BNL-105182-2014-TECH

Booster Technical Note No. 138;BNL-105182-2014-IR

STABILITY OF SCREEN POWER SUPPLY FOR THE RF BAND 1 and 2 P.A.

A. Ratti

May 1989

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

STABILITY OF SCREEN POWER SUPPLY

FOR THE RF BAND 1 & 2 P.A.

AD
BOOSTER TECHNICAL NOTE
NO. 138

A. RATTI and R. T. SANDERS

MAY 12, 1989

ACCELERATOR DEVELOPMENT DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

Stability of Screen Power Supply for the RF Band 1 & 2 P.A.

A. Ratti and R.T. Sanders

Following the guidelines outlined in T.N. 103, it is possible to evaluate the equivalent requirements for the screen power supply for the RF power amplifier for band 1 & 2.

The gap voltage regulation is strictly bound to the anode current in the actual case of a matched load. The anode current regulation can be written as:

$$\delta I_b/I_b = S_{Ec2}\ \delta E_{c2}/E_{c2}$$

when the effect of the instability of the grid P.S. is neglected.

Static regulation

The sensitivity of the anode current vs. the screen voltage can again be estimated in two ways. By definition:

$$S_{Ec2} = E_{c2}/I_b * \delta I_b/\delta E_{c2}$$

Looking at the plots in Fig. 1 & 2, it is possible to estimate S_{Ec2}, for the values of E_{c2} and I_b given in the figures.

$$S_{Ec2} \approx 3.6$$

Using the transconductance definition

$$S_{Ec2} = E_{c2}/I_b * g_m/\mu_2$$

which in this case yields to

$$S_{Ec2} \approx 3.6$$

when $E_{c2} = 1.5kV$, $I_b = 14$ A, $g_m = 0.15$, $\mu_2 \approx 4.5$

Since the two estimates are in good agreement, it can be required that:

$$\delta E_{c2}/E_{c2} = 1/3.6 * \delta I_b/I_b$$

Assuming to want a gap voltage regulation of ±1%, then a stability of ±.25% on the screen voltage is required.

Transient Response

The transient response of the Screen Power Supply is difficult to specify. The gap voltage program for each species of light and medium weight ions differ in rise time and peak amplitude. Also, the voltage rise for Band I is different than for Band II. However, at this time it is being assumed that the hand-off from one band to the next (typically 30 msec), will take more time than the initial rise in gap voltage. Thus, only the response to the initial rise will be considered in this note.

There is some level of uncertainty as to what the actual cavity dissipation will be for Band I. Estimates for a full 17kV gap voltage vary from 150 to 360 kW. For 8.5kV gap voltage cavity dissipation is as high as 70kW. Calculations have been made for 17kV and 200kW, which is the maximum power level at full gap voltage without control grid current, and also 8.5kV and 70kW for a half gap voltage acceleration program. The half gap voltage program assumes that at full voltage the cavity dissipation would run as high as 360kW, and it might be possible to obtain gap voltages as high 12kV with a corresponding cavity dissipation of about 150kW.

During operation, the power amplifier normally will have all potentials applied continuously with only the RF drive being pulsed ON for each acceleration cycle. The various electrode currents will follow the drive demands. The operating point for the power tubes, and in turn, the stage gain is set by all the electrode potentials. Any change in electrode potential due to poor static regulation or transient response could have adverse effects on the gap voltage program. From simple calculations it is noted that the RF bypass capacitors used in a power amplifier, while providing low reactance paths at radio frequencies, do not store enough energy to smooth out variations in electrode voltages due to transients.

The Band I & II Power Amplifiers will use a pair of Y567B power tetrodes operating in pushpull. These tubes can have both positive or negative screen current depending on the operating point, drive level and load impedance. Also, when the anode RF voltage swings down near the screen potential, the screen current can go from minus to plus, and near the end of the swing, suddenly jump to high levels.

For the full gap voltage case, as the gap voltage is increased, the screen current stays in a range of ± 20 mA below 13kV gap voltage. Above 13kV the screen current rises almost linearly to 165 mA. at 17kV. Some calculations have shown that shifting the quiescent operating point just slightly can cause the screen current to go above 200 mA.

The screen current for the half voltage case is about 90 mA. However, if the gap voltage is raised from 8.5kV to 12kV, the average screen current increases to 275 mA. The plot of the gap voltage and screen current versus time for the worst case (see Fig. 3) shows that if the gap voltage is increased linearly from 0 to 17kV, the screen current only becomes greater than 20 mA during the last 5 msec. Thus, the screen power supply load current will be specified as having a risetime of 5 milliseconds. Also, the amplifier stage gain should not vary more than ± 10% for practical reasons that will not be discussed herein. Knowing the anode current sensitivity to screen voltage, we can then state that the screen voltage should not vary more than ± 2.5% during a transient. The power supply transient response specification should read as follows:

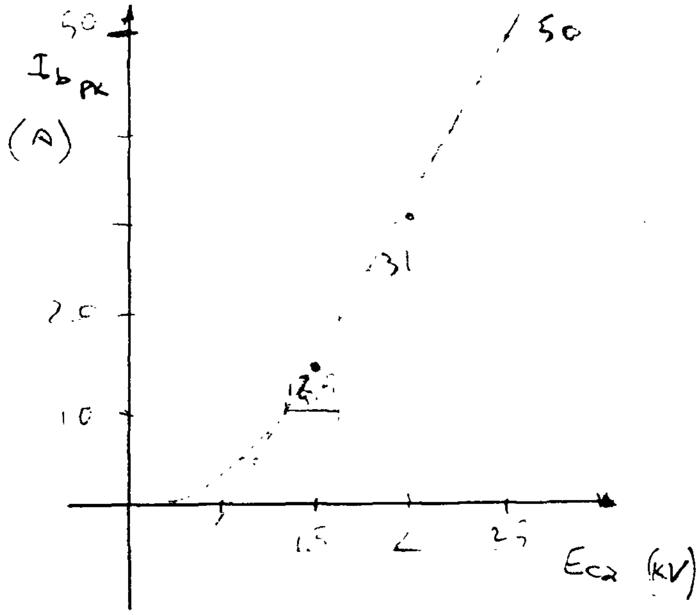
Transient Response For Pulsed Loads:

The output voltage shall not vary more than ± 2.5% and settle to within ± 1% in 10 msec. or less of its original setting, in the range from 1000 to 2000 V, with a step increase or decrease (rise or fall time of 5 msec.), in load current of 700 mA.

References:

- M. Meth - Stability of screen and grid power supplies for the rf power amplifier for proton cavity. - AD/Bstr. T.N. # 103, 12/30/1987

1/23/89

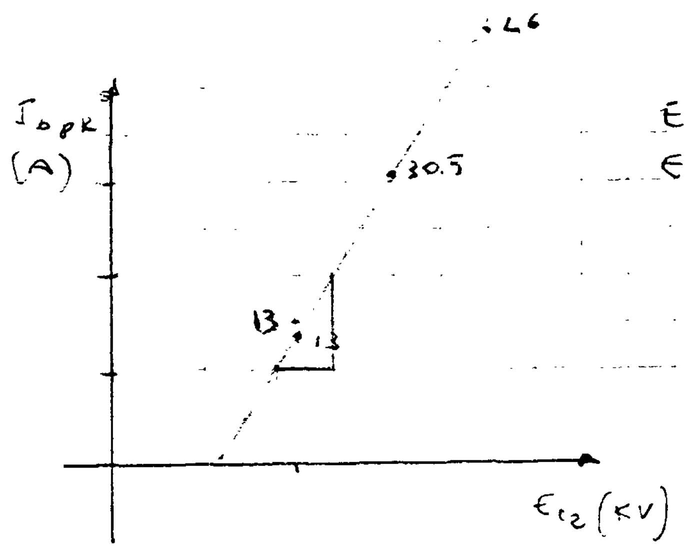


$E_b = 11\,kV$

$E_{c1} = -200\,V$

$$\frac{\partial I_b}{\partial E_{c2}} \approx \frac{1}{28.6\,V} \approx 35.\ mA/V$$

$$S_2 = \frac{E_{c2}}{I} \cdot \frac{dI}{dE_{c2}} = \frac{1.5\ 10^3}{14.5} \cdot 0.035 = 3.62$$



$E_b = 7\,kV$

$E_{c1} = -200\,V$

Fig. 1 and 2 - Evaluation of sensitivity for the shown conditions.

Fig. 3 - Typical extimated average screen current and gap voltage on each tube as a function of time (Band 2).

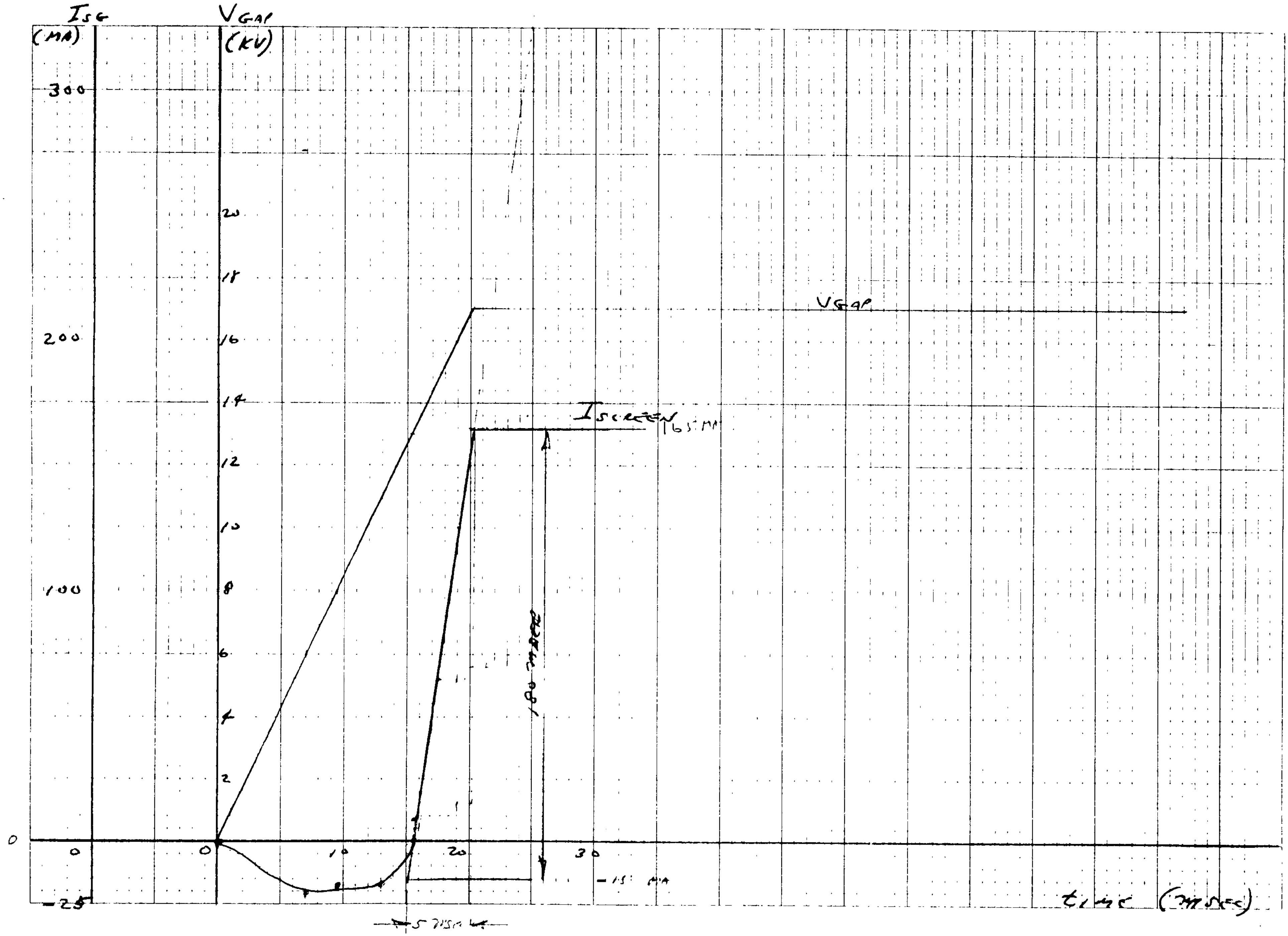


FIG. 3.