUD9	56.41	1.00	600.00	720.00	0.14	0.16	5.10	Berm at Waveguide pen. 7		
129	SSTUDA	62.72	1.00	600.00	720.00	0.35	0.16	12.62	Berm above spectrometer		
130	SSTUDB	54.56	1.00	600.00	720.00	0.15	0.16	5.64	Berm above lambertson		
131	SSTUDC	115.60	1.00	600.00	720.00	1.01	0.20	36.99	Berm above straight dump		
132	SSTUDD	57.13	1.00	600.00	720.00	0.24	0.15	8.67	Berm above momentum dump		
133	SSTUDE	58.22	1.00	600.00	720.00	0.10	0.16	3.77	Berm at fence above access tunnel		
134	SSTUDF	65.59	1.00	600.00	720.00	0.11	0.17	3.96	Access pit behind blocks		
135											
136											
137											
138											
139											
140											

113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140

	A	B	C	D	E	F	G	H	I	J	K
141											
142					Current lost =		Pulse length =		Rep Rate =		
143	Run 5	Loss at entrance to Lambertson			0.83	mA	1.00	microsec	15.00	Hz	
144											
145						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
146		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
147	SSTUD0	100.40	1.00	1200.00	1380.00	-0.01	0.14	-9.61	Tank 9 center penetration		
148	SSTUD1	97.28	1.00	1200.00	1380.00	0.02	0.13	30.42	Between Tank 9 C and Tank 9 D		
149	SSTUD2	116.80	1.00	1200.00	1380.00	0.06	0.14	79.53	Tank 9 Down stream penetration		
150	SSTUD3	379.40	1.00	1200.00	1380.00	2.15	0.18	2742.05	Door to 400 MeV Labyrinth		
151	SSTUD4	200.90	1.00	1200.00	1380.00	0.71	0.16	902.94	400 MeV cable penetrations		
152	SSTUD5	357.20	1.00	1200.00	1380.00	1.16	0.22	1476.32	Booster tunnel below st. dump		
153	SSTUD6	99.41	1.00	1200.00	1380.00	0.00	0.14	3.55	Booster gallery behind st. dump		
154	SSTUD7	111.10	1.00	1200.00	1380.00	0.02	0.14	23.81	Bottom of 400 MeV Chute		
155	SSTUD8	98.00	1.00	1200.00	1380.00	0.13	0.13	159.58	Berm at Waveguide pen. 6		
156	SSTUD9	106.80	1.00	1200.00	1380.00	0.12	0.13	157.74	Berm at Waveguide pen. 7		
157	SSTUDA	159.30	1.00	1200.00	1380.00	0.62	0.14	794.77	Berm above spectrometer		
158	SSTUDB	95.31	1.00	1200.00	1380.00	0.08	0.13	100.09	Berm above lambertson		
159	SSTUDC	118.50	1.00	1200.00	1380.00	0.20	0.14	252.30	Berm above straight dump		
160	SSTUDD	96.94	1.00	1200.00	1380.00	0.13	0.13	169.88	Berm above momentum dump		
161	SSTUDE	111.50	1.00	1200.00	1380.00	0.10	0.14	125.10	Berm at fence above access tunnel		
162	SSTUDF	110.70	1.00	1200.00	1380.00	-0.01	0.14	-10.97	Access pit behind blocks		
163											
164		200SCA read 240mr/hr (MUX was 228)									
165											
166											
167											
168											

	A	B	C	D	E	F	G	H	I	J	K
169											
170											
171											
172	Background	Losses in High Energy end of SCC Linac									
173			1 count equal	2.50E-06	rem						
174		Counts	Multipier	Time (sec)		rem/sec	error				
175	SSTUD0	26.69	1.00	600.00		1.11E-07	2.15E-08		Tank 7 center penetration		
176	SSTUD1	50.28	1.00	600.00		2.10E-07	2.95E-08		Tank 8 center penetration		
177	SSTUD2	33.91	1.00	600.00		1.41E-07	2.43E-08		Tank 8 downstream penetration		
178	SSTUD3	49.22	1.00	600.00		2.05E-07	2.92E-08		Between Tank 9 U and Tank 8 D		
179	SSTUD4	45.78	1.00	600.00		1.91E-07	2.82E-08		Tank 9 upstream penetration		
180	SSTUD5	42.97	1.00	600.00		1.79E-07	2.73E-08		Tank 9 center penetration		
181	SSTUD6	43.13	1.00	600.00		1.80E-07	2.74E-08		Between Tank 9 C and Tank 9 D		
182	SSTUD7	47.03	1.00	600.00		1.96E-07	2.86E-08		Tank 9 downstream penetration		
183	SSTUD8	44.50	1.00	600.00		1.85E-07	2.78E-08		Berm at Waveguide pen. 5		
184	SSTUD9	41.97	1.00	600.00		1.75E-07	2.70E-08		Berm at Waveguide pen. 6		
185	SSTUDA	46.28	1.00	600.00		1.93E-07	2.83E-08		Berm at Waveguide pen. 7		
186	SSTUDB	40.81	1.00	600.00		1.70E-07	2.66E-08		Berm above lambertson		
187	SSTUDC	39.91	1.00	600.00		1.66E-07	2.63E-08		Door to 400 MeV Labyrinth		
188	SSTUDD	43.88	1.00	600.00		1.83E-07	2.76E-08		400 Mev cable penetrations		
189	SSTUDE	47.47	1.00	600.00		1.98E-07	2.87E-08		Bottom of 400 MeV chute		
190	SSTUDF	86.00	1.00	600.00		3.58E-07	3.86E-08		Booster tunnel below st. dump		
191											
192											
193											
194											
195											
196											

	A	B	C	D	E	F	G	H	I	J	K
197											
198					Current lost =		Pulse length =		Rep Rate =		
199	Run 6	Loss at entrance to Lambertson			0.83	mA	1.00	microsec	15.00	Hz	
200											
201						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
202		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
203	SSTUD0	50.25	1.00	975.00	1095.00	0.01	0.11	18.10	Tank 7 center penetration		
204	SSTUD1	96.31	1.00	975.00	1095.00	0.04	0.15	53.44	Tank 8 center penetration		
205	SSTUD2	66.56	1.00	975.00	1095.00	0.04	0.12	54.91	Tank 8 downstream penetration		
206	SSTUD3	96.41	1.00	975.00	1095.00	0.06	0.15	77.34	Between Tank 9 U and Tank 8 D		
207	SSTUD4	85.03	1.00	975.00	1095.00	0.01	0.14	17.41	Tank 9 upstream penetration		
208	SSTUD5	78.78	1.00	975.00	1095.00	0.00	0.14	4.23	Tank 9 center penetration		
209	SSTUD6	77.97	1.00	975.00	1095.00	-0.01	0.14	-8.72	Between Tank 9 C and Tank 9 D		
210	SSTUD7	92.28	1.00	975.00	1095.00	0.06	0.15	75.78	Tank 9 downstream penetration		
211	SSTUD8	80.84	1.00	975.00	1095.00	0.00	0.14	-4.38	Berm at Waveguide pen. 5		
212	SSTUD9	76.63	1.00	975.00	1095.00	0.00	0.14	0.41	Berm at Waveguide pen. 6		
213	SSTUDA	85.50	1.00	975.00	1095.00	0.01	0.14	12.21	Berm at Waveguide pen. 7		
214	SSTUDB	76.97	1.00	975.00	1095.00	0.02	0.13	29.27	Berm above lambertson		
215	SSTUDC	300.40	1.00	975.00	1095.00	2.10	0.19	2673.48	Door to 400 MeV Labyrinth		
216	SSTUDD	153.70	1.00	975.00	1095.00	0.68	0.16	864.89	400 Mev cable penetrations		
217	SSTUDE	87.84	1.00	975.00	1095.00	0.01	0.14	14.18	Bottom of 400 MeV chute		
218	SSTUDF	278.90	1.00	975.00	1095.00	1.13	0.22	1432.70	Booster tunnel below st. dump		
219											
220		200SCA read 248 mr/hr (MUX was 230)									
221											
222											
223											
224											

	A	B	C	D	E	F	G	H	I	J	K
225											
226					Current lost =		Pulse length =		Rep Rate =		
227	Run 7	Loss at entrance to Module 7			0.70	mA	2.00	microsec	15.00	Hz	
228											
229						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
230		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
231	SSTUD0	64.59	1.00	1200.00	1380.00	0.02	0.11	18.02	Tank 7 center penetration		
232	SSTUD1	199.40	1.00	1200.00	1380.00	0.63	0.16	471.13	Tank 8 center penetration		
233	SSTUD2	152.70	1.00	1200.00	1380.00	0.56	0.14	420.23	Tank 8 downstream penetration		
234	SSTUD3	174.30	1.00	1200.00	1380.00	0.46	0.16	343.65	Between Tank 9 U and Tank 8 D		
235	SSTUD4	130.30	1.00	1200.00	1380.00	0.19	0.14	140.66	Tank 9 upstream penetration		
236	SSTUD5	136.10	1.00	1200.00	1380.00	0.28	0.14	209.64	Tank 9 center penetration		
237	SSTUD6	123.00	1.00	1200.00	1380.00	0.18	0.14	133.88	Between Tank 9 C and Tank 9 D		
238	SSTUD7	208.10	1.00	1200.00	1380.00	0.75	0.16	562.11	Tank 9 downstream penetration		
239	SSTUD8	107.70	1.00	1200.00	1380.00	0.04	0.14	30.09	Berm at Waveguide pen. 5		
240	SSTUD9	104.30	1.00	1200.00	1380.00	0.06	0.14	43.70	Berm at Waveguide pen. 6		
241	SSTUDA	132.20	1.00	1200.00	1380.00	0.19	0.15	144.88	Berm at Waveguide pen. 7		
242	SSTUDB	95.56	1.00	1200.00	1380.00	0.01	0.13	9.55	Berm above lambertson		
243	SSTUDC	338.00	1.00	1200.00	1380.00	1.85	0.18	1384.91	Door to 400 MeV Labyrinth		
244	SSTUDD	185.30	1.00	1200.00	1380.00	0.63	0.15	474.62	400 Mev cable penetrations		
245	SSTUDE	150.40	1.00	1200.00	1380.00	0.31	0.15	231.86	Bottom of 400 MeV chute		
246	SSTUDF	271.50	1.00	1200.00	1380.00	0.55	0.20	414.56	Booster tunnel below st. dump		
247											
248		200SCA read 226 mr/hr (MUX was 212)									
249											
250											
251											
252											

	A	B	C	D	E	F	G	H	I	J	K
253											
254					Current lost =		Pulse length =		Rep Rate =		
255	Run 8	Loss at entrance to Module 6			1.50	mA	2.00	microsec	15.00	Hz	
256											
257						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
258		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
259	SSTUD0	64.66	1.00	1200.00	1380.00	0.02	0.11	8.59	Tank 7 center penetration		
260	SSTUD1	172.10	1.00	1200.00	1380.00	0.42	0.16	148.20	Tank 8 center penetration		
261	SSTUD2	149.60	1.00	1200.00	1380.00	0.54	0.14	187.97	Tank 8 downstream penetration		
262	SSTUD3	167.10	1.00	1200.00	1380.00	0.40	0.16	141.47	Between Tank 9 U and Tank 8 D		
263	SSTUD4	214.30	1.00	1200.00	1380.00	0.82	0.16	286.14	Tank 9 upstream penetration		
264	SSTUD5	105.50	1.00	1200.00	1380.00	0.05	0.14	17.51	Tank 9 center penetration		
265	SSTUD6	102.40	1.00	1200.00	1380.00	0.02	0.14	8.40	Between Tank 9 C and Tank 9 D		
266	SSTUD7	127.10	1.00	1200.00	1380.00	0.14	0.15	49.69	Tank 9 downstream penetration		
267	SSTUD8	111.90	1.00	1200.00	1380.00	0.07	0.14	25.07	Berm at Waveguide pen. 5		
268	SSTUD9	144.80	1.00	1200.00	1380.00	0.36	0.14	126.71	Berm at Waveguide pen. 6		
269	SSTUDA	116.10	1.00	1200.00	1380.00	0.07	0.14	25.35	Berm at Waveguide pen. 7		
270	SSTUDB	95.41	1.00	1200.00	1380.00	0.01	0.13	4.06	Berm above lambertson		
271	SSTUDC	385.20	1.00	1200.00	1380.00	2.20	0.18	770.19	Door to 400 MeV Labyrinth		
272	SSTUDD	177.40	1.00	1200.00	1380.00	0.57	0.15	200.75	400 Mev cable penetrations		
273	SSTUDE	111.20	1.00	1200.00	1380.00	0.02	0.14	5.30	Bottom of 400 MeV chute		
274	SSTUDF	223.20	1.00	1200.00	1380.00	0.19	0.20	66.68	Booster tunnel below st. dump		
275											
276		200SCA read 244 mr/hr (MUX was 231)									
277											
278											
279											
280											

	A	B	C	D	E	F	G	H	I	J	K
281											
282											
283											
284	Background	Losses in High Energy end of SCC Linac									
285			1 count equal	2.50E-06	rem						
286		Counts	Multipier	Time (sec)		rem/sec	error				
287	SSTUD0	42.03	1.00	900.00		1.17E-07	1.80E-08		Tank 7 center penetration		
288	SSTUD1	81.97	1.00	900.00		2.28E-07	2.51E-08		Tank 8 center penetration		
289	SSTUD2	58.47	1.00	900.00		1.62E-07	2.12E-08		Tank 8 downstream penetration		
290	SSTUD3	80.03	1.00	900.00		2.22E-07	2.48E-08		Between Tank 9 U and Tank 8 D		
291	SSTUD4	69.72	1.00	900.00		1.94E-07	2.32E-08		Tank 9 upstream penetration		
292	SSTUD5	81.59	1.00	900.00		2.27E-07	2.51E-08		Between Tank 8 U and Tank 8 C		
293	SSTUD6	113.80	1.00	900.00		3.16E-07	2.96E-08		Tank 8 upstream penetration		
294	SSTUD7	70.69	1.00	900.00		1.96E-07	2.34E-08		Between Tank 8 U and Tank 7 D		
295	SSTUD8	72.75	1.00	900.00		2.02E-07	2.37E-08		Berm at Waveguide pen. 5		
296	SSTUD9	69.16	1.00	900.00		1.92E-07	2.31E-08		Berm at Waveguide pen. 6		
297	SSTUDA	72.88	1.00	900.00		2.02E-07	2.37E-08		Berm at Waveguide pen. 7		
298	SSTUDB	58.78	1.00	900.00		1.63E-07	2.13E-08		Berm above lambertson		
299	SSTUDC	61.13	1.00	900.00		1.70E-07	2.17E-08		Door to 400 MeV Labyrinth		
300	SSTUDD	69.41	1.00	900.00		1.93E-07	2.31E-08		400 Mev cable penetrations		
301											
302											
303											
304											
305											
306											
307											
308											

	A	B	C	D	E	F	G	H	I	J	K
309											
310					Current lost =		Pulse length =		Rep Rate =		
311	Run 9	Loss at entrance to Module 5			2.50	mA	7.00	microsec	15.00	Hz	
312											
313						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
314		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
315	SSTUD0	52.25	1.00	900.00	1110.00	0.00	0.11	0.25	Tank 7 center penetration		
316	SSTUD1	305.30	1.00	900.00	1110.00	2.04	0.21	122.52	Tank 8 center penetration		
317	SSTUD2	587.40	1.00	900.00	1110.00	5.15	0.26	309.17	Tank 8 downstream penetration		
318	SSTUD3	168.10	1.00	900.00	1110.00	0.69	0.17	41.64	Between Tank 9 U and Tank 8 D		
319	SSTUD4	203.90	1.00	900.00	1110.00	1.18	0.18	70.75	Tank 9 upstream penetration		
320	SSTUD5	222.10	1.00	900.00	1110.00	1.21	0.19	72.88	Between Tank 8 U and Tank 8 C		
321	SSTUD6	398.60	1.00	900.00	1110.00	2.58	0.24	154.95	Tank 8 upstream penetration		
322	SSTUD7	96.31	1.00	900.00	1110.00	0.09	0.14	5.48	Between Tank 8 U and Tank 7 D		
323	SSTUD8	128.80	1.00	900.00	1110.00	0.39	0.15	23.45	Berm at Waveguide pen. 5		
324	SSTUD9	97.38	1.00	900.00	1110.00	0.12	0.14	7.25	Berm at Waveguide pen. 6		
325	SSTUDA	93.09	1.00	900.00	1110.00	0.03	0.14	1.92	Berm at Waveguide pen. 7		
326	SSTUDB	75.25	1.00	900.00	1110.00	0.03	0.13	1.65	Berm above lambertson		
327	SSTUDC	264.20	1.00	900.00	1110.00	1.89	0.19	113.28	Door to 400 MeV Labyrinth		
328	SSTUDD	207.30	1.00	900.00	1110.00	1.22	0.18	73.02	400 Mev cable penetrations		
329											
330		200SCA read 224 mr/hr (MUX was 208)									

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3											
4	Background	A									
5			1 count equal	2.50E-06	rem						
6		Counts	Multipier	Time (sec)		rem/sec	error				
7	SSTUD0	43.06	1.00	600.00		1.79E-07	2.73E-08	10 feet usptream			
8	SSTUD1	43.03	1.00	600.00		1.79E-07	2.73E-08	8 feet upstream			
9	SSTUD2	28.75	1.00	600.00		1.20E-07	2.23E-08	6 feet upstream			
10	SSTUD3	45.03	1.00	600.00		1.88E-07	2.80E-08	4 feet upstream			
11	SSTUD4	36.91	1.00	600.00		1.54E-07	2.53E-08	2 feet upstream			
12	SSTUD5	44.00	1.00	600.00		1.83E-07	2.76E-08	assumed position of dump (doghouse)			
13	SSTUD6	32.84	1.00	600.00		1.37E-07	2.39E-08	2 feet downstream			
14	SSTUD7	34.78	1.00	600.00		1.45E-07	2.46E-08	4 feet downstream			
15	SSTUD8	62.22	1.00	600.00		2.59E-07	3.29E-08	Booster tunnel - 40' upstream of chute			
16	SSTUD9	109.50	1.00	600.00		4.56E-07	4.36E-08	Booster tunnel - base of chute			
17	SSTUDA	96.13	1.00	600.00		4.01E-07	4.09E-08	Booster tunnel - below dump #1			
18	SSTUDB	79.81	1.00	600.00		3.33E-07	3.72E-08	Booster tunnel - 40' downstream of chute			
19	SSTUDC	0.00	1.00	1.00		0.00E+00	0.00E+00				
20	SSTUDD	0.00	1.00	1.00		0.00E+00	0.00E+00				
21	SSTUDE	0.00	1.00	1.00		0.00E+00	0.00E+00				
22	SSTUDF	0.00	1.00	1.00		0.00E+00	0.00E+00				
23											
24											
25											
26											
27											
28											

	A	B	C	D	E	F	G	H	I	J	K
29											
30					Current lost =		Pulse length =		Rep Rate =		
31	Run 1 A	Longitudinal Run			6.20	mA	7.00	microsec	15.00	Hz	
32											
33						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
34		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
35	SSTUD0	54.31	1.00	600.00	720.00	0.04	0.16	0.96	10 feet usptream		
36	SSTUD1	63.50	1.00	600.00	720.00	0.18	0.17	4.31	8 feet upstream		
37	SSTUD2	65.59	1.00	600.00	720.00	0.47	0.16	11.28	6 feet upstream		
38	SSTUD3	92.19	1.00	600.00	720.00	0.57	0.19	13.85	4 feet upstream		
39	SSTUD4	123.00	1.00	600.00	720.00	1.18	0.20	28.56	2 feet upstream		
40	SSTUD5	163.60	1.00	600.00	720.00	1.66	0.23	40.21	assumed position of dump (doghouse)		
41	SSTUD6	159.80	1.00	600.00	720.00	1.81	0.22	43.69	2 feet downstream		
42	SSTUD7	124.70	1.00	600.00	720.00	1.24	0.20	30.11	4 feet downstream		
43	SSTUD8	95.59	1.00	600.00	720.00	0.31	0.20	7.59	Booster tunnel - 40' upstream of chute		
44	SSTUD9	131.00	1.00	600.00	720.00	-0.01	0.25	-0.15	Booster tunnel - base of chute		
45	SSTUDA	774.90	1.00	600.00	720.00	9.89	0.45	239.35	Booster tunnel - below dump #1		
46	SSTUDB	95.88	1.00	600.00	720.00	0.00	0.22	0.04	Booster tunnel - 40' downstream of chute		
47	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
48	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
49	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
50	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
51											
52		Mux =	0.6 - Berm Dump #1 US (Spectrometer)								
53			2.1 - Berm Dump #1 DS								
54			1.6 - Booster Chute								
55			11.6 - Booster Tunnel Dump #1								
56											

	A	B	C	D	E	F	G	H	I	J	K
57											
58					Current lost =		Pulse length =		Rep Rate =		
59	Run 2 A	Transverse - Coarse			6.20	mA	7.00	microsec	15.00	Hz	
60											
61						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
62		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
63	SSTUD0	95.28	1.00	600.00	720.00	0.65	0.19	15.83	4 feet west of SSTUD7		
64	SSTUD1	139.30	1.00	600.00	720.00	1.31	0.21	31.81	2 feet west of SSTUD7		
65	SSTUD2	146.50	1.00	600.00	720.00	1.68	0.21	40.65	2 feet east of SSTUD7		
66	SSTUD3	134.30	1.00	600.00	720.00	1.20	0.21	29.13	4 feet east of SSTUD7		
67	SSTUD4	102.30	1.00	600.00	720.00	0.87	0.19	21.05	6 feet east of SSTUD7		
68	SSTUD5	169.80	1.00	600.00	720.00	1.76	0.23	42.46	assumed position of dump (doghouse)		
69	SSTUD6	158.80	1.00	600.00	720.00	1.79	0.22	43.33	2 feet downstream		
70	SSTUD7	173.20	1.00	600.00	720.00	1.97	0.22	47.71	1 foot downstream		
71	SSTUD8	94.69	1.00	600.00	720.00	0.30	0.20	7.27	Booster tunnel - 40' upstream of chute		
72	SSTUD9	130.90	1.00	600.00	720.00	-0.01	0.25	-0.18	Booster tunnel - base of chute		
73	SSTUDA	773.90	1.00	600.00	720.00	9.88	0.45	238.99	Booster tunnel - below dump #1		
74	SSTUDB	97.00	1.00	600.00	720.00	0.02	0.22	0.45	Booster tunnel - 40' downstream of chute		
75	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
76	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
77	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
78	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
79											
80		Mux =	0.6 - Berm Dump #1 US (Spectrometer)								
81			2.3 - Berm Dump #1 DS								
82			1.6 - Booster Chute								
83			11.6 - Booster Tunnel Dump #1								
84											

	A	B	C	D	E	F	G	H	I	J	K
85											
86					Current lost =		Pulse length =		Rep Rate =		
87	Run 3 A	Transverse - Fine			6.20	mA	7.00	microsec	15.00	Hz	
88											
89						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
90		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
91	SSTUD0	151.60	1.00	600.00	755.00	1.46	0.22	35.35	2 feet west of SSTUD7		
92	SSTUD1	169.00	1.00	600.00	755.00	1.72	0.23	41.68	1 feet west of SSTUD7		
93	SSTUD2	181.20	1.00	600.00	755.00	2.18	0.23	52.63	1 feet east of SSTUD7		
94	SSTUD3	170.10	1.00	600.00	755.00	1.70	0.23	41.17	2 feet east of SSTUD7		
95	SSTUD4	153.70	1.00	600.00	755.00	1.61	0.22	38.92	3 feet east of SSTUD7		
96	SSTUD5	177.90	1.00	600.00	755.00	1.84	0.24	44.47	assumed position of dump (doghouse)		
97	SSTUD6	166.90	1.00	600.00	755.00	1.88	0.22	45.57	2 feet downstream		
98	SSTUD7	179.30	1.00	600.00	755.00	2.03	0.23	49.19	1 foot downstream		
99	SSTUD8	96.81	1.00	600.00	755.00	0.28	0.21	6.72	Booster tunnel - 40' upstream of chute		
100	SSTUD9	135.50	1.00	600.00	755.00	-0.03	0.26	-0.83	Booster tunnel - base of chute		
101	SSTUDA	775.50	1.00	600.00	755.00	9.82	0.46	237.53	Booster tunnel - below dump #1		
102	SSTUDB	101.10	1.00	600.00	755.00	0.01	0.23	0.24	Booster tunnel - 40' downstream of chute		
103	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
104	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
105	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
106	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			

October 4, 1993

To: Steve Holmes

From: Dixon Bogert; AD/Shielding Review Committee

Subject: Linac Upgrade Shielding Assessment Status

I enclose two documents with this memo:
1) Leveling: "Committee Review of 'Low Intensity Shielding Assessment of the Linac Upgrade dated 9/21/93'", dated 9/30/93
2) Bogert: "Low Intensity Shielding Assessment of the Linac Upgrade" dated 9/27/93

Based upon these two documents, the Committee can report that we support increasing the intensity of operation of the 400MeV Linac. In the first of the aforementioned documents you will find the suggestion that a full power assessment is required with clean transmission to the momentum dump. Until this assessment is complete, beam power to the momentum dump should not exceed 80% of the full hourly intensity limit.

The shielding review committee would be supportive of requests from the Linac Department for help from FESS to increase passive shielding over the straight dump, and the momentum dump if the full power assessment showed 'normal' losses over the unposted minimal occupancy limits.

Please feel free to distribute this letter and the enclosures, as well as the 9/21/93 low intensity assessment to interested parties; the review committee believes that the low intensity assessment is as complete as possible. We await the suggested full beam power assessments.

cc: Members of the AD/Shielding Review Committee

To: Pat Lesiak
Please file in
Linac Shielding
Assessment.
Thanks,
Steve

FERMILAB
Accelerator E S & H
Dept. M.S. 306

9/30/93

TO: Dixon Bogert, Chairman, Shielding Review Committee

FROM: Tony Leveling, Member, Shielding Review Committee

SUBJECT: Committee Review of "Low Intensity Shielding Assessment of the Linac Upgrade" document dated 9/21/93

Craig Moore, Howard Casebolt, and I met on 9/28/93 to review the subject Shielding Assessment. We agreed that the assessment provides sufficient evidence that the existing combination of Linac shielding and interlock detectors is suitable for higher intensity operation. We also agree that it would be useful (but not mandatory) for the Linac Department ask FESS to consider the placement of additional shielding over the straight ahead dump to reduce the need for interlocked detectors.

We did find one area in the assessment which will require further study. In Run 1 (Beam to Momentum Dump) of the data set, two detectors called 'Berm at fence above access tunnel' and 'Access pit behind blocks' show projected rates at full beam power which exceed 2.5 mrem/hr. Since beam to dump can be considered normal operation, these rates would require posting. Because beam transmission to the momentum dump was not clean, significant beam was lost elsewhere in Linac during the measurement. It is not clear from the assessment that the rates in these two locations are due to losses(accident conditions) or due to beam absorption in the dump. In the final (at full beam power) assessment, the measurements should be repeated with clean transmission to the momentum dump. These areas should be examined to determine whether the rates are due to normal or accident conditions and protected acccordingly.

Until the final assessment is complete, beam power to the momentum dump should probably be limited to 75 to 80 % of the full hourly intensity limit so that there is no chance that we will exceed limits prescribed by the Fermilab Radiological Control Manual for these two areas.

If you would like additional information, please let me know.

cc:		
H. Casebolt	D. Bogert	D. Finley
R. Ducar	V. Bharadwaj	K. Vaziri
C. Schmidt	S. Holmes	File I.K.11
T. Kroc	C. Moore	C. Bhat
R. Andrews		

September 27, 1993

To: AD/Shielding Committee Files

From: Dixon Bogert

Subject: Low Intensity Shielding Assessment of the Linac Upgrade

I have reviewed the document "Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning by the Linac Department/Charles Schmidt and Thomas Kroc, dated September 21, 1993.

I note that this document replaces completely two earlier documents prepared earlier in September, and is to be regarded now as the only report on the subject.

The areas of radiation concern resulting from the change from the 200MeV to 400MeV high energy end of the Linac are correctly listed. The radiation classifications for areas of concern are correctly enumerated. The measurements appear complete and relevant to the areas of concern. I concur with the assessment of results presented in the report. I agree that it would be desirable, especially on top of the straight ahead dump, for the Linac Department to propose (by sketch submitted to FESS) an appropriate increase of shielding over the straight ahead dump so that eventually the interlocked detector shown by this assessment to be required over the straight ahead dump on the berm could possibly be eliminated. It might be helpful to know the spectrum of penetrating radiation since if FESS were to find structural limitations for loading earth over the straight ahead dump, perhaps altering the shielding to include some type of "poly" material would be adequate. Note, however, that the use of the interlocked detector is completely acceptable.

Based upon the sketches shown, I do not believe that it is possible to alter the shielding between the straight ahead dump and the Booster enclosure. It will be necessary to accept the conditions found in these measurements and to rely on interlocked detectors and exclusion as necessary to protect the Booster enclosure.

At this time I accept this report and unless I am informed of technical objections from other members of the shielding review committee, I am prepared to accept proposals for operating the 400MeV Linac at higher intensities.

cc: Members of the AD/Shielding Review Committee
C Schmidt
T Kroc

Fermilab
Accelerator Division Headquarters

October 11, 1993

To: Don Cossairt

From: Steve Holmes S.D. Holmes

SUBJECT: SHIELDING ASSESSMENT FOR THE UPGRADED LINAC

The low intensity phase of the shielding assessment for 400 MeV linac operations and subsequent review by the Accelerator Division Shielding Review Committee has been completed. Attached you will find the assessment documentation itself along with the recommendation from the AD Shielding Review Committee that full power operation be authorized subject to a restriction on power delivered to the momentum dump. I have authorized operations of the linac consistent with this recommendation. The Linac Department is being asked to provide a full intensity assessment in this area prior to removal of this restriction.

I ask that the ES&H section review the enclosed information and concur in the finding of the AD Shielding Review Committee. Once you have done so the Accelerator Division will regard this phase of the linac upgrade shielding assessment as complete. I expect to forward the full intensity assessment to ES&H once it becomes available.

Thank you for your attention.

cc

R. Andrews
V. Bharadwaj
C. Bhat
D. Bogert
H. Casebolt
R. Ducar
D. Finley
P. Lesiak
T. Leveling
C. Moore
C. Schmidt

October 4, 1993

To: Steve Holmes

From: Dixon Bogert; AD/Shielding Review Committee

Subject: Linac Upgrade Shielding Assessment Status

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Please feel free to distribute this letter and the enclosures, as well as the 9/21/93 low intensity assessment to interested parties; the review committee believes that the low intensity assessment is as complete as possible. We await the suggested full beam power assessments.

cc: Members of the AD/Shielding Review Committee

FERMILAB
Accelerator E S & H
Dept. M.S. 306

9/30/93

TO: Dixon Bogert, Chairman, Shielding Review Committee

FROM: Tony Leveling, Member, Shielding Review Committee

SUBJECT: Committee Review of"Low Intensity Shielding Assessment of the Linac Upgrade" document dated 9/21/93

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If you would like additional information, please let me know.

cc: H. Casebolt	D. Bogert	D. Finley
R. Ducar	V. Bharadwaj	K. Vaziri
C. Schmidt	S. Holmes	File I.K.11
T. Kroc	C. Moore	C. Bhat
R. Andrews		

September 27, 1993

To: AD/Shielding Committee Files

From: Dixon Bogert

Subject: Low Intensity Shielding Assessment of the Linac Upgrade

I have reviewed the document "Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning by the Linac Department/Charles Schmidt and Thomas Kroc, dated September 21, 1993.

I note that this document replaces completely two earlier documents prepared earlier in September, and is to be regarded now as the only report on the subject.

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Based upon the sketches shown, I do not believe that it is possible to alter the shielding between the straight ahead dump and the Booster enclosure. It will be necessary to accept the conditions found in these measurements and to rely on interlocked detectors and exclusion as necessary to protect the Booster enclosure.

At this time I accept this report and unless I am informed of technical objections from other members of the shielding review committee, I am prepared to accept proposals for operating the 400MeV Linac at higher intensities.

cc: Members of the AD/Shielding Review Committee
C Schmidt
T Kroc

Fermilab
Linac

September 21, 1993

TO: Dixon Bogert, Chairman
Shielding Assessment Committee

FROM: C. Schmidt, C. Schmidt
Linac Department

SUBJECT: Low Intensity Shielding Assessment of the Linac Upgrade

Attached is the complete Linac Report summarizing the Upgrade Shielding Assessment conducted on September 8 and 20, 1993.

A previous report, dated September 13, 1993, has serious errors. It should be ignored and hopefully discarded. The revised report of September 15, 1993 is replaced in its entirety by the present report.

cc: C. Moore
T. Leveling
H. Casebolt
T. Kroc
D. McGinnis
R. Noble
D. Finley

September 21, 1992

?? / CORRECTED TO 1993 IN C. SCHMIDT MEMO OF 4 NOV 1993 WHICH FOLLOWS THIS DOCUMENT. – W. HIGGINS

Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning

Linac Department

Charles Schmidt and Thomas Kroc

Introduction

During the 1993 shutdown, the side-coupled cavities for the Linac Upgrade project were installed in the beam line in the Linac enclosure. These cavities have an output energy of 400 MeV, twice the energy of the previous Linac cavities (200 MeV). Since the energy has been increased the shielding of the affected area must be re-assessed. The Upgrade Commissioning Plan requires a shielding assessment following the attainment of low intensity beam operation of 2.0 mA-sec/hr and 16 mA maximum (down a factor of ~25 from the normal 53.5 mA-sec/hr) before going to higher intensities.

The shielding areas affected by this change are:

1. The momentum dump and straight dump which must be measured for full beam radiation at accessible places outside the enclosure, that is on the berm and in the Booster. This is a normal operating condition so the maximum allowable radiation, for a non-posted minimal occupancy area, is 2.5 mrem/hr for one hour, as on top of the berm and 10 mrem/hr for a posted minimal occupancy area, as in the Booster.

2. Elsewhere in the 400 MeV area where beam losses may occur from accident situations, such as at the momentum line pipe just above the Booster chute, and the spectrometer or the Booster Lambertson magnet. These devices are distributed through the area, are representative of all devices in the 400 MeV area, and are the largest and most likely sources of beam induced radiation in this

area. The radiation they might produce must be measured for full beam loss at accessible places outside the enclosure; that is, on the berm, in the Booster tunnel and gallery, and at and around the high energy (labyrinth) entrance. The loss from these devices is an accident condition and the maximum allowable radiation, for non-posted minimal occupancy, is 10 mrem/hr for one hour, as on the berm and at the labyrinth door, or 100 mrem/hr for one hour for a posted minimal occupancy area, as in the Booster tunnel.

3. The Booster chute and tunnel must be protected for 400 MeV Linac operation. The chute has had the shielding modified for higher energy but needs to be checked with beam for losses in the Booster tunnel. Presently, the Booster tunnel is protected from radiation through the chute by a permanent interlocked detector located in the Booster tunnel at the bottom of the chute, which is set to trip at 10 mrem/hr (rate measure). The permissible level in this area for an accident condition is 100 mrem/hr for one hour and 10 mrem/hr for an hour (integrated dose) for normal operating conditions.

4. The shielding of the Linac tunnel equipment access must be measured for beam loss occurring anywhere in the 400 MeV area or the Upgrade accelerator. The concrete blocks covering the entrance and the soil berm over the access must be checked. The maximum allowable radiation for this non-posted minimal occupancy areas is 10 mrem/hr for one hour for an accident, or 2.5 mrem/hr for an hour for normal conditions. If it requires a higher rating it must be posted.

5. The lower 30 inch diameter Linac utility penetrations for the old Linac which are along side the new cavities have been modified with concrete inserts, filling completely the 12 foot length of these penetrations except for some 4 inch utility holes in the concrete. As was determined for the old Linac, every third penetration is monitored by a permanent interlocked detector set to trip at 50 mrem/hr but now lowered to 10 mrem/hr. The permissible level outside these penetrations for an accident condition is 100 mrem/hr for one hour because of ropes and signs.

6. The upper penetrations for the Linac Upgrade waveguides must be measured under conditions of 400 MeV beam loss. The maximum allowable radiation for non-posted minimal occupancy, as on top of the berm of the Linac enclosure, is 10 mrem/hr for one hour for the accident condition and 2.5 mrem/hr for normal conditions

Measurements

Since the geometry of these areas are difficult to characterize the Linac shielding assessment relies on beam measurements to assess the shielding. The effectiveness of the shielding is measured by producing beam loss at known points of measured beam dose. These points were at or in devices most likely to produce radiation from beam loss or representative of conditions that could occur in the local area. The detection outside the shielding was done using calibrated chipmunk detectors at the spots most likely to have the least or an unknown shielding as determined by drawings or past shielding studies. The detector measurements, in counts, each corresponding to 2.5 microrem, were integrated for the time the beam was on, recorded by the control system and saved on paper copies, converted to a dose rate, and then extrapolated to the maximum possible beam intensity (35 mA x 30 microsec at 15 Hz rate) representative of the worse case accident condition.

Since these measurements had to be taken with low intensity beam (1 to 6 mA x 1 to 7 microsec) as compared to normal operation (35 mA x 30 microsec) and could not exceed the previously determined shielding requirements, the extrapolation to full loss conditions is between 35 and 1300. At the same time an attempt was made to keep the integrated beam loss low so as not to severely irradiate the new equipment and make the working conditions on the accelerator more hazardous. In all significant cases however, the extrapolated radiation is sufficiently low or high that it is not questionable. Where questions may arise additional measurements will be made at higher intensities or with better detection.

The measurements were divided into two major segments. Those around the 400 MeV area (Figure 1, and Runs 1 - 5 of the spreadsheets) and those related to the upper and lower penetrations (Figures 2 and 3, and Runs 6 - 9).

Results

The results of the measurements, their significance and solutions are presented. All given radiation dose rates are extrapolated to a worse case condition, i.e., 35 mA in 30 microseconds pulses for continuous operation at 15 Hz, unless stated otherwise. This is the Linac Beam Safety Envelope.

The Linac Berm above the 400 MeV Area

This area was measured by dumping as much of the low intensity beam into each dump as presently possible. The maximum beam achievable into each dump was, 2.4 mA to the momentum dump and 4.1 mA to the straight dump with a 7 microsec pulse length at 15 Hz rate for 10 minutes. In addition, similar beam was dumped into the spectrometer, the spectrometer arm beam pipe and the Booster Lambertson magnet. These devices are representative of other devices in close proximity in the 400 MeV area.

These conditions are represented by Runs 1 - 4 of the data spreadsheets, detectors SSTUDA through SSTUDD. In all cases the soil shielding above the straight dump is inadequate. In the worse case the radiation may be 250 mrem/hr. Prior to beam commissioning an interlocked detector, set to trip at 5 mrem/hr, was placed at this location and presently provides the required protection. Since this condition can be caused by normal operation the maximum limit is 2.5 mrem/hr for one hour and the detector has been lowered to trip at 2.5 mrem/hr.

At the request of the Shielding Assessment Committee a second set of runs was done for the straight dump with cleaner beam conditions (~100% transmission through the Linac and to the dump. See the toroid printout, Fig. 5) and more detectors to convincingly determine the peak of the radiation from the straight dump. Runs A (1 -3) give the results. Eight detectors were place two feet apart along the beam line from before to after the straight dump (Run 1 A, SSTUD0 - 7). At the maximum point the detectors were moved to traverse the beam line in two foot spacings (Run 2 A). Having found the expected peak the detectors were placed around this point in one foot spacings (Run 3 A, SSTUD0 - 7). With some satisfaction the maximum position was at the place the interlocked detector had previously been placed. As a comparison the previous and present measured levels were in good agreement and with the Radiation MUX readings (Run 4, SSTUDC, Runs A (1 - 3), and the MUX readings for the Berm Dump #1 DS). The peak distribution was surprisingly narrow with a half width of approximately four feet (Fig. 4).

The immediate solution for this area is to leave the interlocked detector in place set to a trip level of 2.5 mrem/hr. A more permanent and passive solution would be to add sufficient soil to the area to absorb the radiation. Until this can be done, re-measured and certified the interlocked detector will remain in place and be considered permanent.

The Booster Chute, Tunnel and Gallery

Measurement of radiation through the Booster chute indicates that the background in the Booster tunnel, due to a significant error of the Linac beam at the 400 MeV momentum line, could be 333 mrem/hr (see Run 2, SSTUD7). An interlocked radiation detector is permanently installed at the bottom of the chute in the Booster tunnel to inhibit beam if the radiation exceeds 10 mrem/hr and the Booster is not secure with a permit. Since this is a posted radiation area the permissible fault level is 100 mrem/hr for one hour while the level due to normal operation is 10 mrem/hr. The detector provides the necessary level of protection required for both cases.

The highest area in the Booster was upstream of the chute. This area is the spot below the end of the straight dump where the soil between the dump and Booster tunnel is the thinnest. High extrapolated levels (483 mrem/hr maximum) were detected in this area with beam loss in the 400 MeV area (see Runs 1 - 5, SSTUD5). An interlocked detectors is necessary and has been installed in this area with a trip level of 10 mrem/hr as at the Booster chute.

These first results also gave concern as to the extent of radiation in the Booster tunnel. During the second measurements two additional detectors were placed in the Booster tunnel upstream and downstream of the interlocked detectors (Fig. 6). These detectors were a factor of 50 or more below the interlocked detectors indicating the radiation is limited to the area of the interlocked detectors (Runs A, 1 - 3, SSTUD8 - B).

The Booster gallery near the dumps had a maximum extrapolated level of 3.5 mrem/hr (see Runs 1 - 5, SSTUD6). This would be limited to <0.05 mrem/hr by the tripping of the Booster chute detector and even more by the new tunnel detector. The Booster gallery is fine.

The 400 MeV Equipment Access

This area was examined at two locations. One behind the 12 foot concrete blocks that form the shielding door and a second on the berm just in front and above this door. The permissible level for an accident condition is 10 mrem/hr for one hour or 2.5 mrem/hr for normal operation. These detectors extrapolate to a maximum of ~4 mrem/hr respectively for loss produced in the 400 MeV area (see Runs 1 - 4, SSTUDE and F). In all cases the Booster tunnel detector would trip beam before levels of 0.2 mrad/hr were reached. For the other high case of 125 mrem/hr due to losses in the Lambertson (Run 5, SSTUDE) the area would be protected by the Linac high energy labyrinth entrance detector. During the run the Lambertson losses were adjusted so the labyrinth detector (200SCA), with its internal background, read 240 mrem/hr (228 mrem/hr on the MUX monitor), very close to tripping. It is set to trip beam at 200 mrem/hr. At this point the actual radiation above the access door was 0.1 mrem/hr and would not have gone much higher before a trip. The same could be said for everything in Run 5 since the Lambertson is just adjacent to the labyrinth tunnel opening to which the labyrinth detector is highly sensitive.

Although the gallery door of the labyrinth and the 400 MeV cable penetrations behind the labyrinth (Run 2, 3 and 5, SSTUD3 and 4) had high levels when extrapolated to full beam loss, their actual maximum levels were 2.15 and 2.0 mrem/hr when the labyrinth was near tripping. They would not exceed the permissible 10 mrem/hr before the labyrinth detector caused a trip.

The Lower Linac Utility Penetrations

In Run 7, losses were produced in module 7 (the highest energy module of the Upgrade Linac, 357 to 401 MeV), mostly at the beginning of the module. Unfortunately because of the loss the module constantly tripped off whenever beam was initiated and inhibited beam. This in itself would prevent excessive loss and radiation if it could be counted on. In order to take data the module rf had to be mistimed and the beam inhibit for this station disabled. Thus only 357 MeV could be achieved but this is the condition at the entrance to this module. It was also necessary to inhibit rf on all other modules downstream of where beam was being lost. Commissioning studies have so far shown all modules to spark and trip with significant beam loss.

For the lower utility penetrations there are permanent interlocked detectors at each "center" penetration for the old Linac (tanks 6, 7, 8 and 9 center) which previously tripped at 50 mrem/hr but are now set to 10 mrem/hr. The permissible level outside these penetrations for an accident condition is 100 mrem/hr for one hour due to posting and limited occupancy. For the losses produced in module 7 the highest radiation was observed at the tank 8 center penetration. All other penetrations and wall surfaces between the penetrations was less than tank 8 center and therefore would not exceed 10 mrem/hr (see Run 7, SSTUD0 - 7). Similarly, excessive losses in module 6 (313 MeV in) would have been prevented by the tank 8 center detector. The tank 9 upstream penetration would have been near 15 mrem/hr at this point but still well within its limit (see Run 8, SSTUD0 - 7). For the last case (see Run 9, SSTUD0 - 7) with losses in module 5 (271 MeV in), the tank 8 downstream penetration would have been at 25 mrem/hr, well below its limit, when a trip of 10 mrem/hr occurred at tank 8 center (see Run 9, SSTUD1 and 2). It should also be noted that the labyrinth detector (200SCA) was near its trip limit when the actual maximum dose was 5.15 mrem/hr (Run 9, SSTUD2) and would have prevented excessive radiation in all these cases except that this may be due to additional losses in or near the Lambertson magnet. Since these are the highest energy modules and the worse cases, the same protection would be true for the other penetrations further upstream which have the same geometry and protection.

The Upper Waveguide Penetrations

The same argument as given for the lower utility penetrations applies to the upper waveguide penetrations (Runs 7, 8 and 9, SSTUD8 - A). The waveguide penetrations have approximately the same level of radiation as the lower penetrations and can thus be protected by the lower detectors. The waveguide penetrations are presently a non-posted minimal occupancy area and have a permissible limit of 10 mrem/hr for one hour. This is achieved with the lower utility penetrations set to trip at 10 mrem/hr.

Conclusion

The areas of the Linac shielding that apply to upgrading the Linac to 400 MeV have been examined and some corrections have been made. The conclusions, necessary changes and possible future changes are:

1. Two interlocked detectors have been placed on the berm, one above and one downstream of the straight dump position to trip at

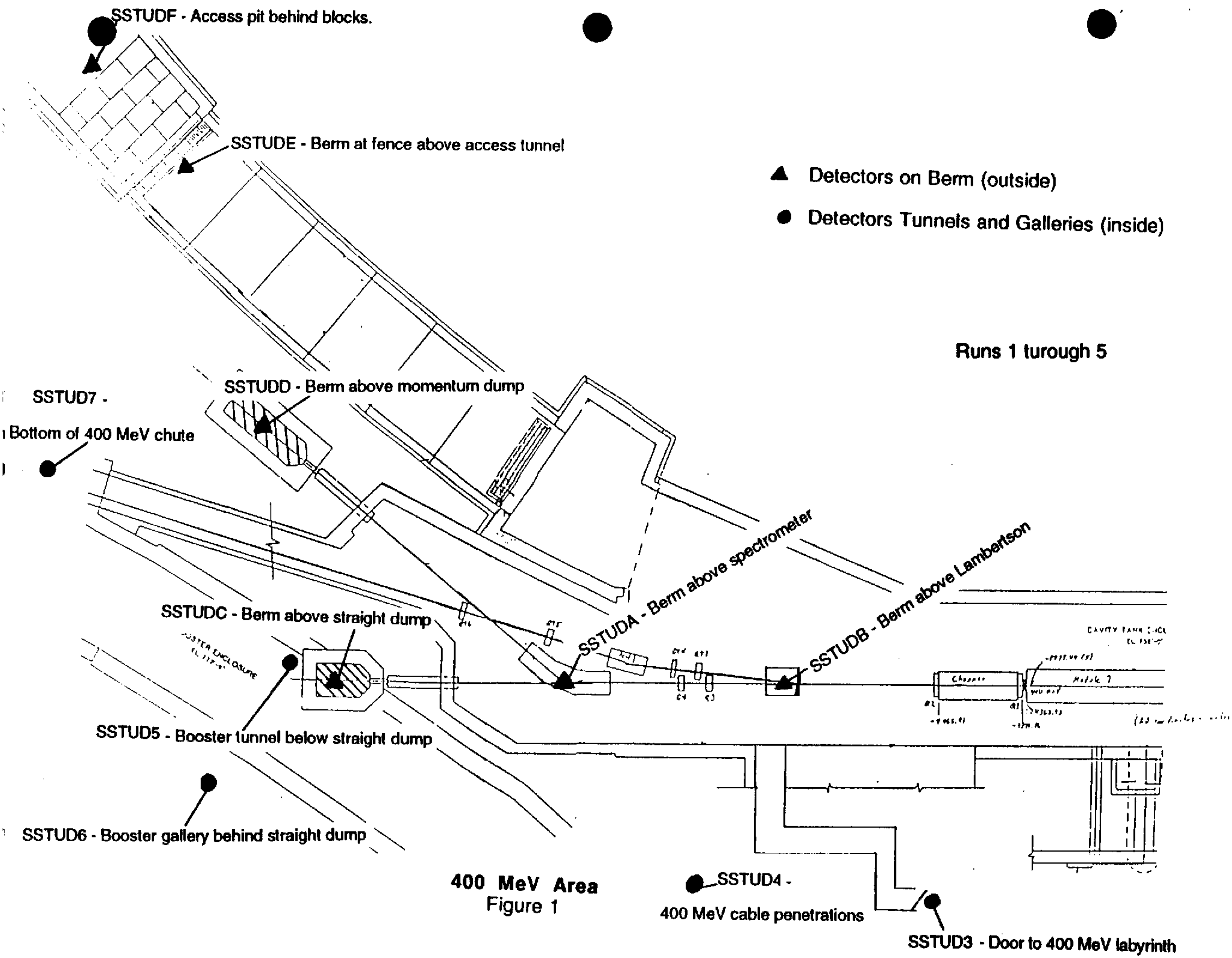
2.5 mrem/hr. This is where the soil slopes down and is the thinnest. Additional soil should be considered for over the straight dump area and re-tested. The interlocked detector on the berm over the straight dump must remain and be permanent until other measures are shown to be effective and approved.

2. An interlocked detector has been placed at the Booster tunnel position closest to the Linac straight dump set to trip at 10 mrem/hr. It is interlocked to Booster operation as is the Booster chute detector to be active whenever the Booster tunnel is accessed.

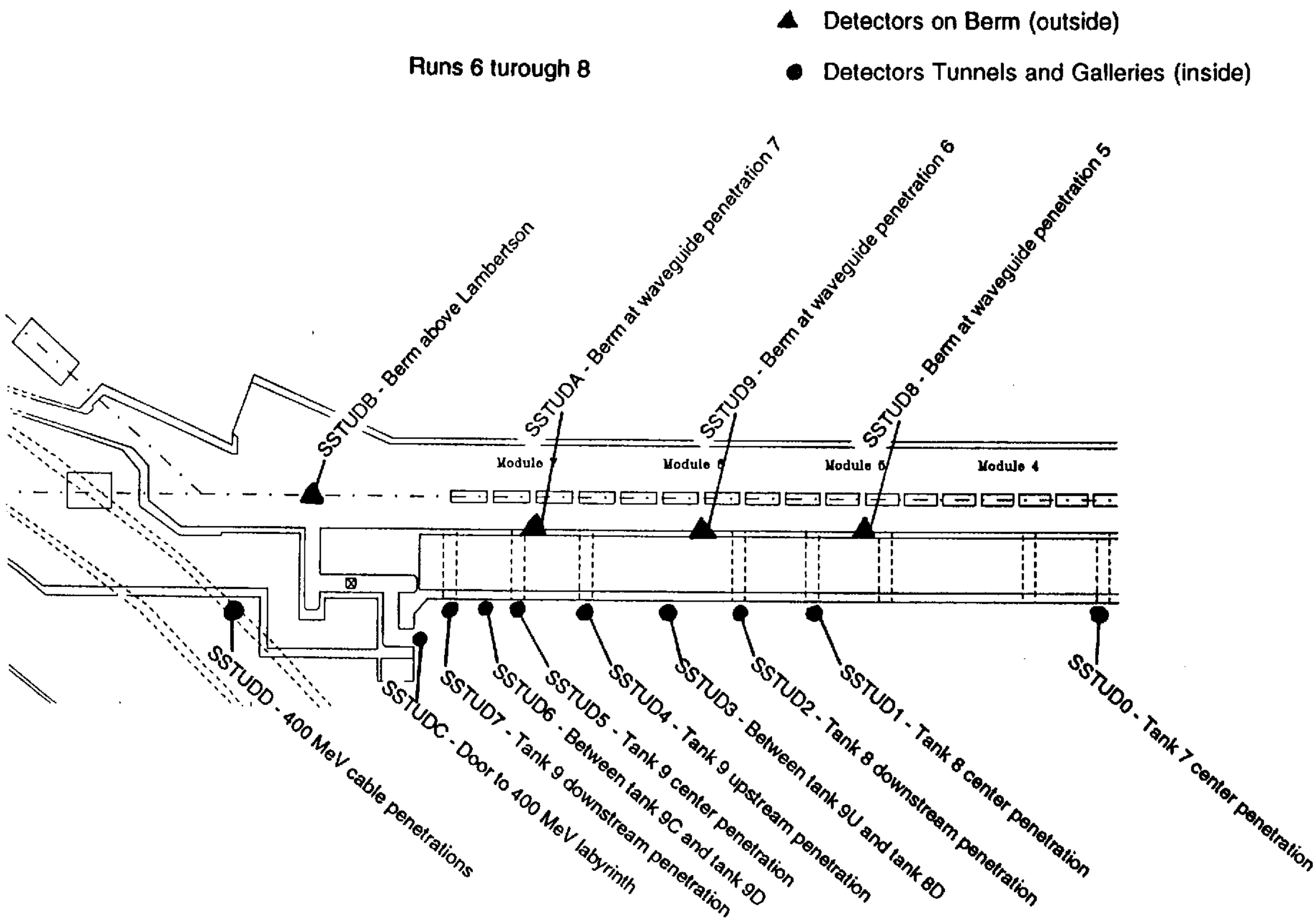
3. The trip level of tanks 6 to 9 lower utility penetration interlocked detectors have been lowered to 10 mrem/hr. They also protect the upper waveguide penetrations.

4. A "temporary" interlocked detector presently located behind the 12 feet of shielding blocks for the Linac equipment access can be removed.

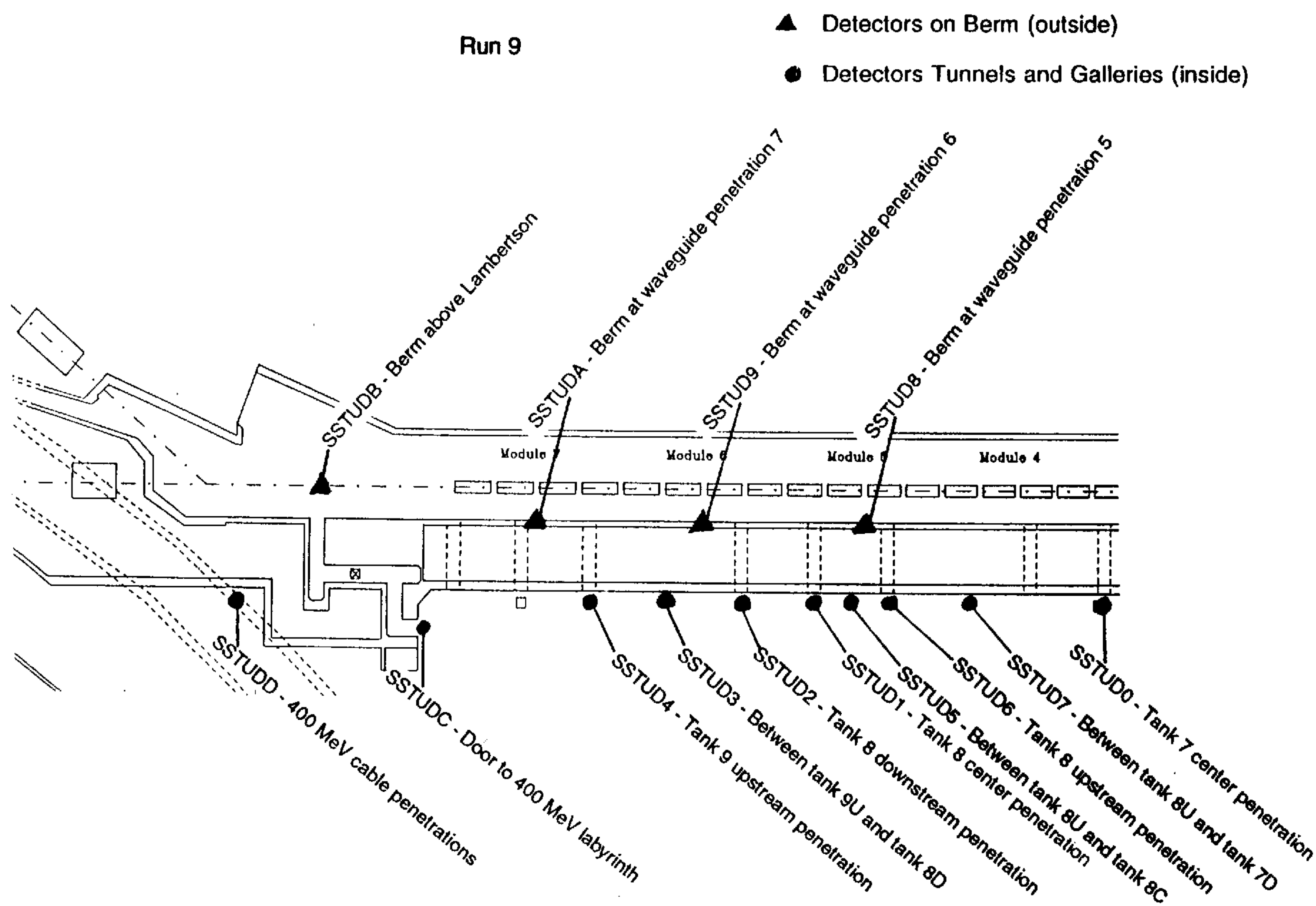
The other areas of the Linac, the low energy end to Tank 5, are not required to be reevaluated and have not. They were found to be appropriate during the original assessment and have not been modified.



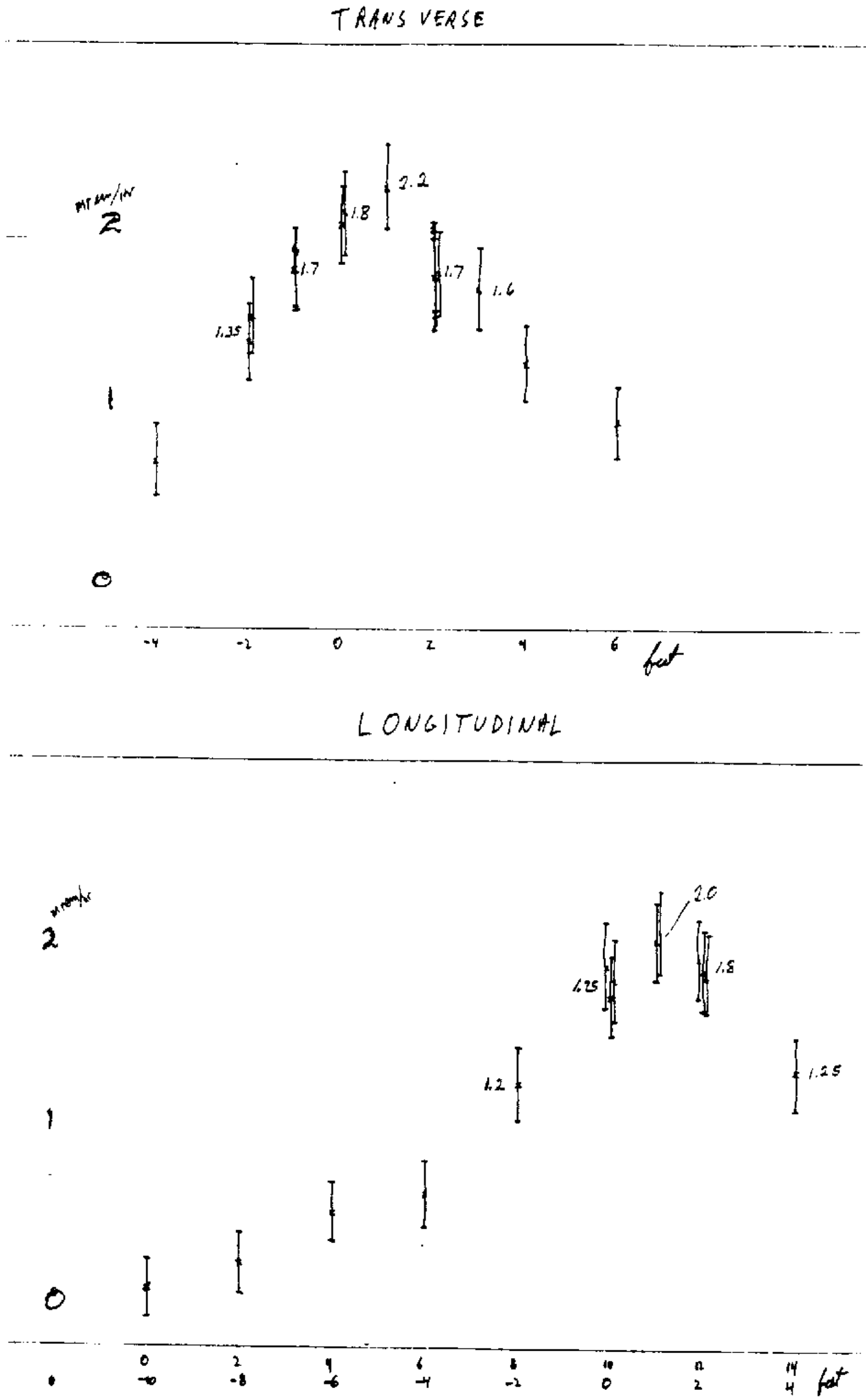
400 MeV Area
Figure 1



Linac Tunnel Area
Figure 2



Linac Tunnel Area
Figure 3



Longitudinal and Transverse Radiation Profiles above Straight Dump

Figure 4

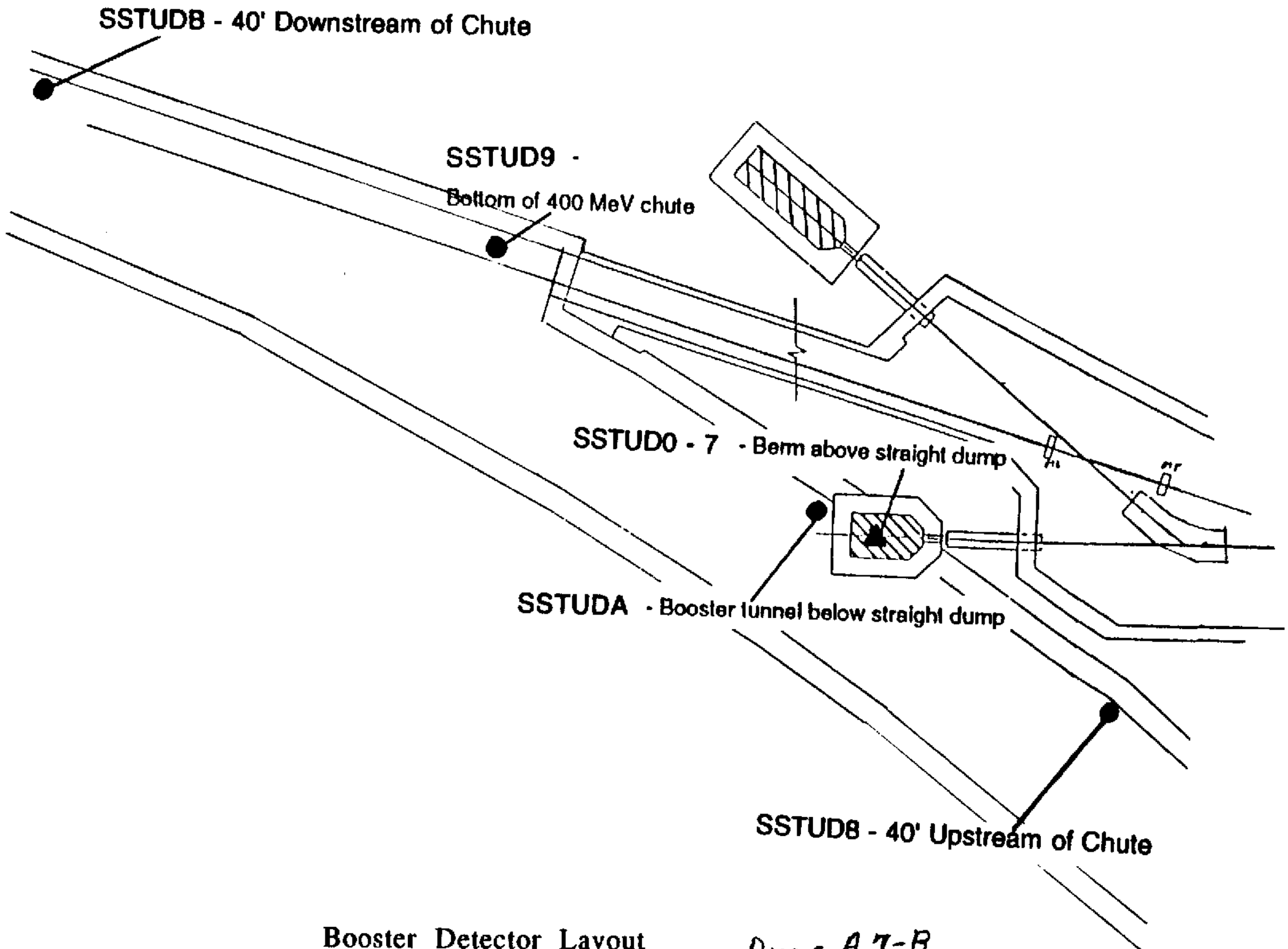
```
C  ole Location 4,               20-SEP-199  0:55
PA:L49  H- SOURCE PARAMS

L49  TOROIDS                                SET      D/A    A/D  Eng-U ♦COPIES♦
-<FTP>+ *SA♦ X-A/D  X=TIME     Y=L:GR2MID,M SE28F ,L        ,L
COMMAND ---- Eng-U  I= 0       I= 0       ,-10     ,-10     ,-10
-< 1>+  One+ AUTO   F= 400     F= 1.2     , 10     , 10     , 10
source  750 kev timers  misc    750 2   TOROIDS spect   reset
 L:HTOR4       H  TOROID  4                            * 50.89  MA
 L:HTOR7       H  TOROID  7                            * 51.83  MA
 L:IHTOR2      BUNCHER IN TOROID                       *-49.73  MA
 L:TO1IN       T1 TOROID IN                            *-50.74  MA
 L:TO4IN       T4 TOROID IN                            *-6.805  MA
 L:TO4OUT      T4 TOROID OUT                           *-6.744  MA
 L:TO5OUT      T5 TOROID OUT                           * 6.726  MA  ← Beam From DT Linac
 L:D0TOR       TRN SECT OUT TORD                       * 6.604   MA
 L:D1TOR       MODULE 1 OUT TORD                       * 6.427   MA
 L:D2TOR       MODULE 2 OUT TORD                       * 6.299   MA
 L:D3TOR       MODULE 3 OUT TORD                       * 6.244   MA
 L:D4TOR       MODULE 4 OUT TORD                       * 6.36    MA
 L:D5TOR       MODULE 5 OUT TORD                       * 6.198   MA
 L:D6TOR       MODULE 6 OUT TORD                       * 6.015   MA
 L:D73TOR      M7 TOROID LINACEND                      * 6.189   MA
 L:D7TOR       MODULE 7 OUT TORO                       * 6.284   MA← Beam From SCS Linac
 L:TORSI       E TOR SPECT IN                          * 6.204  MA
 L:TORSD       E TOR ST DUMP                           *-6.226  MA ← Beam To Straight
                                                                      Dump
```

~100% Transmission To Straight Dump

Toroid Readings for Runs A, 1 - 3

Figure 5



Booster Detector Layout   Runs A 7-B

Figure 6

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3											
4	Background	For losses in 400 MeV Area									
5			1 count equal	2.50E-06	rem						
6		Counts	Multiplier	Time (sec)		rem/sec	error				
7	SSTUD0	44.09	1.00	600.00		1.84E-07	2.77E-08		Tank 9 center penetration		
8	SSTUD1	40.91	1.00	600.00		1.70E-07	2.67E-08		Between Tank 9 C and Tank 9 D		
9	SSTUD2	47.16	1.00	600.00		1.97E-07	2.86E-08		Tank 9 Down stream penetration		
10	SSTUD3	40.06	1.00	600.00		1.67E-07	2.64E-08		Door to 400 MeV Labyrinth		
11	SSTUD4	46.22	1.00	600.00		1.93E-07	2.83E-08		400 MeV cable penetrations		
12	SSTUD5	88.06	1.00	600.00		3.67E-07	3.91E-08		Booster tunnel below st. dump		
13	SSTUD6	43.06	1.00	600.00		1.79E-07	2.73E-08		Booster gallery behind st. dump		
14	SSTUD7	47.22	1.00	600.00		1.97E-07	2.86E-08		Bottom of 400 MeV Chute		
15	SSTUD8	35.34	1.00	600.00		1.47E-07	2.48E-08		Berm at Waveguide pen. 6		
16	SSTUD9	39.25	1.00	600.00		1.64E-07	2.61E-08		Berm at Waveguide pen. 7		
17	SSTUDA	33.06	1.00	600.00		1.38E-07	2.40E-08		Berm above spectrometer		
18	SSTUDB	36.88	1.00	600.00		1.54E-07	2.53E-08		Berm above lambertson		
19	SSTUDC	40.03	1.00	600.00		1.67E-07	2.64E-08		Berm above straight dump		
20	SSTUDD	34.41	1.00	600.00		1.43E-07	2.44E-08		Berm above momentum dump		
21	SSTUDE	42.78	1.00	600.00		1.78E-07	2.73E-08		Berm at fence above access tunnel		
22	SSTUDF	48.63	1.00	600.00		2.03E-07	2.91E-08		Access pit behind blocks		
23											
24											
25											
26											
27											
28											

	A	B	C	D	E	F	G	H	I	J	K
29											
30					Current lost =		Pulse length =		Rep Rate =		
31	Run 1	Beam to Momentum Dump			2.40	mA	7.00	microsec	15.00	Hz	
32											
33						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
34		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
35	SSTUD0	57.47	1.00	600.00	780.00	0.00	0.17	0.14	Tank 9 center penetration		
36	SSTUD1	54.28	1.00	600.00	780.00	0.02	0.17	1.03	Between Tank 9 C and Tank 9 D		
37	SSTUD2	67.63	1.00	600.00	780.00	0.09	0.18	5.93	Tank 9 Down stream penetration		
38	SSTUD3	127.10	1.00	600.00	780.00	1.13	0.21	70.33	Door to 400 MeV Labyrinth		
39	SSTUD4	149.70	1.00	600.00	780.00	1.34	0.23	84.01	400 MeV cable penetrations		
40	SSTUD5	408.40	1.00	600.00	780.00	4.41	0.35	275.55	Booster tunnel below st. dump		
41	SSTUD6	56.44	1.00	600.00	780.00	0.01	0.17	0.43	Booster gallery behind st. dump		
42	SSTUD7	72.69	1.00	600.00	780.00	0.17	0.19	10.60	Bottom of 400 MeV Chute		
43	SSTUD8	45.94	1.00	600.00	780.00	0.00	0.15	0.00	Berm at Waveguide pen. 6		
44	SSTUD9	54.47	1.00	600.00	780.00	0.05	0.16	3.23	Berm at Waveguide pen. 7		
45	SSTUDA	55.25	1.00	600.00	780.00	0.18	0.16	11.51	Berm above spectrometer		
46	SSTUDB	53.59	1.00	600.00	780.00	0.08	0.16	5.29	Berm above lambertson		
47	SSTUDC	93.00	1.00	600.00	780.00	0.61	0.19	38.40	Berm above straight dump		
48	SSTUDD	44.75	1.00	600.00	780.00	0.00	0.15	0.02	Berm above momentum dump		
49	SSTUDE	59.00	1.00	600.00	780.00	0.05	0.17	3.17	Berm at fence above access tunnel		
50	SSTUDF	66.72	1.00	600.00	780.00	0.05	0.18	3.28	Access pit behind blocks		
51											
52											
53											
54											
55											
56											

	A	B	C	D	E	F	G	H	I	J	K
57											
58					Current lost =		Pulse length=		Rep Rate =		
59	Run 2	Beam lost above chute			1.92	mA	7.00	microsec	15.00	Hz	
60											
61						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
62		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
63	SSTUD0	41.03	1.00	360.00	540.00	0.03	0.22	2.63	Tank 9 center penetration		
64	SSTUD1	37.84	1.00	360.00	540.00	0.03	0.21	1.99	Between Tank 9 C and Tank 9 D		
65	SSTUD2	47.16	1.00	360.00	540.00	0.12	0.23	9.21	Tank 9 Down stream penetration		
66	SSTUD3	92.34	1.00	360.00	540.00	1.41	0.28	109.93	Door to 400 MeV Labyrinth		
67	SSTUD4	106.60	1.00	360.00	540.00	1.63	0.30	126.96	400 MeV cable penetrations		
68	SSTUD5	326.60	1.00	360.00	540.00	6.18	0.50	483.10	Booster tunnel below st. dump		
69	SSTUD6	39.59	1.00	360.00	540.00	0.02	0.22	1.63	Booster gallery behind st. dump		
70	SSTUD7	213.20	1.00	360.00	540.00	4.27	0.40	333.40	Bottom of 400 MeV Chute		
71	SSTUD8	34.41	1.00	360.00	540.00	0.07	0.20	5.09	Berm at Waveguide pen. 6		
72	SSTUD9	35.03	1.00	360.00	540.00	-0.01	0.20	-0.58	Berm at Waveguide pen. 7		
73	SSTUDA	59.22	1.00	360.00	540.00	0.74	0.23	57.55	Berm above spectrometer		
74	SSTUDB	37.00	1.00	360.00	540.00	0.10	0.20	7.44	Berm above lambertson		
75	SSTUDC	117.80	1.00	360.00	540.00	2.04	0.31	159.71	Berm above straight dump		
76	SSTUDD	49.88	1.00	360.00	540.00	0.47	0.22	36.94	Berm above momentum dump		
77	SSTUDE	40.50	1.00	360.00	540.00	0.05	0.22	3.90	Berm at fence above access tunnel		
78	SSTUDF	45.34	1.00	360.00	540.00	0.04	0.23	3.07	Access pit behind blocks		
79											
80		200SCA read 191 mr/hr									
81											
82											
83											
84											

	A	B	C	D	E	F	G	H	I	J	K
85											
86					Current lost =		Pulse length =		Rep Rate =		
87	Run 3	Beam lost in Spectrometer			4.05	mA	7.00	microsec	15.00	Hz	
88											
89						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
90		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
91	SSTUD0	40.00	1.00	360.00	540.00	0.01	0.22	0.30	Tank 9 center penetration		
92	SSTUD1	38.94	1.00	360.00	540.00	0.05	0.21	1.96	Between Tank 9 C and Tank 9 D		
93	SSTUD2	49.28	1.00	360.00	540.00	0.17	0.23	6.33	Tank 9 Down stream penetration		
94	SSTUD3	115.90	1.00	360.00	540.00	2.00	0.30	73.93	Door to 400 MeV Labyrinth		
95	SSTUD4	120.80	1.00	360.00	540.00	1.98	0.31	73.34	400 MeV cable penetrations		
96	SSTUD5	439.20	1.00	360.00	540.00	9.00	0.56	333.28	Booster tunnel below st. dump		
97	SSTUD6	39.28	1.00	360.00	540.00	0.01	0.22	0.49	Booster gallery behind st. dump		
98	SSTUD7	48.19	1.00	360.00	540.00	0.14	0.23	5.27	Bottom of 400 MeV Chute		
99	SSTUD8	35.97	1.00	360.00	540.00	0.10	0.20	3.86	Berm at Waveguide pen. 6		
100	SSTUD9	40.47	1.00	360.00	540.00	0.13	0.21	4.76	Berm at Waveguide pen. 7		
101	SSTUDA	60.50	1.00	360.00	540.00	0.77	0.23	28.47	Berm above spectrometer		
102	SSTUDB	37.34	1.00	360.00	540.00	0.10	0.20	3.84	Berm above lambertson		
103	SSTUDC	112.80	1.00	360.00	540.00	1.92	0.30	71.09	Berm above straight dump		
104	SSTUDD	40.06	1.00	360.00	540.00	0.23	0.21	8.42	Berm above momentum dump		
105	SSTUDE	40.06	1.00	360.00	540.00	0.04	0.22	1.44	Berm at fence above access tunnel		
106	SSTUDF	44.69	1.00	360.00	540.00	0.02	0.23	0.85	Access pit behind blocks		
107											
108		200SCA read 220 mr/hr									
109											
110											
111											
112											

	A	B	C	D	E	F	G	H	I	J	K
113											
114					Current lost =		Pulse length =		Rep Rate =		
115	Run 4	Beam to Straight Dump			4.11	mA	7.00	microsec	15.00	Hz	
116											
117						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
118		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
119	SSTUD0	57.44	1.00	600.00	720.00	0.07	0.16	2.48	Tank 9 center penetration		
120	SSTUD1	54.72	1.00	600.00	720.00	0.08	0.16	3.08	Between Tank 9 C and Tank 9 D		
121	SSTUD2	65.63	1.00	600.00	720.00	0.14	0.17	4.95	Tank 9 Down stream penetration		
122	SSTUD3	68.66	1.00	600.00	720.00	0.31	0.17	11.27	Door to 400 MeV Labyrinth		
123	SSTUD4	66.63	1.00	600.00	720.00	0.17	0.17	6.11	400 MeV cable penetrations		
124	SSTUD5	655.30	1.00	600.00	720.00	8.24	0.42	300.89	Booster tunnel below st. dump		
125	SSTUD6	55.38	1.00	600.00	720.00	0.06	0.16	2.03	Booster gallery behind st. dump		
126	SSTUD7	64.66	1.00	600.00	720.00	0.12	0.17	4.38	Bottom of 400 MeV Chute		
127	SSTUD8	49.69	1.00	600.00	720.00	0.11	0.15	3.99	Berm at Waveguide pen. 6		
128	SSTUD9	56.41	1.00	600.00	720.00	0.14	0.16	5.10	Berm at Waveguide pen. 7		
129	SSTUDA	62.72	1.00	600.00	720.00	0.35	0.16	12.62	Berm above spectrometer		
130	SSTUDB	54.56	1.00	600.00	720.00	0.15	0.16	5.64	Berm above lambertson		
131	SSTUDC	115.60	1.00	600.00	720.00	1.01	0.20	36.99	Berm above straight dump		
132	SSTUDD	57.13	1.00	600.00	720.00	0.24	0.15	8.67	Berm above momentum dump		
133	SSTUDE	58.22	1.00	600.00	720.00	0.10	0.16	3.77	Berm at fence above access tunnel		
134	SSTUDF	65.59	1.00	600.00	720.00	0.11	0.17	3.96	Access pit behind blocks		
135											
136											
137											
138											
139											
140											

	A	B	C	D	E	F	G	H	I	J	K
141											
142					Current lost =		Pulse length =		Rep Rate =		
143	Run 5	Loss at entrance to Lambertson			0.83	mA	1.00	microsec	15.00	Hz	
144											
145						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
146		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
147	SSTUD0	100.40	1.00	1200.00	1380.00	-0.01	0.14	-9.61	Tank 9 center penetration		
148	SSTUD1	97.28	1.00	1200.00	1380.00	0.02	0.13	30.42	Between Tank 9 C and Tank 9 D		
149	SSTUD2	116.80	1.00	1200.00	1380.00	0.06	0.14	79.53	Tank 9 Down stream penetration		
150	SSTUD3	379.40	1.00	1200.00	1380.00	2.15	0.18	2742.05	Door to 400 MeV Labyrinth		
151	SSTUD4	200.90	1.00	1200.00	1380.00	0.71	0.16	902.94	400 MeV cable penetrations		
152	SSTUD5	357.20	1.00	1200.00	1380.00	1.16	0.22	1476.32	Booster tunnel below st. dump		
153	SSTUD6	99.41	1.00	1200.00	1380.00	0.00	0.14	3.55	Booster gallery behind st. dump		
154	SSTUD7	111.10	1.00	1200.00	1380.00	0.02	0.14	23.81	Bottom of 400 MeV Chute		
155	SSTUD8	98.00	1.00	1200.00	1380.00	0.13	0.13	159.58	Berm at Waveguide pen. 6		
156	SSTUD9	106.80	1.00	1200.00	1380.00	0.12	0.13	157.74	Berm at Waveguide pen. 7		
157	SSTUDA	159.30	1.00	1200.00	1380.00	0.62	0.14	794.77	Berm above spectrometer		
158	SSTUDB	95.31	1.00	1200.00	1380.00	0.08	0.13	100.09	Berm above lambertson		
159	SSTUDC	118.50	1.00	1200.00	1380.00	0.20	0.14	252.30	Berm above straight dump		
160	SSTUDD	96.94	1.00	1200.00	1380.00	0.13	0.13	169.88	Berm above momentum dump		
161	SSTUDE	111.50	1.00	1200.00	1380.00	0.10	0.14	125.10	Berm at fence above access tunnel		
162	SSTUDF	110.70	1.00	1200.00	1380.00	-0.01	0.14	-10.97	Access pit behind blocks		
163											
164		200SCA read 240mr/hr (MUX was 228)									
165											
166											
167											
168											

	A	B	C	D	E	F	G	H	I	J	K
169											
170											
171											
172	Background	Losses in High Energy end of SCC Linac									
173			1 count equal	2.50E-06	rem						
174		Counts	Multipier	Time (sec)		rem/sec	error				
175	SSTUD0	26.69	1.00	600.00		1.11E-07	2.15E-08		Tank 7 center penetration		
176	SSTUD1	50.28	1.00	600.00		2.10E-07	2.95E-08		Tank 8 center penetration		
177	SSTUD2	33.91	1.00	600.00		1.41E-07	2.43E-08		Tank 8 downstream penetration		
178	SSTUD3	49.22	1.00	600.00		2.05E-07	2.92E-08		Between Tank 9 U and Tank 8 D		
179	SSTUD4	45.78	1.00	600.00		1.91E-07	2.82E-08		Tank 9 upstream penetration		
180	SSTUD5	42.97	1.00	600.00		1.79E-07	2.73E-08		Tank 9 center penetration		
181	SSTUD6	43.13	1.00	600.00		1.80E-07	2.74E-08		Between Tank 9 C and Tank 9 D		
182	SSTUD7	47.03	1.00	600.00		1.96E-07	2.86E-08		Tank 9 downstream penetration		
183	SSTUD8	44.50	1.00	600.00		1.85E-07	2.78E-08		Berm at Waveguide pen. 5		
184	SSTUD9	41.97	1.00	600.00		1.75E-07	2.70E-08		Berm at Waveguide pen. 6		
185	SSTUDA	46.28	1.00	600.00		1.93E-07	2.83E-08		Berm at Waveguide pen. 7		
186	SSTUDB	40.81	1.00	600.00		1.70E-07	2.66E-08		Berm above lambertson		
187	SSTUDC	39.91	1.00	600.00		1.66E-07	2.63E-08		Door to 400 MeV Labyrinth		
188	SSTUDD	43.88	1.00	600.00		1.83E-07	2.76E-08		400 Mev cable penetrations		
189	SSTUDE	47.47	1.00	600.00		1.98E-07	2.87E-08		Bottom of 400 MeV chute		
190	SSTUDF	86.00	1.00	600.00		3.58E-07	3.86E-08		Booster tunnel below st. dump		
191											
192											
193											
194											
195											
196											

	A	B	C	D	E	F	G	H	I	J	K
197											
198					Current lost =		Pulse length =		Rep Rate =		
199	Run 6	Loss at entrance to Lambertson			0.83	mA	1.00	microsec	15.00	Hz	
200											
201						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
202		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
203	SSTUD0	50.25	1.00	975.00	1095.00	0.01	0.11	18.10	Tank 7 center penetration		
204	SSTUD1	96.31	1.00	975.00	1095.00	0.04	0.15	53.44	Tank 8 center penetration		
205	SSTUD2	66.56	1.00	975.00	1095.00	0.04	0.12	54.91	Tank 8 downstream penetration		
206	SSTUD3	96.41	1.00	975.00	1095.00	0.06	0.15	77.34	Between Tank 9 U and Tank 8 D		
207	SSTUD4	85.03	1.00	975.00	1095.00	0.01	0.14	17.41	Tank 9 upstream penetration		
208	SSTUD5	78.78	1.00	975.00	1095.00	0.00	0.14	4.23	Tank 9 center penetration		
209	SSTUD6	77.97	1.00	975.00	1095.00	-0.01	0.14	-8.72	Between Tank 9 C and Tank 9 D		
210	SSTUD7	92.28	1.00	975.00	1095.00	0.06	0.15	75.78	Tank 9 downstream penetration		
211	SSTUD8	80.84	1.00	975.00	1095.00	0.00	0.14	-4.38	Berm at Waveguide pen. 5		
212	SSTUD9	76.63	1.00	975.00	1095.00	0.00	0.14	0.41	Berm at Waveguide pen. 6		
213	SSTUDA	85.50	1.00	975.00	1095.00	0.01	0.14	12.21	Berm at Waveguide pen. 7		
214	SSTUDB	76.97	1.00	975.00	1095.00	0.02	0.13	29.27	Berm above lambertson		
215	SSTUDC	300.40	1.00	975.00	1095.00	2.10	0.19	2673.48	Door to 400 MeV Labyrinth		
216	SSTUDD	153.70	1.00	975.00	1095.00	0.68	0.16	864.89	400 Mev cable penetrations		
217	SSTUDE	87.84	1.00	975.00	1095.00	0.01	0.14	14.18	Bottom of 400 MeV chute		
218	SSTUDF	278.90	1.00	975.00	1095.00	1.13	0.22	1432.70	Booster tunnel below st. dump		
219											
220		200SCA read 248 mr/hr (MUX was 230)									
221											
222											
223											
224											

	A	B	C	D	E	F	G	H	I	J	K
225											
226					Current lost =		Pulse length =		Rep Rate =		
227	Run 7	Loss at entrance to Module 7			0.70	mA	2.00	microsec	15.00	Hz	
228											
229						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
230		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
231	SSTUD0	64.59	1.00	1200.00	1380.00	0.02	0.11	18.02	Tank 7 center penetration		
232	SSTUD1	199.40	1.00	1200.00	1380.00	0.63	0.16	471.13	Tank 8 center penetration		
233	SSTUD2	152.70	1.00	1200.00	1380.00	0.56	0.14	420.23	Tank 8 downstream penetration		
234	SSTUD3	174.30	1.00	1200.00	1380.00	0.46	0.16	343.65	Between Tank 9 U and Tank 8 D		
235	SSTUD4	130.30	1.00	1200.00	1380.00	0.19	0.14	140.66	Tank 9 upstream penetration		
236	SSTUD5	136.10	1.00	1200.00	1380.00	0.28	0.14	209.64	Tank 9 center penetration		
237	SSTUD6	123.00	1.00	1200.00	1380.00	0.18	0.14	133.88	Between Tank 9 C and Tank 9 D		
238	SSTUD7	208.10	1.00	1200.00	1380.00	0.75	0.16	562.11	Tank 9 downstream penetration		
239	SSTUD8	107.70	1.00	1200.00	1380.00	0.04	0.14	30.09	Berm at Waveguide pen. 5		
240	SSTUD9	104.30	1.00	1200.00	1380.00	0.06	0.14	43.70	Berm at Waveguide pen. 6		
241	SSTUDA	132.20	1.00	1200.00	1380.00	0.19	0.15	144.88	Berm at Waveguide pen. 7		
242	SSTUDB	95.56	1.00	1200.00	1380.00	0.01	0.13	9.55	Berm above lambertson		
243	SSTUDC	338.00	1.00	1200.00	1380.00	1.85	0.18	1384.91	Door to 400 MeV Labyrinth		
244	SSTUDD	185.30	1.00	1200.00	1380.00	0.63	0.15	474.62	400 Mev cable penetrations		
245	SSTUDE	150.40	1.00	1200.00	1380.00	0.31	0.15	231.86	Bottom of 400 MeV chute		
246	SSTUDF	271.50	1.00	1200.00	1380.00	0.55	0.20	414.56	Booster tunnel below st. dump		
247											
248		200SCA read 226 mr/hr (MUX was 212)									
249											
250											
251											
252											

	A	B	C	D	E	F	G	H	I	J	K
253											
254					Current lost =		Pulse length =		Rep Rate =		
255	Run 8	Loss at entrance to Module 6			1.50	mA	2.00	microsec	15.00	Hz	
256											
257						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
258		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
259	SSTUD0	64.66	1.00	1200.00	1380.00	0.02	0.11	8.59	Tank 7 center penetration		
260	SSTUD1	172.10	1.00	1200.00	1380.00	0.42	0.16	148.20	Tank 8 center penetration		
261	SSTUD2	149.60	1.00	1200.00	1380.00	0.54	0.14	187.97	Tank 8 downstream penetration		
262	SSTUD3	167.10	1.00	1200.00	1380.00	0.40	0.16	141.47	Between Tank 9 U and Tank 8 D		
263	SSTUD4	214.30	1.00	1200.00	1380.00	0.82	0.16	286.14	Tank 9 upstream penetration		
264	SSTUD5	105.50	1.00	1200.00	1380.00	0.05	0.14	17.51	Tank 9 center penetration		
265	SSTUD6	102.40	1.00	1200.00	1380.00	0.02	0.14	8.40	Between Tank 9 C and Tank 9 D		
266	SSTUD7	127.10	1.00	1200.00	1380.00	0.14	0.15	49.69	Tank 9 downstream penetration		
267	SSTUD8	111.90	1.00	1200.00	1380.00	0.07	0.14	25.07	Berm at Waveguide pen. 5		
268	SSTUD9	144.80	1.00	1200.00	1380.00	0.36	0.14	126.71	Berm at Waveguide pen. 6		
269	SSTUDA	116.10	1.00	1200.00	1380.00	0.07	0.14	25.35	Berm at Waveguide pen. 7		
270	SSTUDB	95.41	1.00	1200.00	1380.00	0.01	0.13	4.06	Berm above lambertson		
271	SSTUDC	385.20	1.00	1200.00	1380.00	2.20	0.18	770.19	Door to 400 MeV Labyrinth		
272	SSTUDD	177.40	1.00	1200.00	1380.00	0.57	0.15	200.75	400 Mev cable penetrations		
273	SSTUDE	111.20	1.00	1200.00	1380.00	0.02	0.14	5.30	Bottom of 400 MeV chute		
274	SSTUDF	223.20	1.00	1200.00	1380.00	0.19	0.20	66.68	Booster tunnel below st. dump		
275											
276		200SCA read 244 mr/hr (MUX was 231)									
277											
278											
279											
280											

	A	B	C	D	E	F	G	H	I	J	K
281											
282											
283											
284	Background	Losses in High Energy end of SCC Linac									
285			1 count equal	2.50E-06	rem						
286		Counts	Multipier	Time (sec)		rem/sec	error				
287	SSTUD0	42.03	1.00	900.00		1.17E-07	1.80E-08		Tank 7 center penetration		
288	SSTUD1	81.97	1.00	900.00		2.28E-07	2.51E-08		Tank 8 center penetration		
289	SSTUD2	58.47	1.00	900.00		1.62E-07	2.12E-08		Tank 8 downstream penetration		
290	SSTUD3	80.03	1.00	900.00		2.22E-07	2.48E-08		Between Tank 9 U and Tank 8 D		
291	SSTUD4	69.72	1.00	900.00		1.94E-07	2.32E-08		Tank 9 upstream penetration		
292	SSTUD5	81.59	1.00	900.00		2.27E-07	2.51E-08		Between Tank 8 U and Tank 8 C		
293	SSTUD6	113.80	1.00	900.00		3.16E-07	2.96E-08		Tank 8 upstream penetration		
294	SSTUD7	70.69	1.00	900.00		1.96E-07	2.34E-08		Between Tank 8 U and Tank 7 D		
295	SSTUD8	72.75	1.00	900.00		2.02E-07	2.37E-08		Berm at Waveguide pen. 5		
296	SSTUD9	69.16	1.00	900.00		1.92E-07	2.31E-08		Berm at Waveguide pen. 6		
297	SSTUDA	72.88	1.00	900.00		2.02E-07	2.37E-08		Berm at Waveguide pen. 7		
298	SSTUDB	58.78	1.00	900.00		1.63E-07	2.13E-08		Berm above lambertson		
299	SSTUDC	61.13	1.00	900.00		1.70E-07	2.17E-08		Door to 400 MeV Labyrinth		
300	SSTUDD	69.41	1.00	900.00		1.93E-07	2.31E-08		400 Mev cable penetrations		
301											
302											
303											
304											
305											
306											
307											
308											

	A	B	C	D	E	F	G	H	I	J	K
309											
310					Current lost =		Pulse length =		Rep Rate =		
311	Run 9	Loss at entrance to Module 5			2.50	mA	7.00	microsec	15.00	Hz	
312											
313						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
314		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
315	SSTUD0	52.25	1.00	900.00	1110.00	0.00	0.11	0.25	Tank 7 center penetration		
316	SSTUD1	305.30	1.00	900.00	1110.00	2.04	0.21	122.52	Tank 8 center penetration		
317	SSTUD2	587.40	1.00	900.00	1110.00	5.15	0.26	309.17	Tank 8 downstream penetration		
318	SSTUD3	168.10	1.00	900.00	1110.00	0.69	0.17	41.64	Between Tank 9 U and Tank 8 D		
319	SSTUD4	203.90	1.00	900.00	1110.00	1.18	0.18	70.75	Tank 9 upstream penetration		
320	SSTUD5	222.10	1.00	900.00	1110.00	1.21	0.19	72.88	Between Tank 8 U and Tank 8 C		
321	SSTUD6	398.60	1.00	900.00	1110.00	2.58	0.24	154.95	Tank 8 upstream penetration		
322	SSTUD7	96.31	1.00	900.00	1110.00	0.09	0.14	5.48	Between Tank 8 U and Tank 7 D		
323	SSTUD8	128.80	1.00	900.00	1110.00	0.39	0.15	23.45	Berm at Waveguide pen. 5		
324	SSTUD9	97.38	1.00	900.00	1110.00	0.12	0.14	7.25	Berm at Waveguide pen. 6		
325	SSTUDA	93.09	1.00	900.00	1110.00	0.03	0.14	1.92	Berm at Waveguide pen. 7		
326	SSTUDB	75.25	1.00	900.00	1110.00	0.03	0.13	1.65	Berm above lambertson		
327	SSTUDC	264.20	1.00	900.00	1110.00	1.89	0.19	113.28	Door to 400 MeV Labyrinth		
328	SSTUDD	207.30	1.00	900.00	1110.00	1.22	0.18	73.02	400 Mev cable penetrations		
329											
330		200SCA read 224 mr/hr (MUX was 208)									

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3											
4	Background	A									
5			1 count equal	2.50E-06	rem						
6		Counts	Multipier	Time (sec)		rem/sec	error				
7	SSTUD0	43.06	1.00	600.00		1.79E-07	2.73E-08	10 feet usptream			
8	SSTUD1	43.03	1.00	600.00		1.79E-07	2.73E-08	8 feet upstream			
9	SSTUD2	28.75	1.00	600.00		1.20E-07	2.23E-08	6 feet upstream			
10	SSTUD3	45.03	1.00	600.00		1.88E-07	2.80E-08	4 feet upstream			
11	SSTUD4	36.91	1.00	600.00		1.54E-07	2.53E-08	2 feet upstream			
12	SSTUD5	44.00	1.00	600.00		1.83E-07	2.76E-08	assumed position of dump (doghouse)			
13	SSTUD6	32.84	1.00	600.00		1.37E-07	2.39E-08	2 feet downstream			
14	SSTUD7	34.78	1.00	600.00		1.45E-07	2.46E-08	4 feet downstream			
15	SSTUD8	62.22	1.00	600.00		2.59E-07	3.29E-08	Booster tunnel - 40' upstream of chute			
16	SSTUD9	109.50	1.00	600.00		4.56E-07	4.36E-08	Booster tunnel - base of chute			
17	SSTUDA	96.13	1.00	600.00		4.01E-07	4.09E-08	Booster tunnel - below dump #1			
18	SSTUDB	79.81	1.00	600.00		3.33E-07	3.72E-08	Booster tunnel - 40' downstream of chute			
19	SSTUDC	0.00	1.00	1.00		0.00E+00	0.00E+00				
20	SSTUDD	0.00	1.00	1.00		0.00E+00	0.00E+00				
21	SSTUDE	0.00	1.00	1.00		0.00E+00	0.00E+00				
22	SSTUDF	0.00	1.00	1.00		0.00E+00	0.00E+00				
23											
24											
25											
26											
27											
28											

	A	B	C	D	E	F	G	H	I	J	K
29											
30					Current lost =		Pulse length =		Rep Rate =		
31	Run 1 A	Longitudinal Run			6.20	mA	7.00	microsec	15.00	Hz	
32											
33						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
34		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
35	SSTUD0	54.31	1.00	600.00	720.00	0.04	0.16	0.96	10 feet usptream		
36	SSTUD1	63.50	1.00	600.00	720.00	0.18	0.17	4.31	8 feet upstream		
37	SSTUD2	65.59	1.00	600.00	720.00	0.47	0.16	11.28	6 feet upstream		
38	SSTUD3	92.19	1.00	600.00	720.00	0.57	0.19	13.85	4 feet upstream		
39	SSTUD4	123.00	1.00	600.00	720.00	1.18	0.20	28.56	2 feet upstream		
40	SSTUD5	163.60	1.00	600.00	720.00	1.66	0.23	40.21	assumed position of dump (doghouse)		
41	SSTUD6	159.80	1.00	600.00	720.00	1.81	0.22	43.69	2 feet downstream		
42	SSTUD7	124.70	1.00	600.00	720.00	1.24	0.20	30.11	4 feet downstream		
43	SSTUD8	95.59	1.00	600.00	720.00	0.31	0.20	7.59	Booster tunnel - 40' upstream of chute		
44	SSTUD9	131.00	1.00	600.00	720.00	-0.01	0.25	-0.15	Booster tunnel - base of chute		
45	SSTUDA	774.90	1.00	600.00	720.00	9.89	0.45	239.35	Booster tunnel - below dump #1		
46	SSTUDB	95.88	1.00	600.00	720.00	0.00	0.22	0.04	Booster tunnel - 40' downstream of chute		
47	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
48	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
49	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
50	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
51											
52		Mux =	0.6 - Berm Dump #1 US (Spectrometer)								
53			2.1 - Berm Dump #1 DS								
54			1.6 - Booster Chute								
55			11.6 - Booster Tunnel Dump #1								
56											

	A	B	C	D	E	F	G	H	I	J	K
57											
58					Current lost =		Pulse length =		Rep Rate =		
59	Run 2 A	Transverse - Coarse			6.20	mA	7.00	microsec	15.00	Hz	
60											
61						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
62		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
63	SSTUD0	95.28	1.00	600.00	720.00	0.65	0.19	15.83	4 feet west of SSTUD7		
64	SSTUD1	139.30	1.00	600.00	720.00	1.31	0.21	31.81	2 feet west of SSTUD7		
65	SSTUD2	146.50	1.00	600.00	720.00	1.68	0.21	40.65	2 feet east of SSTUD7		
66	SSTUD3	134.30	1.00	600.00	720.00	1.20	0.21	29.13	4 feet east of SSTUD7		
67	SSTUD4	102.30	1.00	600.00	720.00	0.87	0.19	21.05	6 feet east of SSTUD7		
68	SSTUD5	169.80	1.00	600.00	720.00	1.76	0.23	42.46	assumed position of dump (doghouse)		
69	SSTUD6	158.80	1.00	600.00	720.00	1.79	0.22	43.33	2 feet downstream		
70	SSTUD7	173.20	1.00	600.00	720.00	1.97	0.22	47.71	1 foot downstream		
71	SSTUD8	94.69	1.00	600.00	720.00	0.30	0.20	7.27	Booster tunnel - 40' upstream of chute		
72	SSTUD9	130.90	1.00	600.00	720.00	-0.01	0.25	-0.18	Booster tunnel - base of chute		
73	SSTUDA	773.90	1.00	600.00	720.00	9.88	0.45	238.99	Booster tunnel - below dump #1		
74	SSTUDB	97.00	1.00	600.00	720.00	0.02	0.22	0.45	Booster tunnel - 40' downstream of chute		
75	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
76	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
77	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
78	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
79											
80		Mux =	0.6 - Berm Dump #1 US (Spectrometer)								
81			2.3 - Berm Dump #1 DS								
82			1.6 - Booster Chute								
83			11.6 - Booster Tunnel Dump #1								
84											

	A	B	C	D	E	F	G	H	I	J	K
85											
86					Current lost =		Pulse length =		Rep Rate =		
87	Run 3 A	Transverse - Fine			6.20	mA	7.00	microsec	15.00	Hz	
88											
89						Measured		Extrapolated	to 35 mA, 30 microsec, 15 Hz		
90		Counts	Multiplier	Beam Time	Total Time	mrem/hr	error	mrem/hr			
91	SSTUD0	151.60	1.00	600.00	755.00	1.46	0.22	35.35	2 feet west of SSTUD7		
92	SSTUD1	169.00	1.00	600.00	755.00	1.72	0.23	41.68	1 feet west of SSTUD7		
93	SSTUD2	181.20	1.00	600.00	755.00	2.18	0.23	52.63	1 feet east of SSTUD7		
94	SSTUD3	170.10	1.00	600.00	755.00	1.70	0.23	41.17	2 feet east of SSTUD7		
95	SSTUD4	153.70	1.00	600.00	755.00	1.61	0.22	38.92	3 feet east of SSTUD7		
96	SSTUD5	177.90	1.00	600.00	755.00	1.84	0.24	44.47	assumed position of dump (doghouse)		
97	SSTUD6	166.90	1.00	600.00	755.00	1.88	0.22	45.57	2 feet downstream		
98	SSTUD7	179.30	1.00	600.00	755.00	2.03	0.23	49.19	1 foot downstream		
99	SSTUD8	96.81	1.00	600.00	755.00	0.28	0.21	6.72	Booster tunnel - 40' upstream of chute		
100	SSTUD9	135.50	1.00	600.00	755.00	-0.03	0.26	-0.83	Booster tunnel - base of chute		
101	SSTUDA	775.50	1.00	600.00	755.00	9.82	0.46	237.53	Booster tunnel - below dump #1		
102	SSTUDB	101.10	1.00	600.00	755.00	0.01	0.23	0.24	Booster tunnel - 40' downstream of chute		
103	SSTUDC	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
104	SSTUDD	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
105	SSTUDE	0.00	1.00	1.00	1.00	0.00	0.00	0.00			
106	SSTUDF	0.00	1.00	1.00	1.00	0.00	0.00	0.00			

Fermilab
Accelerator Division Headquarters

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NOV 17 1993
ACCELERATOR DIVISION
ADMINISTRATION AND ES&H

November 17, 1993

To: Don Cossairt

From: Steve Holmes S. D. Holmes

SUBJECT: LINAC SHIELDING ASSESSMENT SUPPLEMENT

Attached is the supplement that has been prepared for the upgraded Linac Shielding Assessment as requested in your memo of October 19. I ask that the ES&H Section review the enclosed information and concur. Once you have done so the Accelerator Division will regard this phase of the linac upgrade shielding assessment as complete. I still expect to forward the full intensity assessment to ES&H once it becomes available.

cc

D. Bogert
R. Ducar
P. Lesiak
C. Schmidt

Fermilab
Linac

November 4, 1993

TO: S. Holmes

FROM: C. Schmidt *Charles Schmidt*

SUBJECT: Re: ES&H Review of the Linac Shielding Assessment

This memo is in reply to the October 19 memo of D. Cossairt to S. Holmes regarding the Linac Shielding Assessment and the minutes of a review meeting on October 15 by D. Boehnlein and others.

First, it was pointed out in the meeting that the shielding assessment was dated September 21, <u>1992</u> and should be 1993. The title and text of this document correctly gives the year as 1993. No adjustment was felt necessary.

Dose Rates, Data Spreadsheets, and Negative Dose Rates

Since three concerns are related, I shall first comment on the three areas of Dose Rate calculations, Data Spreadsheets and Negative Dose Rates. The dose rates (mrem/hr) were calculated by using the output counts of the chipmunks (calibrated by the ES&H Section/IMAC), where each count equals 2.5 microrem. The pulse train was fed into a frequency-to-voltage converter and read into the control system to give an analog measure of the detector output in counts. Thus fractional counts are an artifact of the analog conversion. On the spreadsheets, column A gives the detector name and column B gives the total counts for the integrating time as given in column D or E. Column C allows for a deadtime multiplier to the counts if it were necessary. A multiplier of one was used and gives no change.

The first page of a run-set gives the background counts with no beam. These counts are mostly due to the internal source of the detector but occasionally there is additional real background as for the booster tunnel (SSTUD5). Column F is the measured radiation due to beam with the background removed. For the beam measurements the total counting time is a few minutes longer than the beam time to allow counts stored in the detector to be discharged and collected (time constant=20 sec). The background subtraction is based on the total counting time, column E, while the net hourly dose rate for the tested beam power is from the beam on time for the measurement, column D. Column G is the square root statistical error. Column H is the radiation dose equivalent rate that would be achieved if beam were extrapolated to the full possible beam conditions even if other limiting factors such as interlocked detectors would prevent the condition.

Thus:
For the background,

$$\text{background rate} = \frac{\text{background counts X 2.5 µrem/count}}{\text{total time}}.$$

For the beam measurements,

background dose = background rate (above) X total time of run,

the measured radiation due to beam is therefore:

$$\text{mrem/hr} = 3600 \text{ X } \frac{\text{(counts X 2.5 µrem/count X multiplier) - background dose}}{\text{beam time}}.$$

The radiation dose equivalent rate extrapolated to maximum possible beam current is therefore:

$$\text{extrapolated mrem/hr} = \frac{\text{measured mrem/hr X 35 mA X 30 µsec X 15 Hz}}{\text{current loss X pulse length X rep rate}}.$$

Errors are statistical, based on the square root of the number and added in quadrature.

For Run 1, SSTUD0:
The background rate is:

44.09 X 2.5 µrem / 600 sec = 0.184 µrem/sec

The measured radiation is:

$$3600 \text{ X } \frac{\text{(57.47 X 2.5 µrem) - (0.184 X 780 sec)}}{\text{600 sec}}$$

= 2.3 µrem/hr = 0.00 mrem/hr.

Extrapolating from 2.4 mA, 7 µsec, and 15 Hz,
the extrapolated radiation is:

2.3 µrem/hr X 35 X 30 X 15 / 2.4 / 7 / 15
= 143 µrem/hr = 0.14 mrem/hr.

The extrapolated radiation assumes that no detector would have turned off the beam before this level was reached. In many cases the beam would have been tripped well before the extrapolated rate.

Negative values, as seen in some cases, are simply statistical differences between the background and the null measurements and caused by subtracting the background

Posting

In regard to posting, there are no outdoor areas around the Linac enclosure that require posting. All of the areas have levels below the guidelines requiring posting or are protected by detectors to levels that are below the posting requirement. As noted by T. Leveling the posting criteria does conform to the present Fermilab Radiological Control Manual and Articles 232 and 238 do not become effective until January 7, 1995. It is our judgment that Article 232 would not require us to post in any event since we do not anticipate an occupancy of 40 hours in a year by any individual on the berm.

Only two areas mentioned in the assessment are posted as radiation areas. These are the Linac gallery lower level and the Booster beam enclosure. The entire Booster beam enclosure has historically been posted as a radiation area because of residual radioactivity due to Booster accelerator operations. That posting is now additionally required because dose equivalent rates under the normal condition of running beam to the Linac straight (#1) dump may be as high as 10 mrem/hr in the proximity of the straight dump.

Regarding the posting in the Linac lower gallery, the posting was necessary under the previous assessment and is still necessary in the low energy part of the gallery where that assessment applies. For the high energy end, the detectors have some spacing were between the detectors the radiation dose equivalent rate could be higher (not exceeding a factor of two as measured) so the signs need to remain.

High extrapolated losses in the Booster tunnel

The issue of high extrapolated losses in the Booster tunnel were discussed and correctly understood by the review committee. High levels in the Booster tunnel would be prevented by the detectors in the Booster tunnel (set to trip at 10 mrem/hr) and generally even sooner by other detectors in the Linac areas. For example, the 400-MeV labyrinth scarecrow detector (200SCA) is highly sensitive to losses near the Lambertson and causes a trip when the Booster is only 1-2 mrem/hr. In these instances extrapolated losses are meaningless and scaling to the first detector to trip is significant. This was discussed and used in the Assessment. It is a necessary and permissible part of the Linac protection system.

In regard to specific issues raised in D. Cossart's memo, posting has been discussed.

Accuracy is variable from a few to 20-30% for toroid current measurements but generally not significant to the final determination. Current monitors, which can have large errors at low current are used to extrapolate losses to full beam current. The current toroids are accurate to +-1/2 mA at the calibrated current of 50 mA due to noise. They are linear through zero but retain a noise variation of ~1/2 mA. At small currents this is significant and several readings are visually averaged to determine a best value. Even with a large error this would not meaningfully change the outcome of the assessment. The levels were in all cases sufficient to require a detector or would be limited by a detector. Reproducibility of the radiation measurements is within a few percent for similar runs with significant levels of radiation. Relative values between detectors are highly reproducible.

Higher intensity or greater precision would not significantly change the assessment. The Linac shielding ultimately relies on interlocked detectors and not on the beam envelope. In only one instance is it necessary to instigate an administrative control of not operating full intensity 15 Hz Linac beam to the momentum dump for more than 3/4 of an hour for any one hour period. This is highly unlikely since presently more than a few Hertz Linac operation causes trips at the 400-MeV labyrinth and is not a meaningful or permitted mode of operation.

The question of V. Cupps regarding maximum total integrated dose during a detector trip by high losses has been computed by T. Leveling. He has found that the dose is very small (<0.4 mrem per a trip maximum). He will be disseminating his work at a later time.

In addition to replying to you (S. Holmes) I am also sending copies of this memo to others in the division who are concerned with this matter. Once accepted, a copy of this memo should go into the Division Document Files for the Linac shielding assessment with all approvals.

cc: D. Filnley
T. Kroc
D. Bogert, Chairman, Assessment Committee
T. Leveling
H. Casebolt

Fermilab
ES&H Section

RECEIVED
OCT 25 1993
ACCELERATOR DIVISION
HEADQUARTERS

October 19, 1993

TO: Steve Holmes

FROM: Don Cossairt

SUBJECT: ES&H Section Review of Linac Upgrade Shielding Assessment

The Linac Upgrade shielding assessment has been reviewed by members of the ES&H Section's Radiation Physics Staff Group and myself. These members of the Radiation Physics Staff Group met with several members of the Accelerator Division on October 15 to discuss the assessment and ask for clarification of several points. The minutes of this meeting are attached. The attendees from the Accelerator Division satisfactorily addressed the concerns of the ES&H attendees and it is clear that the Accelerator Division has given adequate consideration to the potential radiation hazards associated with the Linac upgrade. However, the shielding assessment document itself does not clearly explain how the studies were performed and how the Accelerator Division intends to use the information they provide. These concerns are detailed in the attached minutes. Insofar as it must provide a record for future reference, the shielding assessment document should be revised or supplemented with an appendix containing the necessary clarifications.

In addition to the meeting of October 15, Paul Neeson of the DOE Chicago Operations Office Environment, Safety, and Health Division met with David Boehnlein and myself to discuss the shielding assessment. As you probably recall, Paul is a key member of the Working Group of Fermilab and DOE personnel established by C. Langenfeld and J. Peoples to review this project. During this meeting, Mr. Neeson raised some of the same questions that had previously been raised by the Radiation Physics Group reviewers, including those pertaining to posting and interlocks. He also requested information concerning how the beam current loss was measured during the assessment studies. He also wanted to obtain some idea of the accuracy of those beam current loss measurements, which obviously feeds directly into the accuracy of the assessment since the beam current losses are the basis of the normalization.

Since it is apparent from the October 15 meeting that the Linac Department did a very thorough and well thought-out job of conducting the shielding studies, I am giving provisional approval to the shielding assessment, with the proviso that the Linac Department will issue a revision of or supplement to the shielding assessment document that will contain the clarifications requested by the Radiation Physics Group and the Department of Energy. This revision/supplement will itself be subject to review and approval by the ES&H Section. I would like to receive from you a schedule for revising the assessment.

Att.

cc w/att.:
D. Boehnlein
B. Chrisman
D. Finley
T. Miller
J. Peoples
K. Stanfield
R. Stefanski
D. Theriot

To: Chuck Schmidt
Dave Finley
Could you please work together to develop the requested information.

Linac Upgrade Shielding Assessment Meeting Minutes

October 15, 1993

Attendees: D. Boehnlein, H. Casebolt, V. Cupps, N. Grossman, T. Kroc, G. Lauten, T. Leveling, C. Schmidt, K. Vaziri

This meeting was held to discuss the contents of the *Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning* by Charles Schmidt and Thomas Kroc of the Linac Department. Although it is clear that a good deal of effort went into the studies described in this document, the paper itself does not adequately explain several aspects of the assessment. The clarification of these aspects for the members of the ES&H Section was the point of this meeting. The attendees from the Accelerator Division gave this clarification verbally in the course of the meeting but it is necessary that the document be revised or supplemented before it can be used as a stand-alone reference. The points addressed at the meeting are listed below.

Posting The references in the text to "posted" and "unposted" areas are unclear to the ES&H Radiation Physics Staff. A complete description of the posting and interlock devices in use should be given in the document. The posting criteria in use does not seem to conform to Article 238 of the *Fermilab Radiological Control Manual*. T. Leveling pointed out that this article is not due to be implemented until January 7, 1995. However, the ES&H Section strongly recommends that some consideration be given to the implementation prior to that time.

Data Spreadsheets The data from the assessment measurements are contained in a series of spreadsheets. It is unclear from the document how the *Measured mrem/hr* field is calculated from the raw data. C. Schmidt and T. Kroc will provide an explanation of the calculation in the document revision/supplement. D. Boehnlein had additional questions regarding the data fields, which were answered by C. Schmidt and T. Kroc:

- The decimal numbers in the *Counts* field is an artifact of the frequency-to voltage conversion of the detector signal along with the subsequent reconversion of the analog voltage datum back to a digital datum.

- The difference between *Beam Time* and *Total Time* is due to the time constant of the Chipmunk.

- The *error* column contains the statistical error of the measured dose rate.

An explanation of the spreadsheet fields should also be included in the revision/supplement.

Extrapolation of Dose Rates T. Leveling and C. Schmidt said that the scaling method used is well supported by measurements near loss points under accident conditions.

Negative Dose Rates Comparison of these data with their associated errors indicates that they are not statistically different from zero.

Beam Loss at the Lambertson D. Boehnlein was concerned about the extremely high extrapolated dose rate in the Booster tunnel from such a loss. H. Casebolt explained that only a small amount of beam was actually lost at the Lambertson, the rest going on to the Straight Dump, which is much nearer to the Booster tunnel. It was pointed out that the beam would be tripped well before such levels were reached in the Booster tunnel.

V. Cupps asked about the total integrated dose to hypothetical personnel in the Booster enclosure in the event of such a loss. T. Leveling replied that the dose would be well under a mrem. The revision/supplement to the assessment document should include this calculation.

Distribution
Attendees