MI-0219

"Ground Water, Air-Borne & Soil Activation from the Operation of the MI-40 Beam Absorber During the FMI Era"

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GROUND WATER , AIR-BORNE AND SOIL ACTIVATION FROM
THE OPERATION OF THE MI-40 BEAM ABSORBER
DURING THE FMI ERA

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MI Note 0219

Beam absorber built near the MI-40 straight section [1,2] will be used during the Fermilab Main Injector commissioning and operation. This will also be used during the Recycler Ring commissioning and its study using proton beam. A proton beam of energy from 8 GeV to 150 GeV will be aborted towards the absorber and stopped in it. The interaction of these particles (and secondaries) with the absorber and its surrounding soil induces radioactivity in them which will be of concern for operation of the Main Injector.

In this report we address the ground water, air-borne and soil radioactivations arising from the use of the absorber. The total beam transported and aborted from the Recycler Ring towards the MI40 beam absorber is expected to be only a fraction of a percent of that from the Main Injector. The precautionary steps established for the Main Injector operation to protect personnel from radiation should provide enough coverage both for the MI and Recycler Ring. Hence, in the rest of the report we concentrate only on the Main Injector operating conditions.

1. Ground Water Activation :

The ground water issue related to the MI40 beam absorber is explained in detail in ref. [2]. Here we summarize the final results of our analysis. The ground water activation arising from the MI40 beam absorber is estimated by using concentration model [3,4]

The following quantities are used in our calculations :

- the highest star density in the uncontrolled soil = $5.0\text{x}10^{-10}$ star/cc, (from CASIM calculations).
- the average star density in the soil is $3.65\ \text{x}10^{-11}$ star/cc[1],

[1] In reference [2], adopts an average star density in the soil as $0.019\ \text{X}\ 5.0\text{x}10^{-10}$ star/cc which is in accordance with the reference [3]. However, a more accurate estimation of the average star density should take into account of the detailed geometry of the surrounding. In the present case such an estimation is $0.073\ \text{x}\ 5.0\text{x}10^{-10}$ star/cc,

- the distance between the lowest boundary of "99% volume" [3] and the aquifer (dolomite) = 8.53 ft,
- the density of the soil = 2.25 gm/cc (moist soil),
- the weight of the water divided by the weight of the soil that corresponds to 90% leaching [3,4] : 0.27 for ^3H and 0.52 for ^{22}Na.

Using Eq. 3 of reference 3, we get the initial concentration

C_i (^3H) = 9.0×10^{-19} pCi/ml-year/150GeV proton
C_i (^{22}Na) = 2.0×10^{-20} pCi/ml-year/150GeV proton

Assuming instantaneous mixing of the produced radioactive nuclei in the ground water, we obtain the final concentrations as

C_f (^3H) = 1.69×10^{-18} pCi/ml-year/150GeV proton
C_f (^{22}Na) = 5.8×10^{-21} pCi/ml-year/150GeV proton

The EPA and DOE, however, allow 20 pCi/ml-year from ^3H nuclei and 0.4 pCi/ml-year from ^{22}Na nuclei in ground water. Thus we find that the upper limit on the total 150 beam stopped in the absorber without contaminating the ground water above the EPA allowed limits is **1.0×10^{19} protons / year**. A preliminary safety analysis of the MI , however, suggests that allowed yearly beam aborted to be 3.52×10^{18} protons at 150 GeV [2,5], which is about 2.8 times smaller than the beam intensity limit suggested by the concentration model.

2. Air-borne Radioactivity :

In the past, the air-borne radioactivity have been measured at various locations around Fermilab accelerators [6 and Appendix-A]. The locations include many beam extraction regions and AP0 prevault. Necessary precautions were taken if the air-borne activity is larger than the allowed limits. In the case of newly built Main Injector enclosure, one encounters many locations of concern. The present study focuses on two regions: a) MI tunnel in the vicinity of MI40 beam extraction region and b) inside the MI40 beam absorber enclosure. Below, we investigate them separately .

a) MI enclosure

During the beam extraction towards the MI40 beam absorber we expect beam losses at the extraction region. The beam loss would give rise to radioactivity of the air in the MI enclosure. We use the results of the measurements carried out in the Tevatron 800 GeV proton beam extraction region at PSEPs [Appendix-A] and scale it to estimate the air-borne radioactivity level in the MI enclosure.

During the Tevatron fixed target experiments Derived Air Concentration (DAC) Ratio sum around the Tevatron Extraction PSEPs (SWYD PSEP) is 0.445 [Appendix-A] [2] immediately after the beam delivery is stopped. Hourly extracted beam was 2.4 x 10^{15} p at 800 GeV. In the case of MI40 extraction region the "Fermilab Main Injector Preliminary Safety Analysis Report" [5] allows an average of total beam aborted on the MI40 absorber as 5.9E14 p /hour @ 150 GeV during the commissioning period and regular operation (allowed beam aborted on the beam absorber is 3.52E18p/year; 1 year = 6000 hr) . To estimate the air-borne activity around the MI40 beam extraction region we make following assumptions :

a) the air-borne activity measured at SWYD PSEP location can be scaled down to the operating conditions at MI40 beam extraction region.
b) the average amount of beam extracted via the SWYD PSEP location is 2.4E15p@800 GeV /hr and at MI40 extraction region is 5.9E14p @150 GeV/hr
c) the beam losses around both locations are essentially the same.
d) the air-borne activity scales as $E^{0.75}$.

Then the expected DAC at the MI40 beam extraction point is

DAC = 0.445 x (5.9E14/ 2.4E15) x (150/800)**0.75
= 0.031

which is smaller than the DOE allowed limit of 0.1 (). The DAC value scales 1 linearly with the beam loss at the extraction point

[2] In the case of SWYD PSEP necessary precautions were taken in compliance with the FRCM[7] prior to entry to this region, during fixed target operation of the Tevatron.

b) MI40 beam absorber enclosure

The MI40 beam absorber is installed in a separate enclosure in the vicinity of the MI40 straight section. The entry to this enclosure is near location MI-409 and the entry way (which is under the MI tunnel enclosure) is provided with locked gate (not air tight). The beam absorber enclosure has an exhaust (normally off), can be activated prior to the entry to the dump enclosure.

The extracted beam towards the absorber is transported through a vacuum pipe for about 100 ft and about 10 ft of air before it is stopped in the MI40 absorber. To estimate the air-borne activity we take the measured air-borne radioactivity in the AP0-vault area [6] and scale it to the MI40 beam absorber operating scenarios.

During the pbar production a 120 GeV proton beam traverses about 10 ft of air prior to its interaction with the pbar target in the AP0-vault. The primaries and secondaries further interact with many beam line elements in air before they are stopped in the AP0 beam absorber. The approximate total distance traversed by the particles is about 25 ft. Average hourly beam stopped in the absorber is about 4.1 x 10^{15} p @120 GeV. With an allowed beam intensity of 5.4 x 10^{15} p @120 GeV one expects the resulting DAC ratio as 2.19 [6].

To estimate the air-borne activity in the MI40 beam absorber enclosure we make following assumptions :

a) the air-borne activity measured at AP0 vault area may be scaled[3] down to the operating conditions of the MI40 beam absorber.
b) the average amount of beam stopped in AP0 beam absorber is 5.4 x 10^{15} p@120 GeV/hr and that in the MI40 beam absorber is 5.9E14p @150 GeV/hr.
c) the air-borne activity scales as $E^{0.75}$.

Then, the expected average DAC Ratio at the MI40 beam absorber :

DAC = 2.19 X (5.9 E14 / 5.4E15) x (150/120)**0.75
= 0.28

This value is greater than the allowed limit of 0.1. We estimate that the air-borne activity will be reduced to about 20% of its original value in 40 min. However, we recommend

[3]This is a highly conservative assumption, because, in the MI40 beam enclosure the primary beam interacts only with about 10 ft of air column before it is stopped in the core of the absorber, where as in the AP0-vault, beam interacts with many high density material before it is absorbed in the AP0 Beam absorber.

monitoring of the air-borne activity at the exhaust before the air in the enclosure is let to atmosphere. During commissioning of the MI40 beam absorber, the air activation will be monitored and appropriate signs should be posted in accordance with FRCM. Also, the Beams Division procedure [8] should be followed for entry into the absorber enclosure.

3. Soil Activation :

The radioactivity induced in the soil forming the bulk shielding around an accelerator enclosure is of special interest from the point of view of ground water contamination which is explained in section 1. However, a number of other long lived radioactive elements can be seen in the soil samples from the area around the beam absorber shielding. Some of these radioactive elements have life times comparable to the ^{3}H and ^{22}Na isotopes. The maximum star density in the soil adjacent to the beam stop enclosure is estimated to be 5×10^{-10} stars/cc @ 150 GeV. This corresponds to a residual activity D of

$$D\,(\max) = (5E\text{-}10 / 1E\text{-}10) \times (3.52E18 / 2.93E19) \times 2.0E\text{-}4 \text{ rad at contact}^{4}$$
$$= 0.13 \text{ mRad}$$

However, if this area or any section of the beam line tunnel is to be decommissioned or remodeled in future, the soil will be tested and necessary precautions will be taken in accordance with FRCM [7] .

Author would like to thank A. Leveling for providing the measurement data on air-borne activity at different locations in the accelerator complex.

REFERENCES :

[1] "A Design Study of MI40 Beam-Abort Dump" C.M. Bhat, MI Note 86, 1993,

[2] Ground-water Activation from the upcoming operation of MI40 Beam Absorber, C. M. Bhat and L. Read, Fermilab TM-1985 (1996).

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[4]From Table VI of ref.[9], it is evident that for for 10^{-10} star/cc /proton at 150 GeV the dose at contact is 2.0E-4 rad

[3] "Use of a Concentration-based Model for Calculating the Radio activation of Soil and Ground water at Fermilab", J. D. Cossairt, Environmental Protection Note 8 (1994).

[4] "Ground water Migration of Radionucleides at Fermilab", A. J. Malensek et al., FERMILAB TM 1851, (1993). Private communication with A. J. Malensek and Kamran Vaziri (January 30, 1997) .

[5] "Fermilab Main Injector Preliminary Safety Analysis Report" , by S. D. Holmes *et al* , May 1992

[6] "Airborne Radioactivity in Accelerator Division", G. Lautenschlager and A.F.Leveling, Radiation Physics Note 128 (1996).

[7] Fermilab Radiological Control Manual.

[8] Beams Division procedure to enter the MI40 beam Absober Enclosure (under preperation)

[9] A design study of the MI40 beam -abort dump, C.M. Bhat MI-86 (1993).

Appendix - 1

FERMILAB

Beams ES&H Dept.
Radiation Safety, M.S. 371

Friday, March 21, 1997

TO: BD ES&H Files VI J.6

FROM: Gary Lauten, BD Radiation Safety Officer *Gary Lauten*

SUBJECT: Airborne Radioactivity Evaluation of Switchyard G2 Enclosure and the Tevatron PSEP septa transfer line from Tevatron to Switchyard.

Airborne radioactivity in several Beams Division areas have previously been evaluated and is described in Radiation Physics Note 128, November 1996 by Gary Lautenschlager and Tony Leveling. This memorandum documents the results of airborne radioactivity measurements at two additional areas: the Switchyard G2 Enclosure and the Tevatron extraction line which transfers beam from the Tevatron to the Switchyard.

The results are presented on the two attached spreadsheets. These results indicate that both of these enclosure areas have instantaneous airborne radioactivity levels that exceed 10% of the DAC at limiting safety envelope intensities. The airborne radioactivity present consists solely of short-lived positron emitters which do not pose an internal dosimetry hazard. The resulting immersion exposure to a worker from the airborne radioactivity levels in G2 and Tevatron extraction is insignificant (less than 0.32 DAC-hours per shift or 0.8 mrem per shutdown) compared with the dose to workers from activated beam line components at beam loss points. Additionally, operational delays introduce radioactive decay times that further reduce the concentrations of airborne radioactivity.

Data: Raw and Adjusted Stack Monitor Data by Location

Monitor MUX Quad/Address	Location	Average cpm	Average Beam Intensity (p/h)	Allowed Beam Intensity (p/h)	% of Allowed Beam Intensity	Estimated Average cpm at Allowable Intensity
2-2129	TeV Extraction PSEPs	566	7.2E14 ✓	2.4E15	30.0	1887
2-3005	G2 Lambertsons	619	4.2E14	2.4E15	17.5	3537

cc: T. Leveling
H. Casebolt
D. Cossairt, MS 119
K. Vaziri, MS 119

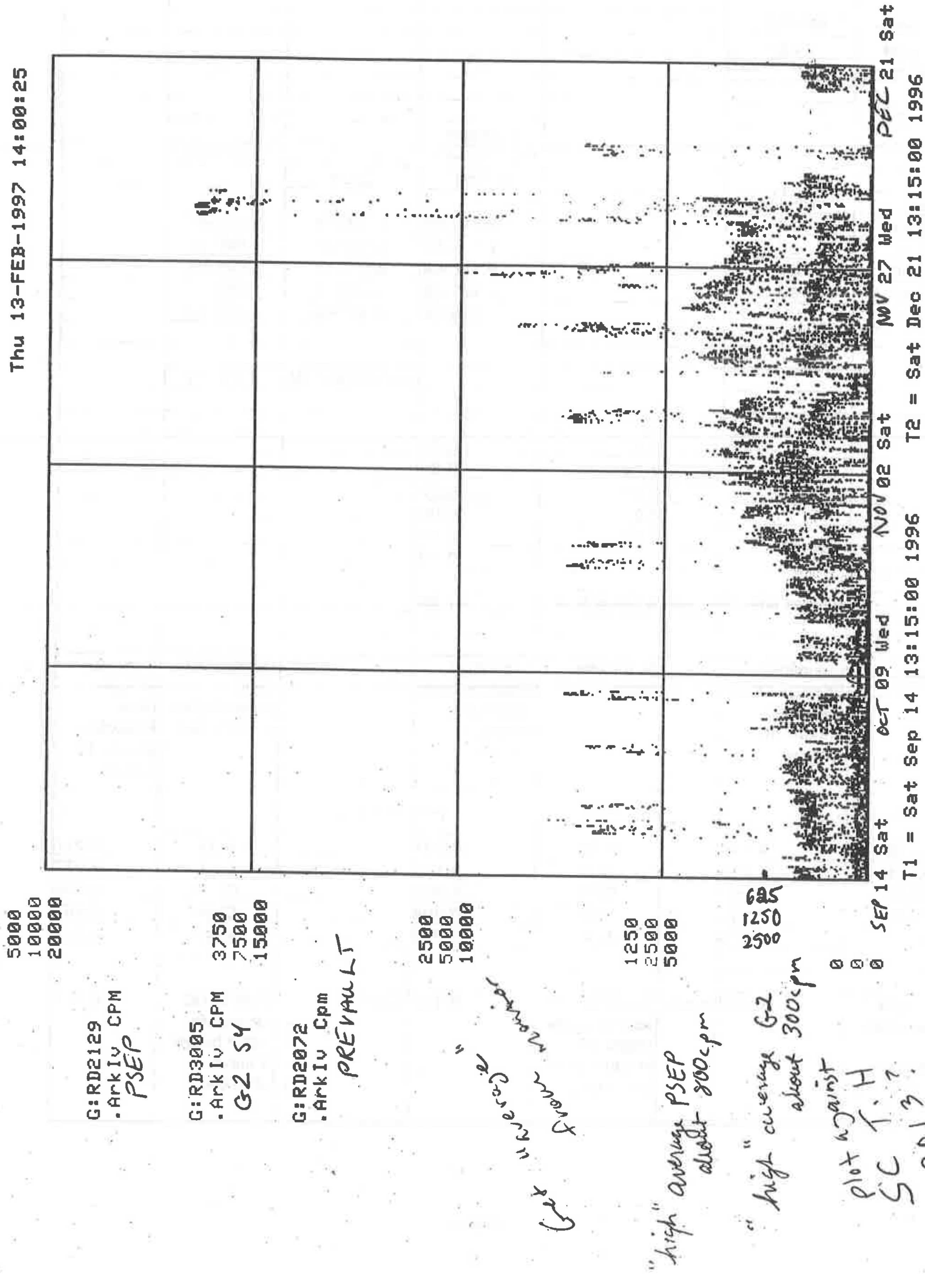
	MUX Quad/Address:		2-3005		Enclosure:	SWYD G2	
Count Rate= (Input stack monitor cpm)	INPUT CR 3537						
Isotope	1/2 life			Enclosure Concentration µCi/ml	DAC'S	DAC RATIO	
N-13	10			1.86E-06	4.00E-06	4.64E-01	
C-11	20			1.41E-06	4.00E-06	3.52E-01	
Cl-38	37			1.71E-08	3.00E-06	5.69E-03	
Cl-39	57			1.74E-08	3.00E-06	5.80E-03	
Ar-41	110			2.13E-08	3.00E-06	7.09E-03	
					DAC RATIO SUM	8.35E-01	
t=	46.40		0.46	0.02			
			0.35	0.07			
			0.01	0.00			
			0.01	0.00			
			0.01	0.01			
				0.10			
	Minutes until DAC ratio is below 0.10			46.40			
0 minutes delay	Committed Effective Dose Equivalent (mrem) by Isotope		20 minutes delay	Committed Effective Dose Equivalent (mrem) by Isotope		Minutes Delay Until concentration is <10% DAC	Committed Effective Dose Equivalent (mrem) by Isotope
N-13	0.279		N-13	0.070		N-13	0.011
C-11	0.423		C-11	0.212		C-11	0.085
Cl-38	0.013		Cl-38	0.009		Cl-38	0.005
Cl-39	0.020		Cl-39	0.016		Cl-39	0.011
Ar-41	0.047		Ar-41	0.041		Ar-41	0.035
Total CEDE for access which begins immediately after beam off	0.782	mrem	Total CEDE for access which begins 20 minutes after beam off	0.347	mrem	Total CEDE for access which begins 0 minutes after beam off	0.148

	MUX Quad/Address:	2-2129		Enclosure:	**SWYD PSEP**
Count Rate= (input stack monitor cpm)	INPUT CR 1887				

Isotope	1/2 life	Enclosure Concentration µCi/ml	DAC'S	DAC RATIO
N-13	10	9.91E-07	4.00E-06	2.48E-01
C-11	20	7.51E-07	4.00E-06	1.88E-01
Cl-38	37	9.11E-09	3.00E-06	3.04E-03
Cl-39	57	9.28E-09	3.00E-06	3.09E-03
Ar-41	110	1.13E-08	3.00E-06	3.78E-03
			DAC RATIO SUM	4.45E-01

t=	31.08	0.25	0.03
		0.19	0.06
		0.00	0.00
		0.00	0.00
		0.00	0.00
			0.10
	Minutes until DAC ratio is below 0.10		31.08

0 minutes delay	Committed Effective Dose Equivalent (mrem) by Isotope		20 minutes delay	Committed Effective Dose Equivalent (mrem) by Isotope		Minutes Delay Until concentration is <10% DAC	Committed Effective Dose Equivalent (mrem) by Isotope
N-13	0.149		N-13	0.037		N-13	0.017
C-11	0.226		C-11	0.113		C-11	0.077
Cl-38	0.007		Cl-38	0.005		Cl-38	0.004
Cl-39	0.011		Cl-39	0.008		Cl-39	0.007
Ar-41	0.025		Ar-41	0.022		Ar-41	0.021
Total CEDE for access which begins immediately after beam off	0.417	mrem	Total CEDE for access which begins 20 minutes after beam off	0.185	mrem	Total CEDE for access which begins 0 minutes after beam off	0.126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PSEP
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G:RD3005 .ArkIv CPM
G2 SY
3750 7500 15000
G:RD2072 .ArkIv Cpm
PREVAULT
2500 5000 10000
1250 2500 5000
625 1250 2500
0 0 0
SEP 14 Sat
OCT 09 Wed
NOV 02 Sat
NOV 27 Wed
DEC 21 Sat
T1 = Sat Sep 14 13:15:00 1996
T2 = Sat Dec 21 13:15:00 1996
Get "average" from number
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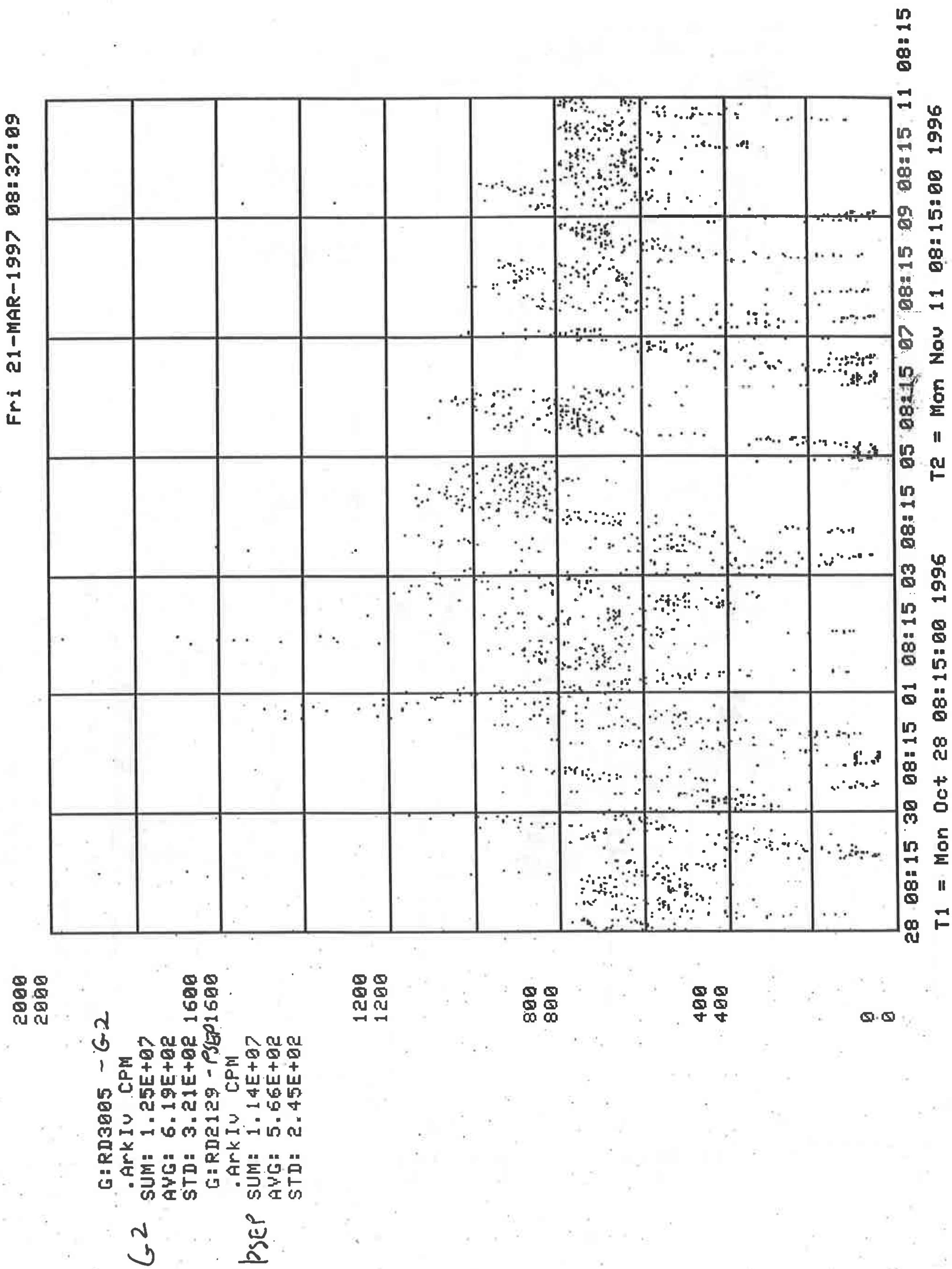
"high" average G-2 about 300cpm
plot "against" SC T. H 2013?

PSEP & G2 AIRBORNE RAD



Console Location 236,
Accelerator Data Plot Package

14-MAR-1997 13:13

5.66