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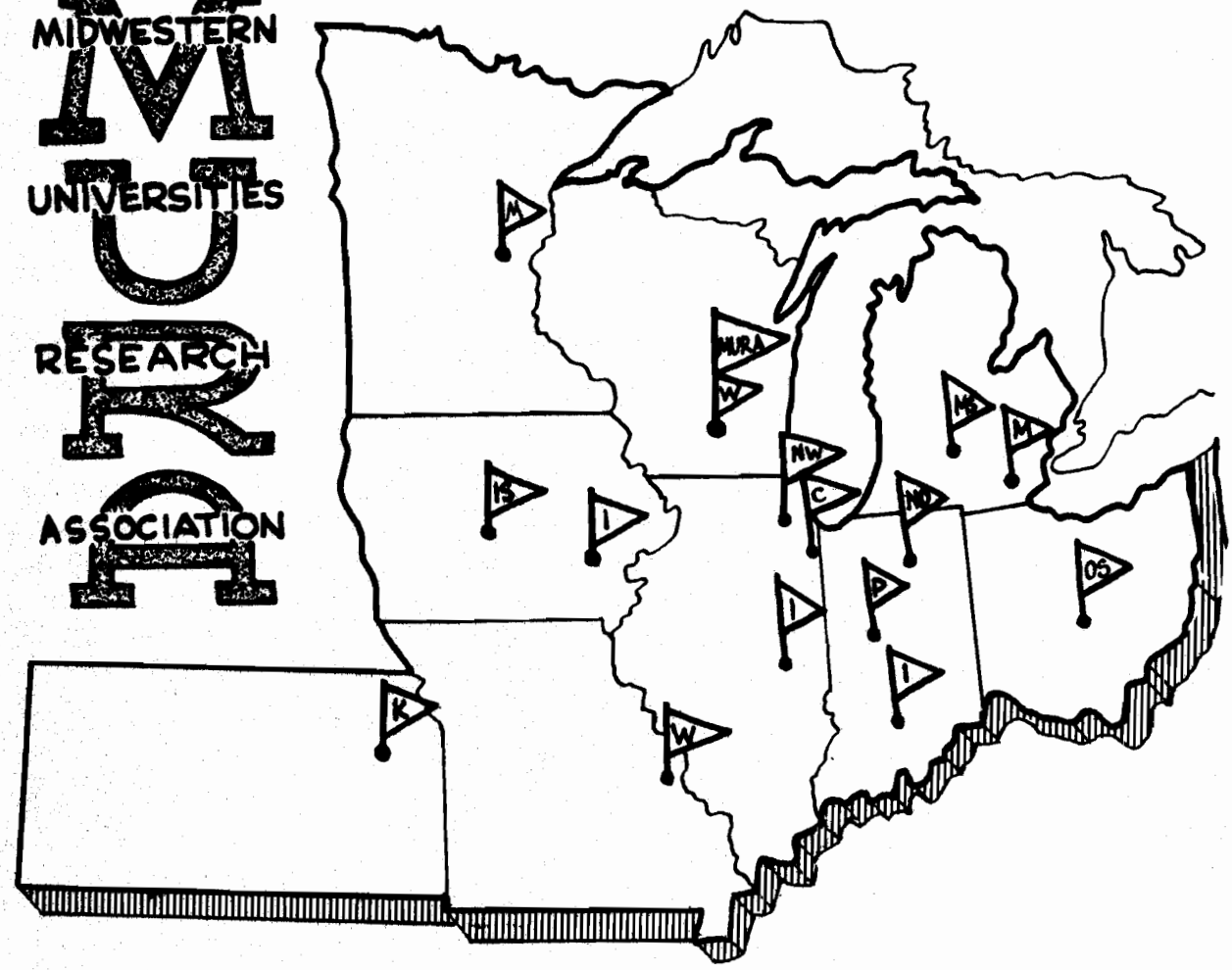


# THE EFFECT OF NEARBY BUCKETS ON BUCKET AREA IN RF ACCELERATION

J. B. Boilen

**REPORT** **NUMBER** 606

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Printed in USA. Price $0.50. Available from the

Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

MURA-606
UC-28, Particle Accelerators and
High Voltage Machines
TID-4500 (16th Edition)

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# THE EFFECT OF NEARBY BUCKETS ON BUCKET AREA IN RF ACCELERATION

J. B. Boilen
(as told to K. R. Symon)

February 14, 1961

## ABSTRACT

Computer studies have been made of rf acceleration in the presence of equal accelerating voltages at frequencies resonant with energies equally spaced above and below the synchronous energy. It is concluded that the accelerating bucket area is not significantly affected if the frequency spacing is such that $\Delta y \gtrsim 4$, but that for $\Delta y < 4$, the bucket area falls rapidly toward zero. ($\Delta y = \left[(2\pi h\,|df/dE|)/(fV)\right]^{1/2} \Delta E$.)

*AEC Research and Development Report. Research supported by the U. S. Atomic Energy Commission, Contract No. AT(11-1)-384.

In the design of multiple-frequency acceleration systems like that of Robinson and generalizations thereof (MURA-475, MURA-558), it is important to know how closely spaced the frequency modulated accelerating buckets may be without interference with one another. Preliminary studies by G. Bronca (MURA-558) indicated that the spacing $\Delta E$ between centers of successive buckets may be as small as $\Delta y \sim 5$, where

$$\Delta y = \left[ \frac{2\pi h}{fV} \left| \frac{df}{dE} \right| \right]^{1/2} \Delta E \, . \tag{1}$$

For comparison, the maximum half-height of a frequency modulated bucket is, in y-units, approximately $y_1 = 2 - \sin \varphi_s$. (See MURA-106, Figs. 12, 13.) Thus at $\Delta y = 4$, the bucket boundaries would touch for a low rate of frequency modulation ($\varphi_s << \pi/2$).

In order to check this point more carefully, computations of particle trajectories in E, $\varphi$-space were carried out at two values of $\Gamma = \sin \varphi_s$, and for various separations $\Delta y$. A central rf voltage was frequency modulated to accelerate particles, while two equal neighboring rf voltages were likewise frequency modulated so as to remain synchronous at energies $\pm \Delta y$ above and below the central bucket. Particles were started initially at points on a rectangular mesh in E, $\varphi$-space covering the central bucket. By noting which particles were accelerated to the final energy, it was possible to map out the area corresponding to stable acceleration. The final energy was about 14 y-units above the initial energy for $\Gamma = 0.7$, and 8 y-units for $\Gamma = 0.4$. The acceleration process lasted for about two phase oscillations.

For purposes of convenience in computation and interpretation of results, the actual computations were carried out using constant frequency rf voltages, with a constant negative energy kick each turn, so that a particle not trapped in a bucket steadily loses energy. It is easy to show that this process is equivalent to one in which particles are accelerated by modulating the frequencies.

The results are shown in Fig. 1, where we plot the area ratio $A/A_o$ vs. the bucket separation $\Delta y$. The area A is the area accelerated in the presence of the perturbing rf frequencies, and $A_o$ is the unperturbed bucket area. Values are plotted for $\Gamma = 0.4$ and $\Gamma = 0.7$. The points labelled "coarse mesh" correspond to a mesh size such that $A_o = 36$ mesh units for $\Gamma = 0.4$, and $A_o = 46$ mesh units for $\Gamma = 0.7$. For $\Gamma = 0.7$, the perturbing voltages actually seem to increase the bucket area slightly for large separation $\Delta y$. In order to determine whether this was an error due to the coarse mesh, a fine mesh with $A_o = 185$ mesh units was also used. It is seen that the results are essentially unaffected by the coarseness of the mesh. Although in the case $\Gamma = 0.4$, some particles, corresponding to roughly $1/2\ A_o$ were accelerated even down to $\Delta y = 1$, the shape of the accelerated area becomes extremely irregular, and even disconnected at $\Delta y \lesssim 3$, and it is not clear that even these particles would not have been lost had the acceleration process continued longer.

We conclude that it is safe to space buckets down to perhaps $\Delta y = 4$, but that at smaller spacings the perturbations result in a serious loss of phase area.
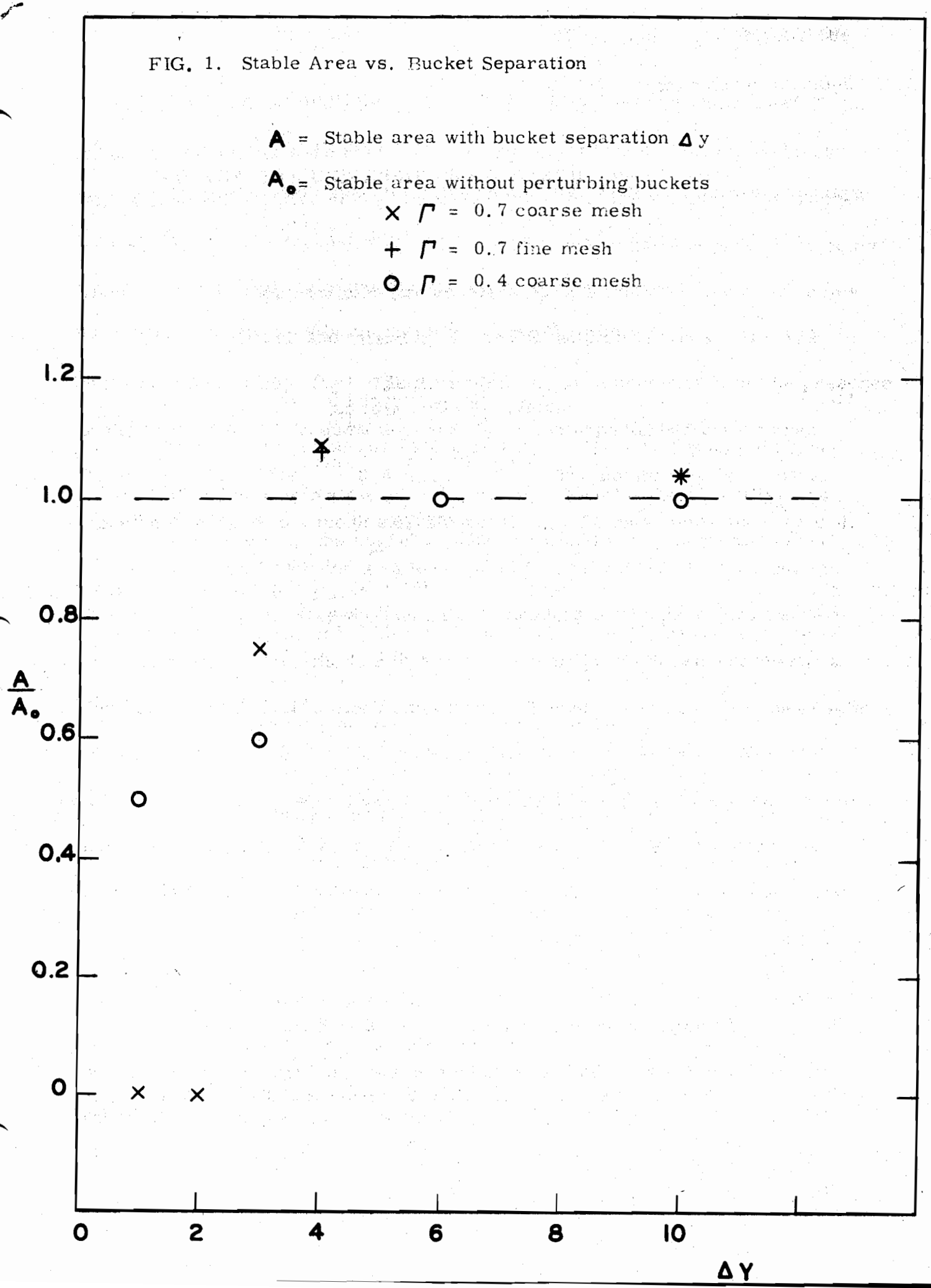
FIG. 1. Stable Area vs. Bucket Separation