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CRYOGENIC MAGNETS AND SYNCHROTRONS, CRYOGENIC AND VACUUM TECHNOLOGIES. SESSION I - Panel Discussion on Superconducting Synchrotrons

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SESSION I -- CRYOGENIC MAGNETS AND SYNCHROTRONS, CRYOGENIC AND VACUUM TECHNOLOGIES

Panel Discussion on Superconducting Synchrotrons*

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INTRODUCTORY REMARKS - Panel Discussion on Superconducting Synchrotrons

Some recent developments lend encouragement to the Berkeley Group investigating the pulse dipole magnets that are needed for future superconducting protron synchrotrons.

Fine Wire Developments

Early in 1970 it became apparent that the filamentary NbTi superconductor below about 20μ in diameter, from all the major suppliers, had considerable electrical resistance, well below transition current levels.[1] Fig. 1 shows this for the material labeled April 1970--this curve is similar to data taken for other vendors' material of this vintage. On a log ρ V_c log J Plot, a well behaved superconductor should have a virtually vertical slope; curvature indicates metallurgical failure due to breaks, cracks, fractures, geometrical variations, compositional changes, and other still unresolved problems. The useable current density is that corresponding to a resistivity of 10^{-12} ohm-cm or lower.

Cryomagnetics** developed a variety of improved composite superconductors in December 1970 which we have been testing. The results on 3 of these conductors appear on Fig. 1. The regular alloy identified as 10μ, December 1970 is to be compared with the 10μ, April 1970 curve discussed above. One can see that the curve is vertical, so the metallurgical problems have been solved. In addition, the critical current density has been much increased (the curve is moved to the right). The 2 curves labeled experimental alloy are even more exciting. The curve labeled 4μ is a 3 mil wire and the vertical curve shows excellent metallurgy and the current density is quite high. The curve to the left is still a straight vertical line; the wire is only 1 mil and the filaments are only 1 1/4μ. The vendor is not willing to predict whether this drop in current density must occur in the region between 4μ and 1μ or is dependent on processing procedure. In any case, we have material at 4μ that is far better than material at 7μ that was produced only half a year ago. Most synchrotron calculations have been done on the basis of filaments of 7 to 12μ diameter; we can now consider recalculation on the basis of the lower hysteretic loss 4μ material.

Model Pulse Dipole Results

Fig. 2 is a picture of a pulse dipole using the older material mentioned above. Details are given by Ferd Voelker in paper I-10[2]. The magnet was degraded in that it didn't reach its short sample limit. However, it pulsed easily at a $\dot{B}$ of 6kG/sec to its 23kG central field maximum with a very low loss of some 9J/cycle or a "Q" of 500 which is just what we calculate for the 7μ filaments NbTi used***.

Parametric Design - Cost Estimate

We thought it useful to take a new look at the systems aspects of superconducting synchrotron main rings in the light of the progress noted above. A relatively optimistic viewpoint was taken with regard to economical solutions of still outstanding problems. These cost estimates were done by Michael Green[3]. For NbTi superconductor, a filament diameter of about 1/2 mil (12μ) was assumed, so in this sense the suspension of disbelief required is minimal. An advanced high temperature high-field conductor, either filamentary Nb_3Sn or V_3Ga, having the following properties was assumed: the cost per pound would be no higher than the NbTi materials, the average current density of the composite would be some 3 times that of the NbTi composite, the filaments would be as small or smaller than the NbTi filaments so that the pulse loss would be the same per ampere-meter of conductor. Fig. 3 shows total capital costs and capital costs plus 10 year power costs for both type materials vs synchrotron cycle time. Since the magnet loss is hysteretic rather than resistive in nature, one naturally pays heavily for shorter cycle time. One also gains proton intensity as the repetition rate increases. Fig. 4 shows the costs vs beam aperture, and a larger beam aperture is a way to gain more intensity. The cost-aperture curve rises much more slowly for a superconducting magnet system than for a conventional copper-iron one. Hence, for a given intensity the superconducting synchrotron will tend to a slower--larger aperture optimum.

Fig. 5 shows the final cost vs field and shows that the costs come to some 3 or 4 times lower than conventional machines when one includes the 10 year power bill. An additional benefit is that higher energy main rings can be installed at copper-iron magnet sites at reasonable costs.

Fig. 6 is a breakdown of individual component costs vs field for one specific set of parameters. The main conclusion of this data is that no one component dominates the total system costs.

References

1. Ferd Voelker, "Resistance in Small, Twisted, Multicore Superconducting Wires", Particle Accelerators, 1970, Vol. 1, pp 205-207.
2. W. Eaton, W. Gilbert, R. Kilpatrick, R. Meuser, F. Toby, F. Voelker, "Superconducting Pulsed Synchrotron Dipoles and DC Beam Transport Magnets", Proc. 1971 Particle Accelerator Conference, UCRL Report 20188.
3. Michael A. Green, "Factors Which Will Affect the Cost of a Superconducting Synchrotron", submitted to the HEPAP Panel on Advanced Accelerator Technolgy, Lawrence Radiation Laboratory UCRL-20299.

* This work performed under the auspices of the Atomic Energy Commission.

** Cryomagnetics Corporation, 4955 Bannock St., Denver, Colorado, 80216

*** Norton Company - Supercon Division, 9 Erie Drive, Natick, Mass. 01760

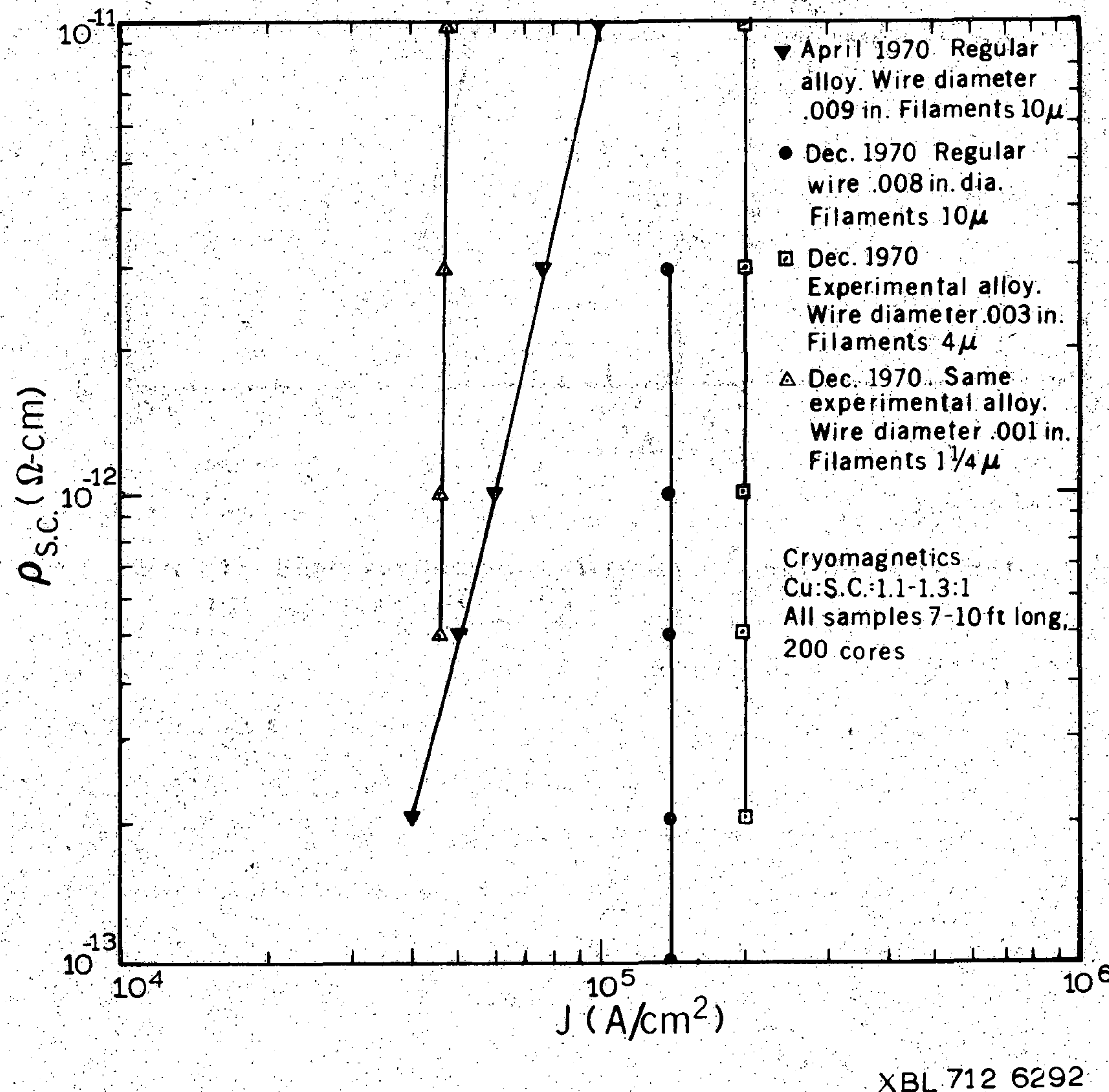

Fig. 1. Superconductor resistivity vs current density in fine composite NbTi-Cu wires at 50kG.

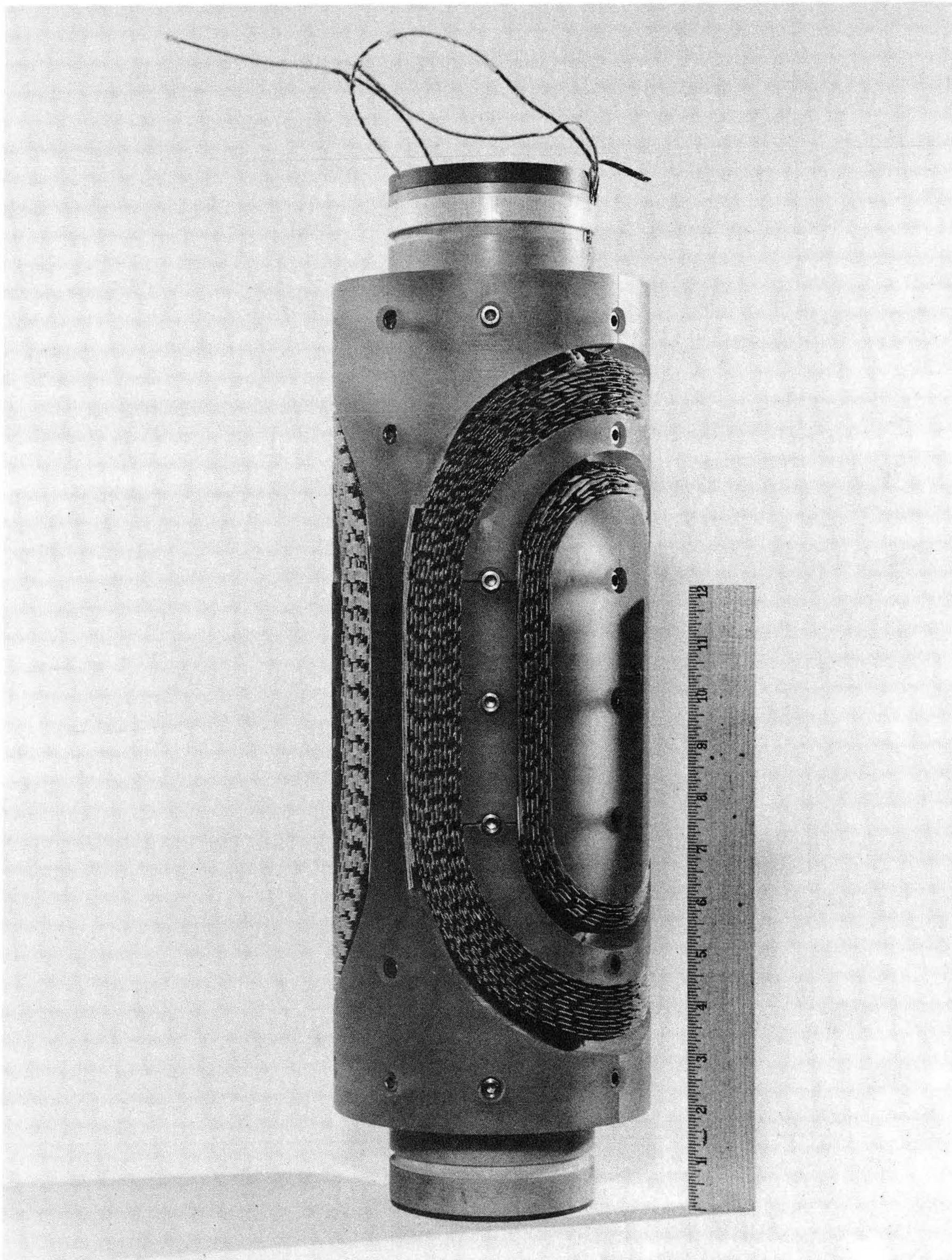

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Fig. 2. Pulse dipole.

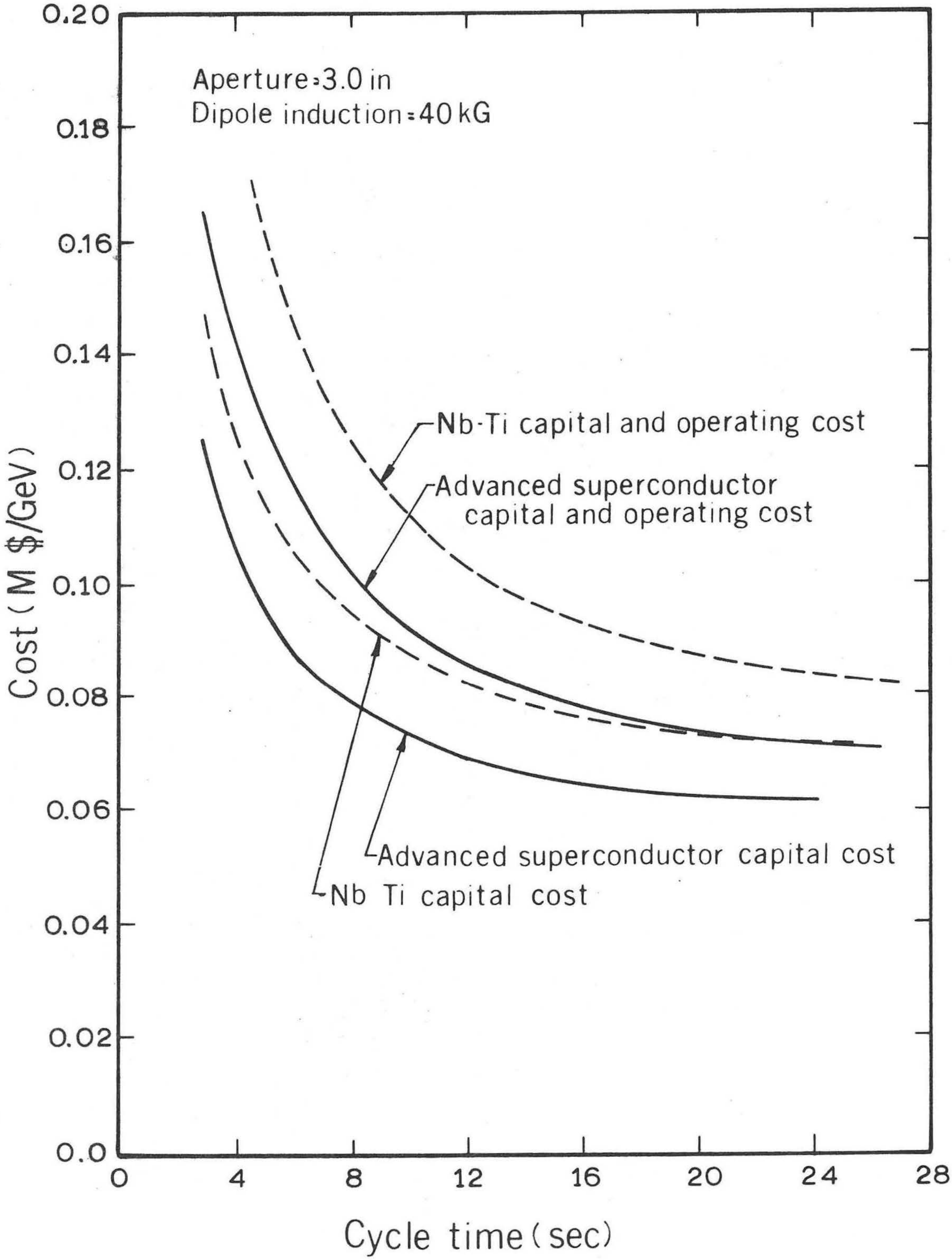

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Fig. 3. Synchrotron main ring costs vs cycle time.

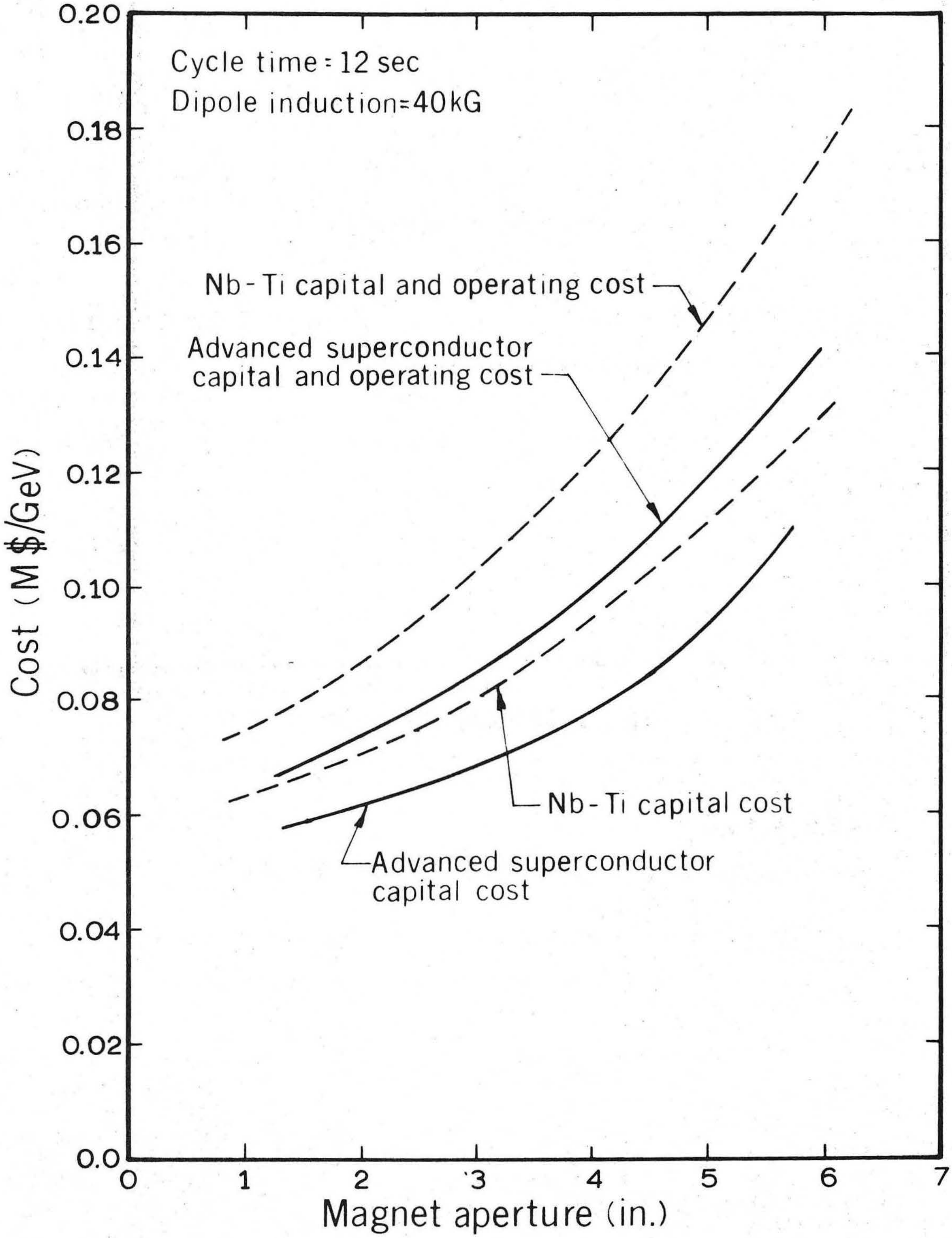

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Fig. 4. Synchrotron costs vs magnet aperture.

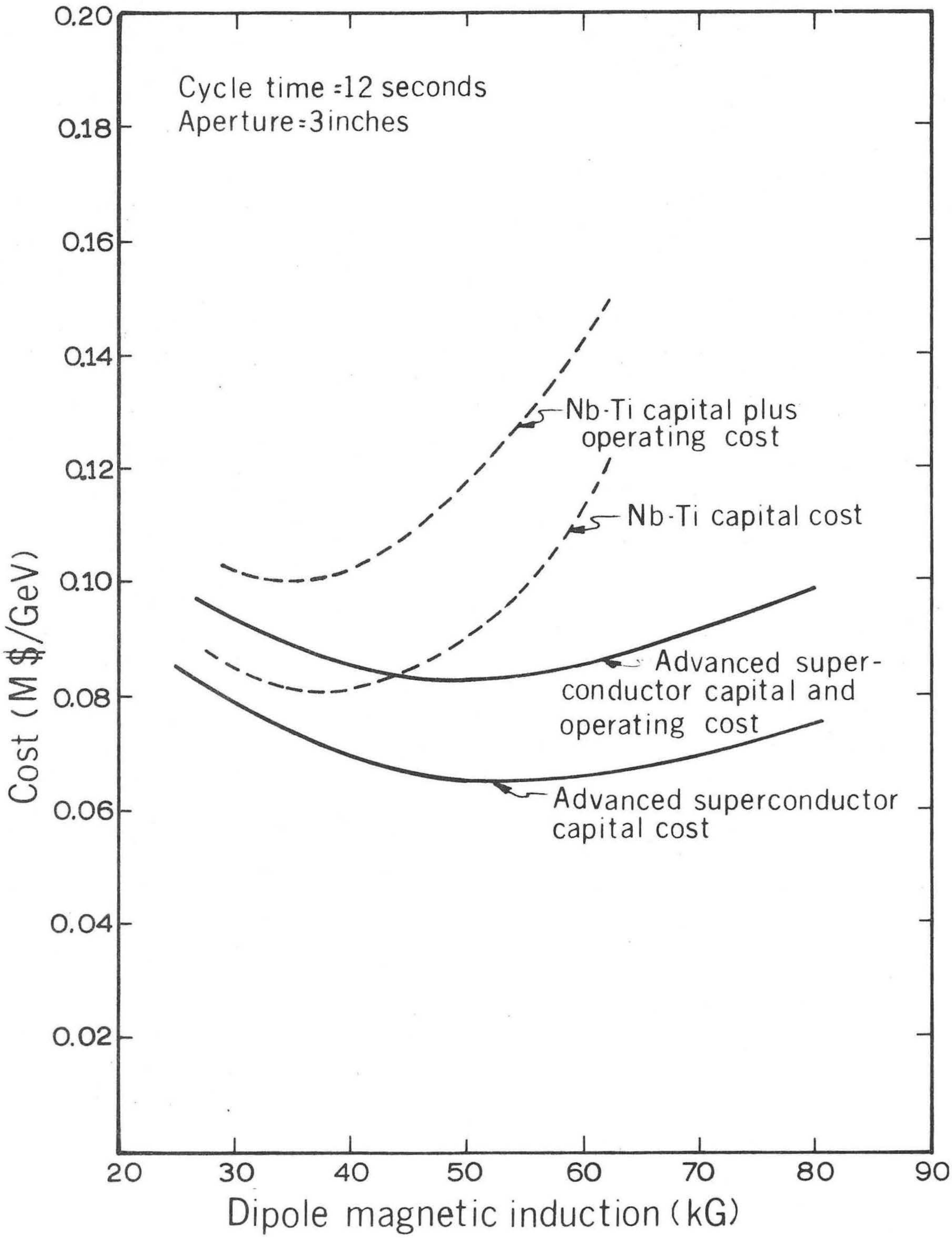

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Fig. 5. Synchrotron costs vs maximum magnetic field.

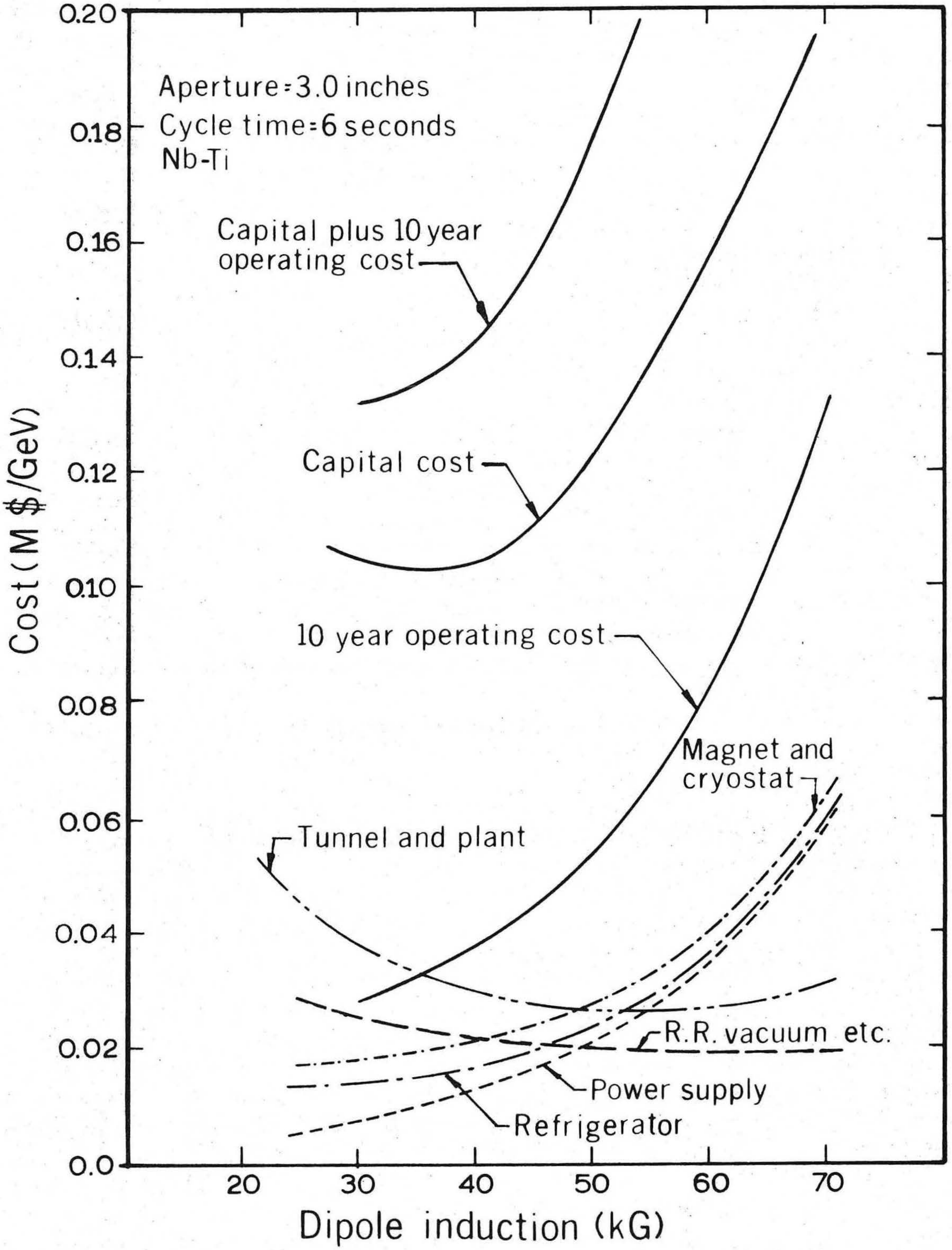

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Fig. 6. Synchrotron cost - detailed breakdown.

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