BNL-104135-2014-TECH

AGS.SN259;BNL-104135-2014-IR

Beam Losses on Si+14 Injection Due to Ambient Gases and Contrived CO2 Pressures in the AGS

E. Gill

June 1989

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

AGS Studies Report

Date: June 28, 1989 Time: 12:30 - 13:30

Experimenters: E.G. Gill, L.A. Ahrens

Reported by: K.M. Welch

Subject: Beam Losses on Si^{+14} Injection Due to Ambient Gases and Contrived CO_2 Pressures in the AGS

INTRODUCTION

At the conclusion of the "proton run" this spring, the machine was set up to run Si^{+14}. Late one evening, the Operations Group called one of the authors out of a sound sleep. They couldn't "find the beam" on injection. Woody Glenn had the suspicion that a high pressure "bump" in one of the vacuum sectors of the AGS might be causing problems. Due to leaks in two separate indium seals, Vacuum Sector I pressure was $\approx 2 \times 10^{-6}$ Torr. The leaks were repaired, and shortly thereafter they "found the beam". This raised interests as to the possible consequences of pressures in the AGS when accelerating heavy ions.

At the conclusion of the heavy ion run, an experiment was conducted to assess the effect of gas pressure on heavy ion beam transmission in the AGS. Using a pickup electrode at G-7 and a beam current monitor at L-20, beam intensity as a function of time was monitored at injection. These measurements were conducted with the existing "ambient" AGS pressure and after introducing a "pressure bump" at the ion profile monitor at E-10. The data were somewhat qualitative. However, some important conclusions could be reached on analysis of the data.

It will be shown that it is not required that one know the absolute "ambient" pressure to quantitatively determine total cross sections for a given test gas. It is only essential that a good "ambient" pressure, beam intensity base line be established prior to the "bump" being introduced. It is assumed in the analysis that electron capture cross sections dominate.

PRESENTATION OF DATA

The "ambient" pressure of the AGS is 2-3 x 10^{-7} Torr, comprising primarily H_2O, CO, N_2 and traces of O_2. Heavy hydrocarbons are also present in unknown partial pressures. The induced "pressure bump" resulted in an average increase in the AGS CO_2 pressure of $\approx 5 \times 10^{-8}$ Torr. Oscilloscope tracings of the beam loss runs for the two (or more) conditions are given in the back section of this report, as Data Pages (DP) 1 - 3. The pressure "bump" conditions vs. ambient pressure conditions for PUE data in all three DPs were not the same. One reaches this conclusion by plotting the signal amplitude as a function of time on log-log paper. Slopes of all of the functions differ. Therefore, in analysis of the data, we will proceed as if data in DP 1 & 2 correlate and data in DP 3 correlate.

The beam current transformer readings, given in DP 1 & 2, were graphically extrapolated back to "zero" time. The PUE data were extrapolated back to "zero" time plotting the log of beam intensity as a function of a linear display of time. Data for the two current transformer plots were normalized at "zero" time to take into account possible variations in beam injection intensities and capture efficiencies. The PUE data were similarly treated. These data are plotted in Figures 1 & 2. Theoretical predictions of the upper limit of electron capture losses (i.e., beam intensity) for the two conditions are also plotted in these figures.

INTERPRETATION OF TEST RESULTS

Current data on electron-capture cross sections are given by Schlachter,[1] et. al. These data are reported as valid for energies $\lesssim$ 8 MeV/nucleon. Cross section, σ_i, for species "i" target gas is given by the following equation:

$$\sigma_i \quad = \quad a q^{3.9} Z_i^{4.2} / E^{4.8}, \qquad (1)$$

where
a = is a constant of proportionality, 1.1×10^{-8},
q = the charge state of the accelerated particle,
Z_i = the atomic number of species "i" target gas,
E = the kinetic energy of the accelerated particle (keV).

The electron-capture cross section varies as a function of the distance, x, which the particle travels in the accelerator. That is,

$$N_i \sigma_i \quad = N_i Z_i^{4.2} q^{3.9} \; f(E(x)) \qquad (2)$$

$$= \Psi_i f(E(x))$$

$$E(x) = E_0 + x(dP/dt) \quad (3)$$

and, E_0 = the initial kinetic energy of the beam particles,
dP/dt = the rate of change in momentum of the beam particles,
x = the distance travelled in the machine (cm),
N_i = the density of "i" gas (particles/cm^3).

Total beam intensity, I(x) as a function of x is found by solution of (4), which assumes "n" separate gas species in the AGS.

$$\int dI(x)/I(x) = -\int \sum_{i=1}^{n} \Psi_i f(x)dx \quad (4)$$

$$I(x) = I(0)\exp[-(\Psi_1 + \Psi_2 + ... + \Psi_n)\,\Phi(x)] \quad (5)$$

Equation (4) has the solution given in (5), assuming the exponents of both Z_i and "q" are not energy dependent. For gas species "i", $\Psi_i\Phi$ is simply:

$$\Psi_i\Phi(x) = \frac{a N_i q^{3.9} Z_i^{4.2}}{3.8\ dP/dt}[E_0^{-3.8} - (E_0 + x\,dP/dt)^{-3.8}]. \quad (6)$$

Energy at injection is ≈ 6.38 MeV/nucleon. The change in momentum, with time is $dP/dt \approx 2.5 \times 10^{-17}$ kg m/sec^2 for a 300 ms period. This gives us all the information we need to evaluate (5) and (6). Note that the invariance of "q" and Z_i with energy need not be assumed in evaluation of the integral leading to (5). That is I(x) could take the form:

$$I(x) = I(0)\exp[-(\Psi_1(x) + \Psi_2(x) + ... + \Psi_{n+1}(x))\Phi(x)], \quad (7)$$

where $\Psi_{n+1}(x)\Phi(x)$ is the capture cross section of, say, the test gas. One need only solve for the natural log of the ratio of (7) and (5) to determine the absolute cross section of species "n+1".

Theoretical curves are plotted of (5), for both beam current (Fig. 1) and beam intensity (Fig. 2). These data were compared with measured results in the respective figures. Data provided in the accompanying figures and tables were calculated assuming the following conditions:

Case 1: "Ambient" Vacuum (Table I, Fig. 1 & 2)

H_2O Partial Pressure:	10^{-7} Torr
N_2, CO Partial pressures:	5×10^{-8} Torr, each
O_2 Partial Pressure:	1.5×10^{-8} Torr
CO_2 Partial Pressure:	5×10^{-9} Torr ("Test Gas")

Case 2: Effect of Introduced Gas (Table II, Fig. 1 & 2)

CO_2 Total Pressure:	5×10^{-8} Torr

Case 3: Increased AGS Pressures Due to a Leak (Table III)

H_2O Partial Pressure:	10^{-7} Torr
N_2/CO Partial Pressure:	1.3×10^{-7} Torr
O_2 Partial Pressure:	2.5×10^{-8} Torr
CO_2 Partial Pressure:	5×10^{-9} Torr

Case 4: The AGS in 1990 (Table IV)

H_2O Partial Pressure:	10^{-8} Torr
N_2/CO Partial Pressure:	10^{-9} Torr
CO_2 Partial Pressure:	10^{-9} Torr

CONCLUSIONS

If one believes the PUE data, it appears that the electron capture cross sections of Si^{+14}, at energies $\gtrsim$ 6 MeV per nucleon, are less than that predicted by the reference (for energies up to 8 MeV). Data taken with the current transformer are in much closer agreement with theory; however, this could be due to instrumentation problems. We must make better measurements of beam losses in the first 10 ms. This will prove important in assessing probable beam losses in the Booster at injection.

Using (5) and (7), one may easily calculate the absolute cross sections of a number of gases as a function of beam energy. There is sufficient data herein for one to make rough approximations of the total cross section of CO_2 as a function of energy. This is left as an exercise for the reader. When "going through the arithmetic", one must assume that machine beam losses as a function of time, unrelated to vacuum conditions, are the same in the two plots given in Fig. 2.

It is possible to drastically alter theoretical beam decay by altering gas target species, as well beam energy dependence. That is, the data are in sufficiently close agreement with the theory that we should continue to focus on the quality of the AGS and Booster vacuum systems.

Lastly, calculations predict one would have problems "finding the Si^{+14} beam" if a leak, which would be rich in oxygen, caused the average pressure in one vacuum sector to be $\gtrsim 2\times 10^{-6}$ Torr.

PROPOSED FUTURE EXPERIMENTS

It is proposed that in the spring of 1990 we conduct tests with both oxygen and silicon beams. The background pressure in the AGS will be improved over the present pressures; however, it has been shown that this is not a requirement for these tests. One sector with a particularly low rate-of-pressure rise could be selected for a "test" chamber. Controlled and well defined pressure gradients of various gas species could be introduced while shutting off some of the sputter-ion pumps in the given sector. With a good beam current monitor, beam intensities can be calculated and precise measurements made of electron capture cross sections of a number of gases.

ACKNOWLEDGEMENTS

The writer is particularly indebted to L.A. Ahrens. His probing questions and discussions helped the author immeasurably in challenging some of his own assumptions and in understanding a little about how the AGS works. The author learned a great deal by these discussions. The author also appreciates the effort extended by E.G. Gill in making these measurements. The author would like to thank J.W. Glenn for finding errors in one of his initial calculations, C.E. Gardner for his helpful discussions and H.C. Hseuh for providing a copy of Schlachter's paper. M.V. Heimerle showed her usual thoroughness in proof reading several drafts of this report.

REFERENCES

1) Schlachter, A.S., et al., "Electron capture for fast highly charged ions in gas targets: An empirical scaling rule," Phys. Rev. A 27(11), 3327(1983).

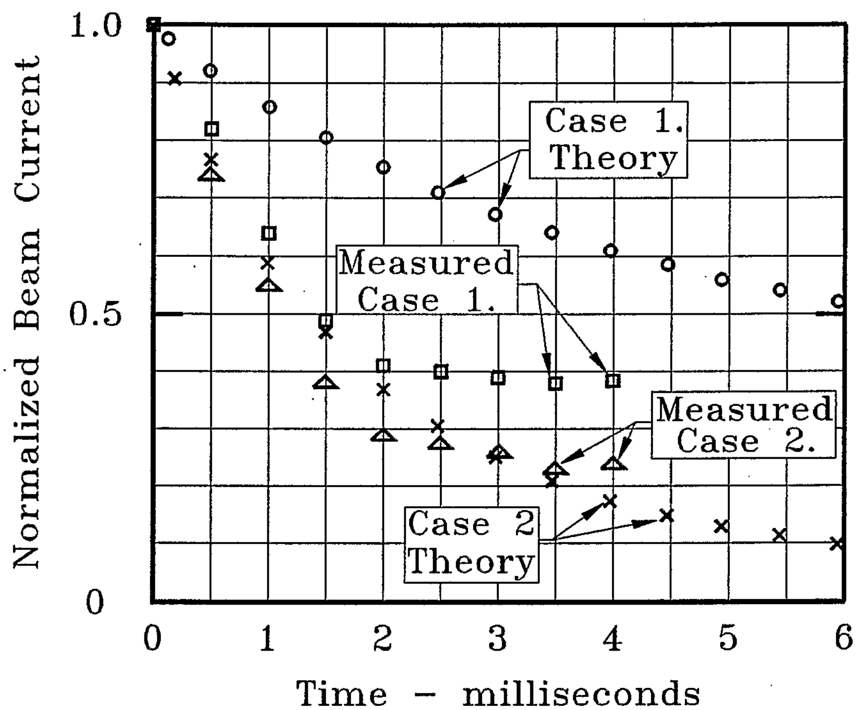


Figure 1. Theoretical vs Measured Si^{+14} Beam Current as a Function of Time.

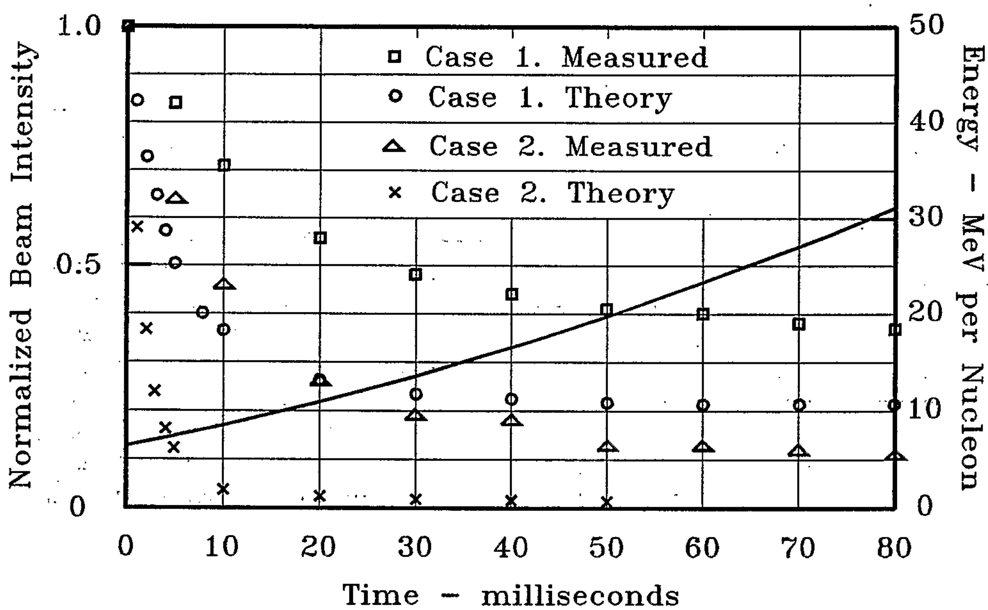


Figure 2. Theoretical vs Measured Si^{+14}
Beam Intensity as a Function of Time

TABLE I. Case 1

Kimo M. Welch 8/6/89

3.90E+00 = q exponent
-3.80E+00 = E exponent
4.20E+00 = Z exponent

mo = 4.65E-26 kg
D = Pdot = 2.49E-17 kg*m/sec^2
Eo = 2.86E-11 joules
c = 3.00E+08 m/sec^2
B = (Eo + moc^2) = 4.21E-09
A = moc^2 = 4.19E-09
vo = 3.49E+07

PARTIAL PRESSURES
OF AGS GASES

GAS	PRESSURE	
OXYGEN	1.50E-08	#1
CO/N2	5.00E-08	#2
WATER	1.00E-07	#3
TEST GAS	5.00E-09	#4

t = ((cD)^-1)*[(B^2) - (A^2) + 2*B*D*x + (D^2)*x^2]^.5

v(t) = c*(1-(A/(B+D*x))^2)^.5

	NORMALIZED BEAM INTENSITY							
	TEST GAS ONLY	"AMBIENT" & TEST GAS					NORMALIZED BEAM	ENERGY/ NUCLEON
the exp.	e"^exp.		"x"meter	"t" sec	v(t)	v(t)/vo	CURRENT	MeV
-9.96E-04	9.99E-01	9.96E-01	7.85E+02	2.25E-05	3.49E+07	1.00E+00	9.96E-01	6.38E+00
-1.99E-03	9.98E-01	9.92E-01	1.57E+03	4.50E-05	3.49E+07	1.00E+00	9.93E-01	6.39E+00
-3.96E-03	9.96E-01	9.84E-01	3.14E+03	9.00E-05	3.49E+07	1.00E+00	9.85E-01	6.40E+00
-5.93E-03	9.94E-01	9.76E-01	4.71E+03	1.35E-04	3.50E+07	1.00E+00	9.78E-01	6.41E+00
-7.88E-03	9.92E-01	9.69E-01	6.28E+03	1.80E-04	3.50E+07	1.00E+00	9.71E-01	6.41E+00
-9.81E-03	9.90E-01	9.61E-01	7.85E+03	2.25E-04	3.50E+07	1.00E+00	9.64E-01	6.42E+00
-2.12E-02	9.79E-01	9.19E-01	1.73E+04	4.93E-04	3.52E+07	1.01E+00	9.25E-01	6.48E+00
-4.18E-02	9.59E-01	8.46E-01	3.53E+04	1.01E-03	3.54E+07	1.01E+00	8.58E-01	6.58E+00
-6.01E-02	9.42E-01	7.86E-01	5.26E+04	1.49E-03	3.57E+07	1.02E+00	8.03E-01	6.67E+00
-7.79E-02	9.25E-01	7.31E-01	7.07E+04	2.00E-03	3.59E+07	1.03E+00	7.53E-01	6.77E+00
-9.39E-02	9.10E-01	6.86E-01	8.80E+04	2.47E-03	3.62E+07	1.04E+00	7.11E-01	6.87E+00
-1.09E-01	8.96E-01	6.45E-01	1.06E+05	2.97E-03	3.65E+07	1.04E+00	6.73E-01	6.97E+00
-1.24E-01	8.83E-01	6.08E-01	1.24E+05	3.47E-03	3.67E+07	1.05E+00	6.40E-01	7.07E+00
-1.37E-01	8.72E-01	5.76E-01	1.42E+05	3.96E-03	3.70E+07	1.06E+00	6.10E-01	7.17E+00
-1.51E-01	8.60E-01	5.46E-01	1.61E+05	4.46E-03	3.72E+07	1.07E+00	5.83E-01	7.27E+00
-1.62E-01	8.50E-01	5.22E-01	1.78E+05	4.93E-03	3.75E+07	1.07E+00	5.60E-01	7.37E+00
-1.74E-01	8.41E-01	4.98E-01	1.97E+05	5.43E-03	3.77E+07	1.08E+00	5.39E-01	7.48E+00
-1.84E-01	8.32E-01	4.77E-01	2.16E+05	5.93E-03	3.80E+07	1.09E+00	5.19E-01	7.58E+00
-2.21E-01	8.02E-01	4.11E-01	2.91E+05	7.88E-03	3.90E+07	1.12E+00	4.60E-01	8.00E+00
-2.51E-01	7.78E-01	3.65E-01	3.77E+05	1.00E-02	4.02E+07	1.15E+00	4.20E-01	8.47E+00
-3.30E-01	7.19E-01	2.65E-01	8.01E+05	2.00E-02	4.53E+07	1.30E+00	3.44E-01	1.08E+01
-3.60E-01	6.98E-01	2.36E-01	1.28E+06	3.00E-02	5.05E+07	1.45E+00	3.41E-01	1.35E+01
-3.72E-01	6.89E-01	2.24E-01	1.81E+06	4.00E-02	5.56E+07	1.59E+00	3.57E-01	1.64E+01
-3.78E-01	6.86E-01	2.19E-01	2.40E+06	5.00E-02	6.07E+07	1.74E+00	3.82E-01	1.97E+01
-3.82E-01	6.83E-01	2.16E-01	3.02E+06	6.00E-02	6.57E+07	1.88E+00	4.07E-01	2.32E+01
-3.82E-01	6.82E-01	2.15E-01	3.71E+06	7.00E-02	7.06E+07	2.02E+00	4.36E-01	2.70E+01
-3.83E-01	6.82E-01	2.15E-01	4.44E+06	8.00E-02	7.55E+07	2.16E+00	4.65E-01	3.10E+01
-3.83E-01	6.82E-01	2.15E-01	6.05E+06	1.00E-01	8.51E+07	2.44E+00	5.24E-01	4.00E+01
-3.84E-01	6.81E-01	2.14E-01	1.68E+07	2.00E-01	1.29E+08	3.69E+00	7.90E-01	9.98E+01
-3.84E-01	6.81E-01	2.14E-01	3.14E+07	3.00E-01	1.64E+08	4.70E+00	1.01E+00	1.81E+02

TABLE II. Case 2 — Kimo M. Welch — 8/6/89

3.90E+00 = q exponent
-3.80E+00 = E exponent
4.20E+00 = Z exponent

mo = 4.65E-26 kg
D = Pdot = 2.49E-17 kg*m/sec^2
Eo = 2.86E-11 joules
c = 3.00E+08 m/sec^2
B = (Eo + moc^2) = 4.21E-09
A = moc^2 = 4.19E-09
vo = 3.49E+07

PARTIAL PRESSURES OF AGS GASES

GAS	PRESSURE	
OXYGEN	1.50E-08	#1
CO/N2	5.00E-08	#2
WATER	1.00E-07	#3
TEST GAS	5.00E-08	#4

t = ((cD)^-1)*[(B^2) - (A^2) + 2*B*D*x + (D^2)*x^2]^.5
v(t) = c*(1-(A/(B+D*x))^2)^.5

	NORMALIZED BEAM INTENSITY							
	TEST GAS ONLY	"AMBIENT" & TEST GAS					NORMALIZED BEAM	ENERGY/ NUCLEON
the exp.	e"^exp.		"x"meter	"t" sec	v(t)	v(t)/vo	CURRENT	MeV
-9.96E-03	9.90E-01	9.87E-01	7.85E+02	2.25E-05	3.49E+07	1.00E+00	9.87E-01	6.38E+00
-1.99E-02	9.80E-01	9.74E-01	1.57E+03	4.50E-05	3.49E+07	1.00E+00	9.75E-01	6.39E+00
-3.96E-02	9.61E-01	9.50E-01	3.14E+03	9.00E-05	3.49E+07	1.00E+00	9.51E-01	6.40E+00
-5.93E-02	9.42E-01	9.26E-01	4.71E+03	1.35E-04	3.50E+07	1.00E+00	9.27E-01	6.41E+00
-7.88E-02	9.24E-01	9.03E-01	6.28E+03	1.80E-04	3.50E+07	1.00E+00	9.05E-01	6.41E+00
-9.81E-02	9.07E-01	8.80E-01	7.85E+03	2.25E-04	3.50E+07	1.00E+00	8.83E-01	6.42E+00
-2.12E-01	8.09E-01	7.59E-01	1.73E+04	4.93E-04	3.52E+07	1.01E+00	7.65E-01	6.48E+00
-4.18E-01	6.59E-01	5.81E-01	3.53E+04	1.01E-03	3.54E+07	1.01E+00	5.89E-01	6.58E+00
-6.01E-01	5.48E-01	4.58E-01	5.26E+04	1.49E-03	3.57E+07	1.02E+00	4.68E-01	6.67E+00
-7.79E-01	4.59E-01	3.63E-01	7.07E+04	2.00E-03	3.59E+07	1.03E+00	3.73E-01	6.77E+00
-9.39E-01	3.91E-01	2.95E-01	8.80E+04	2.47E-03	3.62E+07	1.04E+00	3.06E-01	6.87E+00
-1.09E+00	3.35E-01	2.41E-01	1.06E+05	2.97E-03	3.65E+07	1.04E+00	2.51E-01	6.97E+00
-1.24E+00	2.90E-01	1.99E-01	1.24E+05	3.47E-03	3.67E+07	1.05E+00	2.10E-01	7.07E+00
-1.37E+00	2.53E-01	1.67E-01	1.42E+05	3.96E-03	3.70E+07	1.06E+00	1.77E-01	7.17E+00
-1.51E+00	2.22E-01	1.41E-01	1.61E+05	4.46E-03	3.72E+07	1.07E+00	1.50E-01	7.27E+00
-1.62E+00	1.98E-01	1.21E-01	1.78E+05	4.93E-03	3.75E+07	1.07E+00	1.30E-01	7.37E+00
-1.74E+00	1.76E-01	1.04E-01	1.97E+05	5.43E-03	3.77E+07	1.08E+00	1.13E-01	7.48E+00
-1.84E+00	1.58E-01	9.07E-02	2.16E+05	5.93E-03	3.80E+07	1.09E+00	9.88E-02	7.58E+00
-2.21E+00	1.09E-01	5.62E-02	2.91E+05	7.88E-03	3.90E+07	1.12E+00	6.28E-02	8.00E+00
-2.51E+00	8.15E-02	3.82E-02	3.77E+05	1.00E-02	4.02E+07	1.15E+00	4.40E-02	8.47E+00
-3.30E+00	3.68E-02	1.36E-02	8.01E+05	2.00E-02	4.53E+07	1.30E+00	1.76E-02	1.08E+01
-3.60E+00	2.74E-02	9.26E-03	1.28E+06	3.00E-02	5.05E+07	1.45E+00	1.34E-02	1.35E+01
-3.72E+00	2.42E-02	7.89E-03	1.81E+06	4.00E-02	5.56E+07	1.59E+00	1.26E-02	1.64E+01
-3.78E+00	2.29E-02	7.34E-03	2.40E+06	5.00E-02	6.07E+07	1.74E+00	1.28E-02	1.97E+01
-3.82E+00	2.20E-02	6.96E-03	3.02E+06	6.00E-02	6.57E+07	1.88E+00	1.31E-02	2.32E+01
-3.82E+00	2.18E-02	6.89E-03	3.71E+06	7.00E-02	7.06E+07	2.02E+00	1.39E-02	2.70E+01
-3.83E+00	2.17E-02	6.85E-03	4.44E+06	8.00E-02	7.55E+07	2.16E+00	1.48E-02	3.10E+01
-3.83E+00	2.17E-02	6.82E-03	6.05E+06	1.00E-01	8.51E+07	2.44E+00	1.66E-02	4.00E+01
-3.84E+00	2.16E-02	6.79E-03	1.68E+07	2.00E-01	1.29E+08	3.69E+00	2.50E-02	9.98E+01
-3.84E+00	2.16E-02	6.79E-03	3.14E+07	3.00E-01	1.64E+08	4.70E+00	3.19E-02	1.81E+02

TABLE III. Case 3 Kimo M. Welch 8/6/89

3.90E+00 = q exponent
-3.80E+00 = E exponent
4.20E+00 = Z exponent

mo =	4.65E-26	kg
D = Pdot =	2.49E-17	kg*m/sec^2
Eo =	2.86E-11	joules
c =	3.00E+08	m/sec^2
B = (Eo + moc^2) =	4.21E-09	
A = moc^2 =	4.19E-09	
vo =	3.49E+07	

PARTIAL PRESSURES
OF AGS GASES

GAS	PRESSURE	
OXYGEN	2.50E-08	#1
CO/N2	1.30E-07	#2
WATER	1.00E-07	#3
TEST GAS	5.00E-09	#4

t = ((cD)^-1)*[(B^2) - (A^2) + 2*B*D*x + (D^2)*x^2]^.5
v(t) = c*(1-(A/(B+D*x))^2)^.5

	NORMALIZED BEAM INTENSITY							
	TEST GAS ONLY	"AMBIENT" & TEST GAS					NORMALIZED BEAM CURRENT	ENERGY/ NUCLEON MeV
the exp.	e"^exp.		"x"meter	"t" sec	v(t)	v(t)/vo		
-9.96E-04	9.99E-01	9.93E-01	7.85E+02	2.25E-05	3.49E+07	1.00E+00	9.93E-01	6.38E+00
-1.99E-03	9.98E-01	9.86E-01	1.57E+03	4.50E-05	3.49E+07	1.00E+00	9.87E-01	6.39E+00
-3.96E-03	9.96E-01	9.73E-01	3.14E+03	9.00E-05	3.49E+07	1.00E+00	9.74E-01	6.40E+00
-5.93E-03	9.94E-01	9.60E-01	4.71E+03	1.35E-04	3.50E+07	1.00E+00	9.62E-01	6.41E+00
-7.88E-03	9.92E-01	9.47E-01	6.28E+03	1.80E-04	3.50E+07	1.00E+00	9.49E-01	6.41E+00
-9.81E-03	9.90E-01	9.34E-01	7.85E+03	2.25E-04	3.50E+07	1.00E+00	9.37E-01	6.42E+00
-2.12E-02	9.79E-01	8.63E-01	1.73E+04	4.93E-04	3.52E+07	1.01E+00	8.70E-01	6.48E+00
-4.18E-02	9.59E-01	7.49E-01	3.53E+04	1.01E-03	3.54E+07	1.01E+00	7.60E-01	6.58E+00
-6.01E-02	9.42E-01	6.59E-01	5.26E+04	1.49E-03	3.57E+07	1.02E+00	6.74E-01	6.67E+00
-7.79E-02	9.25E-01	5.82E-01	7.07E+04	2.00E-03	3.59E+07	1.03E+00	6.00E-01	6.77E+00
-9.39E-02	9.10E-01	5.21E-01	8.80E+04	2.47E-03	3.62E+07	1.04E+00	5.41E-01	6.87E+00
-1.09E-01	8.96E-01	4.68E-01	1.06E+05	2.97E-03	3.65E+07	1.04E+00	4.89E-01	6.97E+00
-1.24E-01	8.83E-01	4.23E-01	1.24E+05	3.47E-03	3.67E+07	1.05E+00	4.45E-01	7.07E+00
-1.37E-01	8.72E-01	3.85E-01	1.42E+05	3.96E-03	3.70E+07	1.06E+00	4.08E-01	7.17E+00
-1.51E-01	8.60E-01	3.52E-01	1.61E+05	4.46E-03	3.72E+07	1.07E+00	3.75E-01	7.27E+00
-1.62E-01	8.50E-01	3.25E-01	1.78E+05	4.93E-03	3.75E+07	1.07E+00	3.49E-01	7.37E+00
-1.74E-01	8.41E-01	3.00E-01	1.97E+05	5.43E-03	3.77E+07	1.08E+00	3.24E-01	7.48E+00
-1.84E-01	8.32E-01	2.78E-01	2.16E+05	5.93E-03	3.80E+07	1.09E+00	3.03E-01	7.58E+00
-2.21E-01	8.02E-01	2.16E-01	2.91E+05	7.88E-03	3.90E+07	1.12E+00	2.41E-01	8.00E+00
-2.51E-01	7.78E-01	1.75E-01	3.77E+05	1.00E-02	4.02E+07	1.15E+00	2.01E-01	8.47E+00
-3.30E-01	7.19E-01	1.01E-01	8.01E+05	2.00E-02	4.53E+07	1.30E+00	1.31E-01	1.08E+01
-3.60E-01	6.98E-01	8.23E-02	1.28E+06	3.00E-02	5.05E+07	1.45E+00	1.19E-01	1.35E+01
-3.72E-01	6.89E-01	7.56E-02	1.81E+06	4.00E-02	5.56E+07	1.59E+00	1.20E-01	1.64E+01
-3.78E-01	6.86E-01	7.28E-02	2.40E+06	5.00E-02	6.07E+07	1.74E+00	1.27E-01	1.97E+01
-3.82E-01	6.83E-01	7.09E-02	3.02E+06	6.00E-02	6.57E+07	1.88E+00	1.33E-01	2.32E+01
-3.82E-01	6.82E-01	7.05E-02	3.71E+06	7.00E-02	7.06E+07	2.02E+00	1.43E-01	2.70E+01
-3.83E-01	6.82E-01	7.02E-02	4.44E+06	8.00E-02	7.55E+07	2.16E+00	1.52E-01	3.10E+01
-3.83E-01	6.82E-01	7.01E-02	6.05E+06	1.00E-01	8.51E+07	2.44E+00	1.71E-01	4.00E+01
-3.84E-01	6.81E-01	6.99E-02	1.68E+07	2.00E-01	1.29E+08	3.69E+00	2.58E-01	9.98E+01
-3.84E-01	6.81E-01	6.99E-02	3.14E+07	3.00E-01	1.64E+08	4.70E+00	3.28E-01	1.81E+02

TABLE IV. Case 4 — Kimo M. Welch — 8/6/89

3.90E+00 = q exponent
-3.80E+00 = E exponent
4.20E+00 = Z exponent

mo = 4.65E-26 kg
D = Pdot = 2.49E-17 kg*m/sec^2
Eo = 2.86E-11 joules
c = 3.00E+08 m/sec^2
B = (Eo + moc^2) = 4.21E-09
A = moc^2 = 4.19E-09
vo = 3.49E+07

PARTIAL PRESSURES OF AGS GASES

GAS	PRESSURE	
OXYGEN	1.00E-10	#1
CO/N2	1.00E-09	#2
WATER	1.00E-08	#3
TEST GAS	1.00E-09	#4

t = ((cD)^-1)*[(B^2) - (A^2) + 2*B*D*x + (D^2)*x^2]^.5

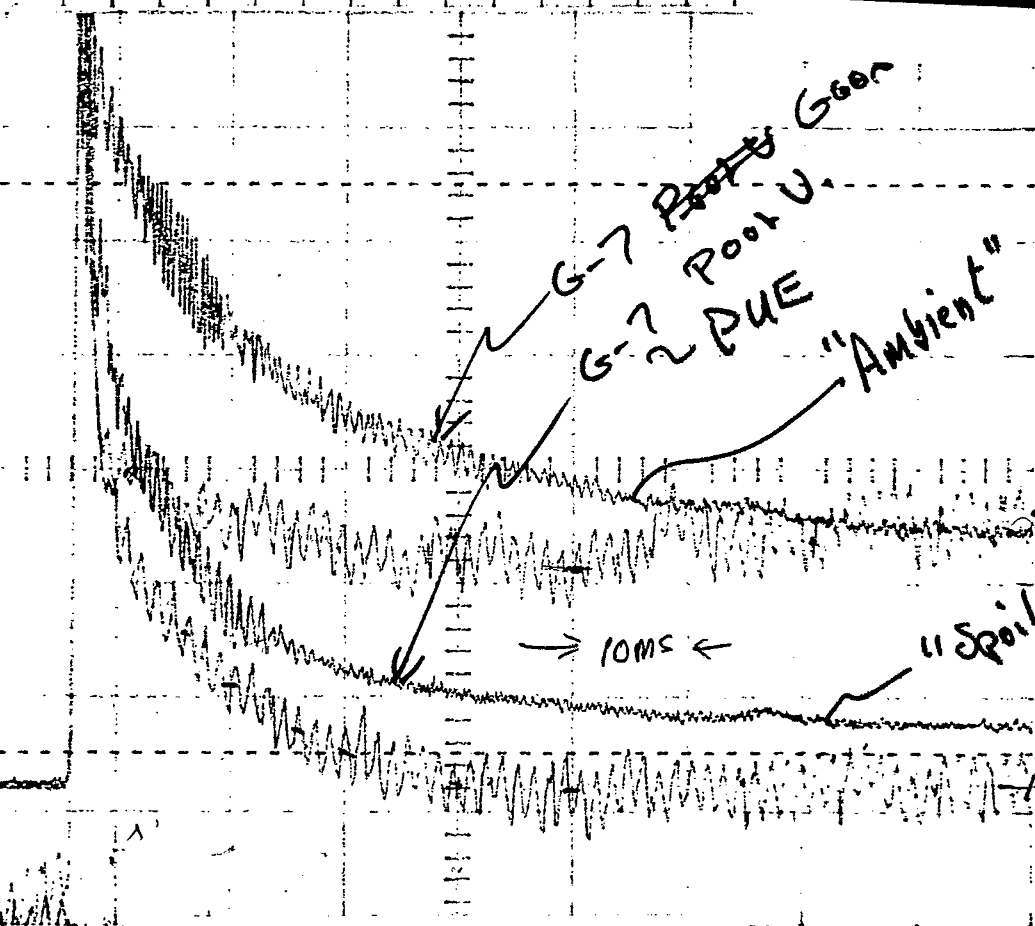
v(t) = c*(1-(A/(B+D*x))^2)^.5

the exp.	NORMALIZED BEAM INTENSITY TEST GAS ONLY e"^exp.	"AMBIENT" & TEST GAS	"x"meter	"t" sec	v(t)	v(t)/vo	NORMALIZED BEAM CURRENT	ENERGY/ NUCLEON MeV
-1.99E-04	1.00E+00	1.00E+00	7.85E+02	2.25E-05	3.49E+07	1.00E+00	1.00E+00	6.38E+00
-3.98E-04	1.00E+00	9.99E-01	1.57E+03	4.50E-05	3.49E+07	1.00E+00	1.00E+00	6.39E+00
-7.93E-04	9.99E-01	9.99E-01	3.14E+03	9.00E-05	3.49E+07	1.00E+00	1.00E+00	6.40E+00
-1.19E-03	9.99E-01	9.98E-01	4.71E+03	1.35E-04	3.50E+07	1.00E+00	1.00E+00	6.41E+00
-1.58E-03	9.98E-01	9.98E-01	6.28E+03	1.80E-04	3.50E+07	1.00E+00	1.00E+00	6.41E+00
-1.96E-03	9.98E-01	9.97E-01	7.85E+03	2.25E-04	3.50E+07	1.00E+00	1.00E+00	6.42E+00
-4.23E-03	9.96E-01	9.93E-01	1.73E+04	4.93E-04	3.52E+07	1.01E+00	1.00E+00	6.48E+00
-8.35E-03	9.92E-01	9.87E-01	3.53E+04	1.01E-03	3.54E+07	1.01E+00	1.00E+00	6.58E+00
-1.20E-02	9.88E-01	9.82E-01	5.26E+04	1.49E-03	3.57E+07	1.02E+00	1.00E+00	6.67E+00
-1.56E-02	9.85E-01	9.76E-01	7.07E+04	2.00E-03	3.59E+07	1.03E+00	1.01E+00	6.77E+00
-1.88E-02	9.81E-01	9.71E-01	8.80E+04	2.47E-03	3.62E+07	1.04E+00	1.01E+00	6.87E+00
-2.19E-02	9.78E-01	9.67E-01	1.06E+05	2.97E-03	3.65E+07	1.04E+00	1.01E+00	6.97E+00
-2.48E-02	9.76E-01	9.63E-01	1.24E+05	3.47E-03	3.67E+07	1.05E+00	1.01E+00	7.07E+00
-2.75E-02	9.73E-01	9.59E-01	1.42E+05	3.96E-03	3.70E+07	1.06E+00	1.02E+00	7.17E+00
-3.01E-02	9.70E-01	9.55E-01	1.61E+05	4.46E-03	3.72E+07	1.07E+00	1.02E+00	7.27E+00
-3.24E-02	9.68E-01	9.51E-01	1.78E+05	4.93E-03	3.75E+07	1.07E+00	1.02E+00	7.37E+00
-3.47E-02	9.66E-01	9.48E-01	1.97E+05	5.43E-03	3.77E+07	1.08E+00	1.03E+00	7.48E+00
-3.69E-02	9.64E-01	9.45E-01	2.16E+05	5.93E-03	3.80E+07	1.09E+00	1.03E+00	7.58E+00
-4.42E-02	9.57E-01	9.34E-01	2.91E+05	7.88E-03	3.90E+07	1.12E+00	1.04E+00	8.00E+00
-5.01E-02	9.51E-01	9.26E-01	3.77E+05	1.00E-02	4.02E+07	1.15E+00	1.07E+00	8.47E+00
-6.61E-02	9.36E-01	9.03E-01	8.01E+05	2.00E-02	4.53E+07	1.30E+00	1.17E+00	1.08E+01
-7.19E-02	9.31E-01	8.95E-01	1.28E+06	3.00E-02	5.05E+07	1.45E+00	1.29E+00	1.35E+01
-7.44E-02	9.28E-01	8.92E-01	1.81E+06	4.00E-02	5.56E+07	1.59E+00	1.42E+00	1.64E+01
-7.55E-02	9.27E-01	8.90E-01	2.40E+06	5.00E-02	6.07E+07	1.74E+00	1.55E+00	1.97E+01
-7.63E-02	9.26E-01	8.89E-01	3.02E+06	6.00E-02	6.57E+07	1.88E+00	1.67E+00	2.32E+01
-7.65E-02	9.26E-01	8.89E-01	3.71E+06	7.00E-02	7.06E+07	2.02E+00	1.80E+00	2.70E+01
-7.66E-02	9.26E-01	8.89E-01	4.44E+06	8.00E-02	7.55E+07	2.16E+00	1.92E+00	3.10E+01
-7.66E-02	9.26E-01	8.89E-01	6.05E+06	1.00E-01	8.51E+07	2.44E+00	2.17E+00	4.00E+01
-7.67E-02	9.26E-01	8.89E-01	1.68E+07	2.00E-01	1.29E+08	3.69E+00	3.28E+00	9.98E+01
-7.67E-02	9.26E-01	8.89E-01	3.14E+07	3.00E-01	1.64E+08	4.70E+00	4.17E+00	1.81E+02

E5PI.P	+1.23e-07	TOR	5.00e
E6PI.P	+1.10e-07	TOR	5.00e
E7PI.P	+1.78e-07	TOR	5.00e
E8PI.P	+3.55e-07	TOR	5.00e
E9PI.P	+7.15e-07	TOR	5.00e
E10PI.P	+9.90e-19	TOR	5.00e
E11PI.P	+8.80e-07	TOR	5.00e
E12PI.P	+3.47e-07	TOR	5.00e
E13PI.P	+2.29e-07	TOR	5.00e

E5PI.P	+1.05e-07	TOR	5.00e-
E6PI.P	+1.00e-07	TOR	5.00e-
E7PI.P	+1.95e-07	TOR	5.00e-
E8PI.P	+6.60e-07	TOR	5.00e-
E9PI.P	+9.90e-07	TOR	5.00e-
E10PI.P	+9.90e-19	TOR	5.00e-
E11PI.P	+1.21e-06	TOR	5.00e-
E12PI.P	+6.05e-07	TOR	5.00e-
[illegible]	+2.57e-07	TOR	5.00e-

POOR V



Channel 1
10 ms .5 V

Channel 2
10 ms .2 V

Ch 1 .5 V =
T/div 10 ms Ch 2 .2 V =
Trig 2.00 V + EXT =

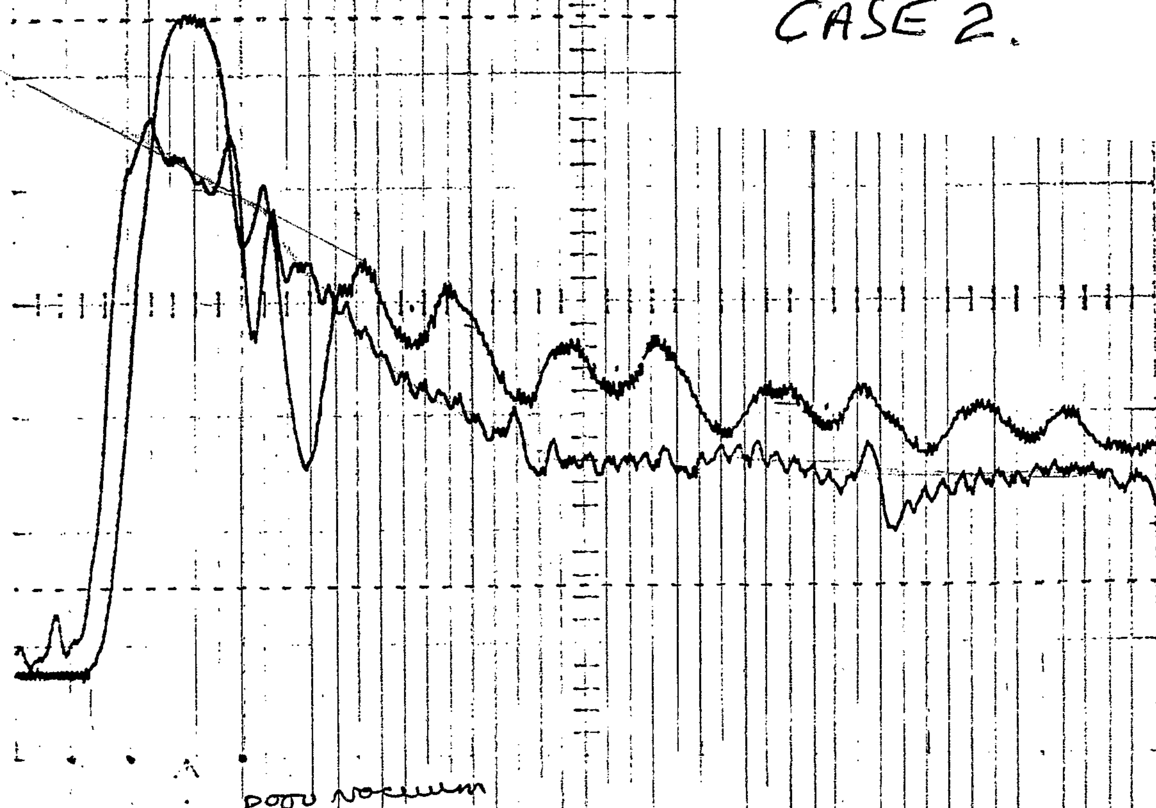
DATA PAGE 3

CASE 1 & 2 (?)

BOOK 449

DATA PAGE 2

CASE 2.



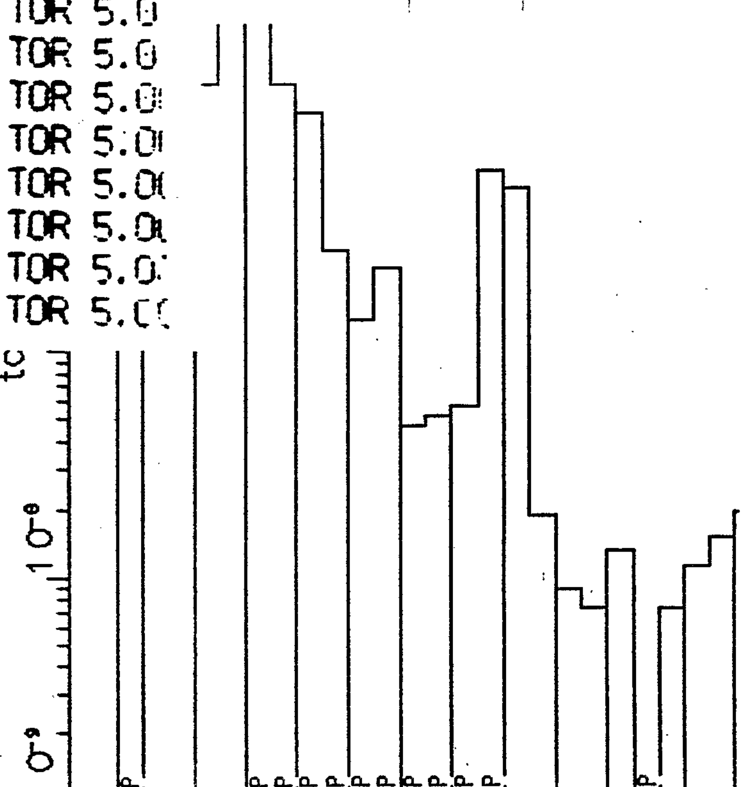
Channel 1
.5 ms 1 V

Channel 2
.5 ms .5 V

Ch 1 1 V =
T/div .5 ms Ch 2 .5 V =
Trig 2.00 V + EXT =

NAME	RDBK_VAL	UNT	RE
[illegible]	+1.66e-07	TOR	5.0
E5PI.P	+2.24e-07	TOR	5.0
E6PI.P	+6.60e-07	TOR	5.0
E7PI.P	+6.05e-07	TOR	5.0
E8PI.P	+1.54e-06	TOR	5.0
E9PI.P	+3.68e-06	TOR	5.0
E10PI.P	-9.90e-19	TOR	5.0
E11PI.P	-4.56e-06	TOR	5.0
E12PI.P	+1.59e-06	TOR	5.0
E13PI.P	+1.10e-06	TOR	5.0

@E10 vac = 800 cnts ⇒

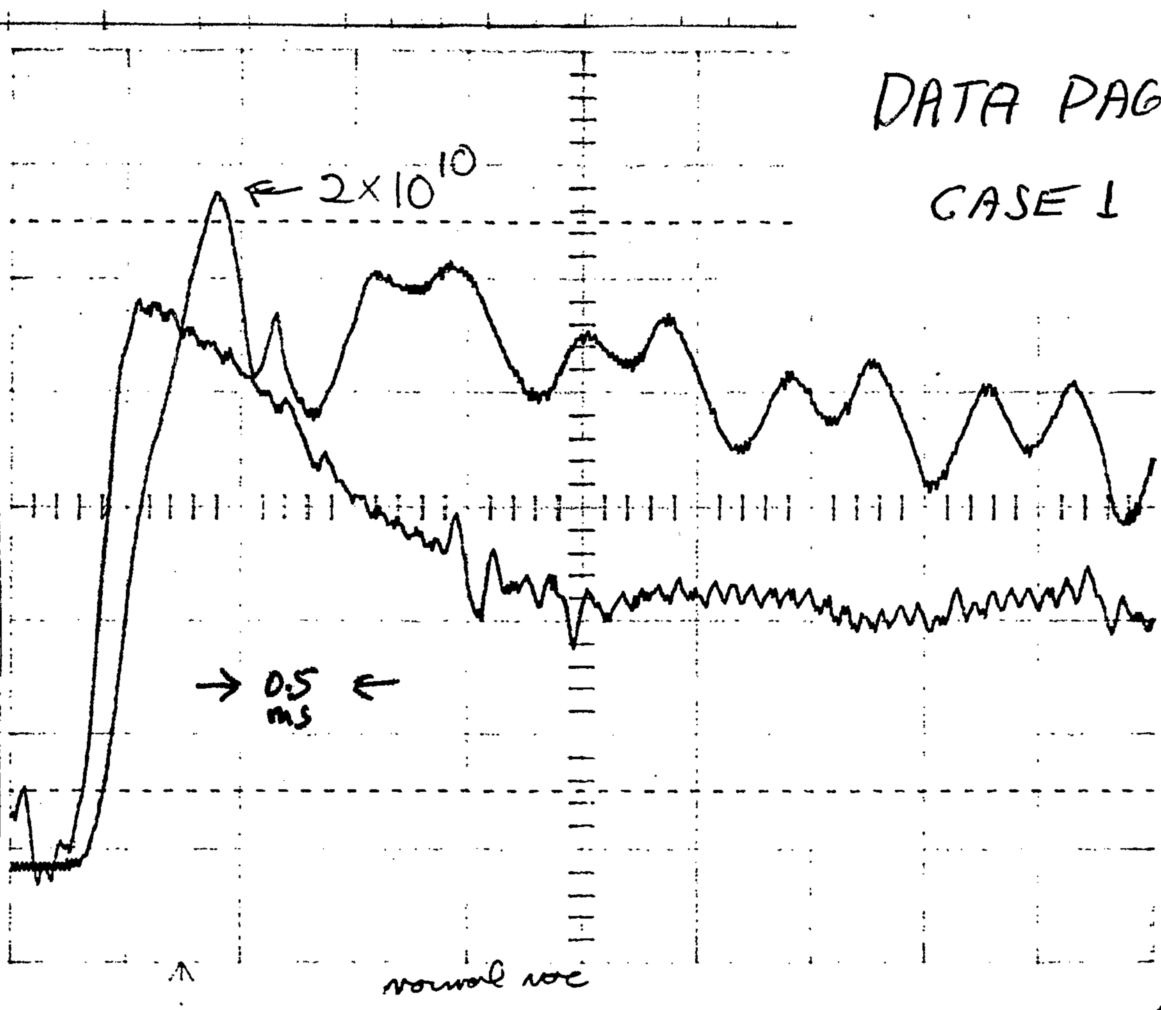


DATA PAGE 1

CASE 1

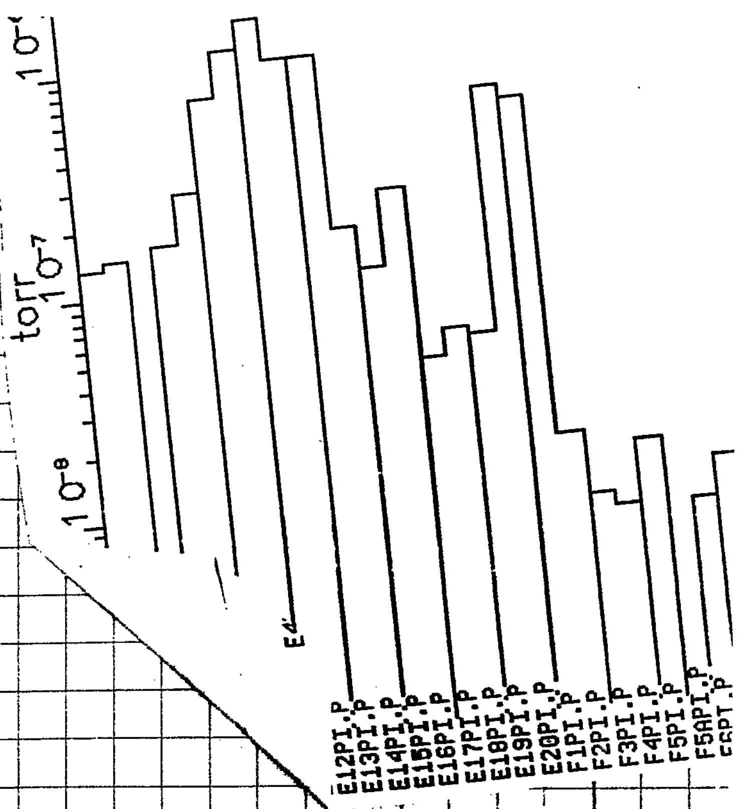
G. 7 or 20?

G-20



L20 cutoff @ 20KHz

NAME	RDBK_VAL	UNT	REF_VAL
[illegible]	-1.26e-07	TOR	5.00e-06
E5PI.P	-1.35e-07	TOR	5.00e-06
E6PI.P	-1.32e-07	TOR	5.00e-06
E7PI.P	-2.24e-07	TOR	5.00e-06
E8PI.P	-6.05e-07	TOR	5.00e-06
E9PI.P	-8.80e-07	TOR	5.00e-06
E10PI.P	-9.90e-19	TOR	5.00e-06
E11PI.P	-1.10e-06	TOR	5.00e-0
E12PI.P	-6.60e-07	TOR	5.00e-0
E13PI.P	-7.15e-07	TOR	5.00e-0



450 = (2.2 x 10^-7)

@ E10 Voc = ~~800~~ counts