SSC-N-684
A.Chao
November, 1989

Possible Scenario to Reach Higher Luminosity

The basic equations are

$$L = N^2 c\gamma/4\pi\varepsilon_N\beta^* S$$

$$P/C = Z_o N e^2 c^2 \gamma^4/3CS\rho$$

$$\Delta\nu_{HO} = N r_p/4\pi\varepsilon_N$$

$$\Delta\nu_{LR} = N r_p L_{LR}/\pi\gamma\beta^*\alpha^2 S$$

where N = number of protons per bunch, S = bunch spacing, L = luminosity, β^* = beta-function at the high-luminosity IP, P/C = synchrotron radiation power per unit length, Z_o = *377 ohms, C = circumference, ρ = bending radius, $\Delta\nu_{HO}$ = head-on beam-beam tune* shift per IP (same for high- and medium-luminosity IP's), r_p = classical proton radius, ε_N = normalized rms emittance, $\Delta\nu_{LR}$ = long range beam-beam tune shift per high-luminosity IP, α = crossing angle, L_{LR} = length over which two beams interact with long range beam-beam interaction.

In this attempt of optimization, we fix the following quantities:

β^* = 0.35 m
α = 150 microrad
L_{LR} = 170 m
ρ = 10 km
C = 85 km
r_p = 1.535×10^{-18} m
S = 5 m
2 high- and 2 mediun-luminosity IP's

The value of β^* assumes a peak IR triplet gradient of 270 T/m. Expressing L in $10^{33}cm^{-2}s^{-1}$, N in 10^{10}, E in TeV, ε_N in π mm-mrad, P/C in kW/m, we have the following expressions:

$$L = 0.145\ N^2E / \varepsilon_N$$

$$P/C = 8.9\text{x}10^{-7}\ NE^4$$

$$\Delta\nu_{HO} = 0.00123\ N/\varepsilon_N$$

$$\Delta\nu_{LR} = 0.0198\ N/E$$

One way to specify the beam-beam limit is to impose a limit on the total head-on tune shift. With 4 IP's, for example, one might require

$$4\ \Delta\nu_{HO} < 0.01, \qquad (1)$$

which reads

$$0.00492\ N/\varepsilon_N < 0.01$$

In this case, the long-range beam-beam effects are ignored.

A more conservative limit on the beam-beam effect (particularly for the pacman bunches) may be to consider a limit of total beam-beam tune shift

$$\Delta\nu_{tot} = 4\ \Delta\nu_{HO} + 2\Delta\nu_{LR} < 0.02 \qquad (2)$$

which reads

$$0.00492\ N/\varepsilon_N + 0.0396\ N/E < 0.02$$

In addition, we consider a limit on synchrotron radiation power per unit length

$$P/C < 0.4\ \text{kW/m} \qquad (3)$$

which reads

$$8.9\text{x}10^{-7}\ NE^4 < 0.4$$

We will ignore the collective instability limits.

<u>Case 1</u> In this case, we ignore the long-range beam-beam effects. The optimal luminosity is given by simultaneously reaching the limits (1) and (3). This gives

$$N = 4.5\text{x}10^5\ E^{-4}$$
$$\varepsilon_N = 2.2\text{x}10^5\ E^{-4}$$

which gives

$$\Delta\nu_{LR} = 8.9\text{x}10^3\, E^{-5}$$

$$L = 1.33\text{x}10^5\, E^{-3}$$

Case 2 In this case, we impose the limit (2), which gives a curve for N versus ε_N. Luminosity is optimized along this curve. The optimum occurs when

$$4\,\Delta\nu_{HO} = 2\Delta\nu_{LR} = 0.01. \qquad (4)$$

This means that, when optimized, the head-on and the long-range limits are reached separatly, each contributing a total tune shift of 0.01. At the optimum, one has

$$N = 0.253\, E$$
$$\varepsilon_N = 0.124\, E$$

In this case, we have

$$P/C = 2.25\text{x}10^{-7}\, E^5$$

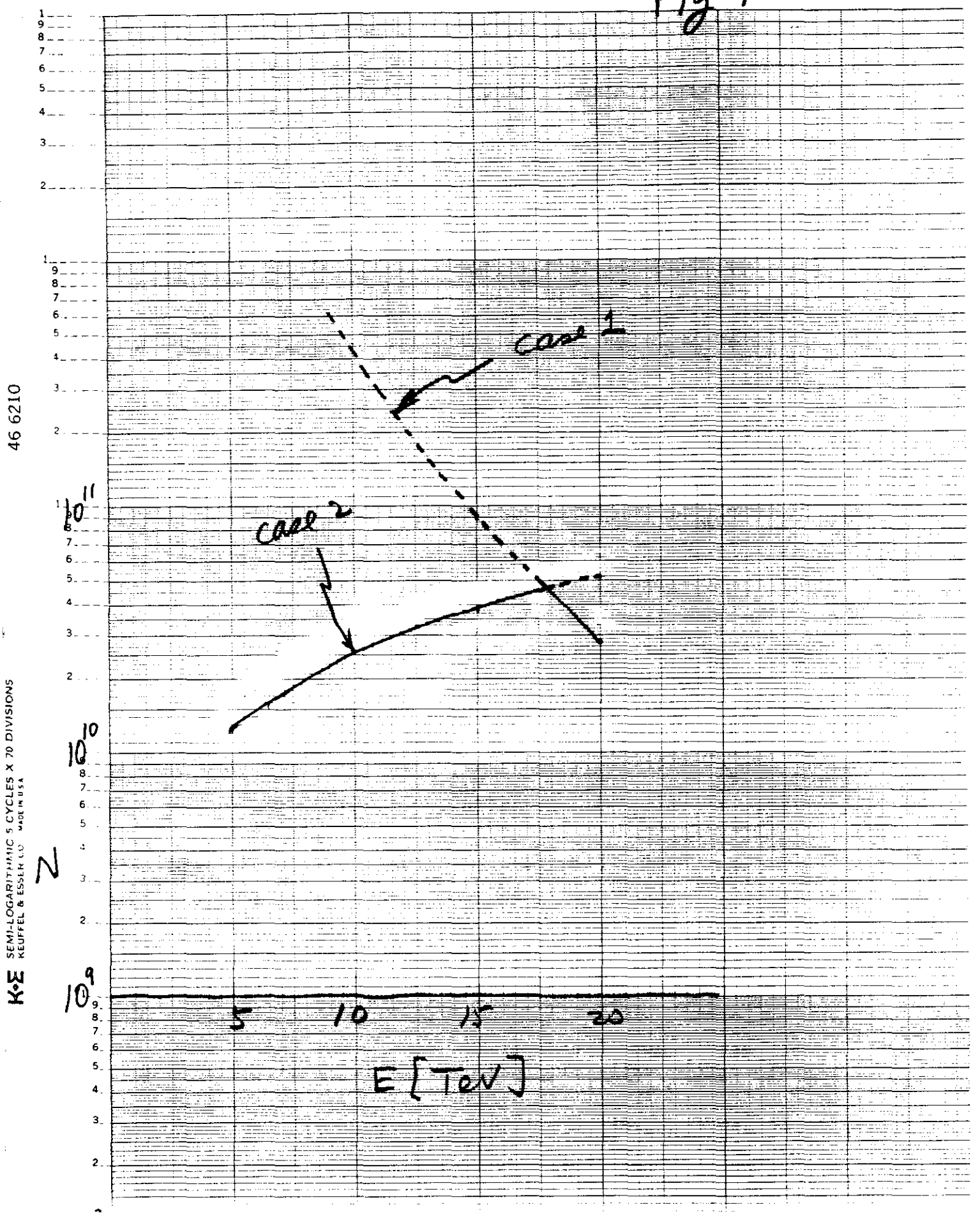
$$L = 0.075\, E^2$$

For E>18 TeV, the P/C limit (3) is violated.

The energy dependences of various parameters for the two cases above are plotted in figures 1-6. The expected optimal choice of parameters as functions of beam energy is given by the solid curves.

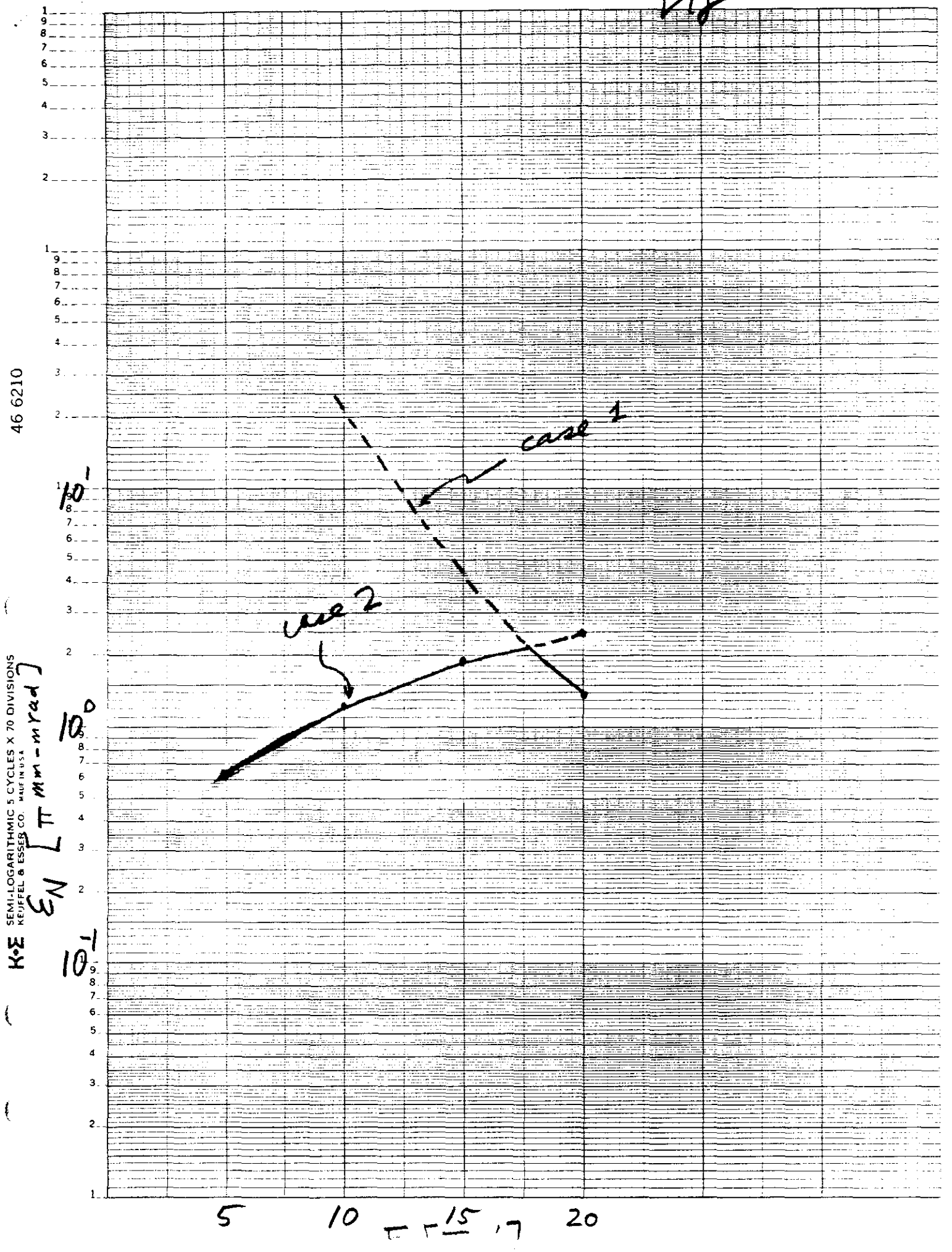
Helen Edwards contributed essentially to the discussions leading to this study. Jacques Gareyte helped clarifying some questions concerning the long-range and single beam collective effects. A study using an alternative limit for the long-range limit (which emphasizes a possible diffusion effect due to the long range interactions) was performed, yielding basically the same result as case 2 above.

Fig 1



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6210

Fig 2



46 6210
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Fig 3

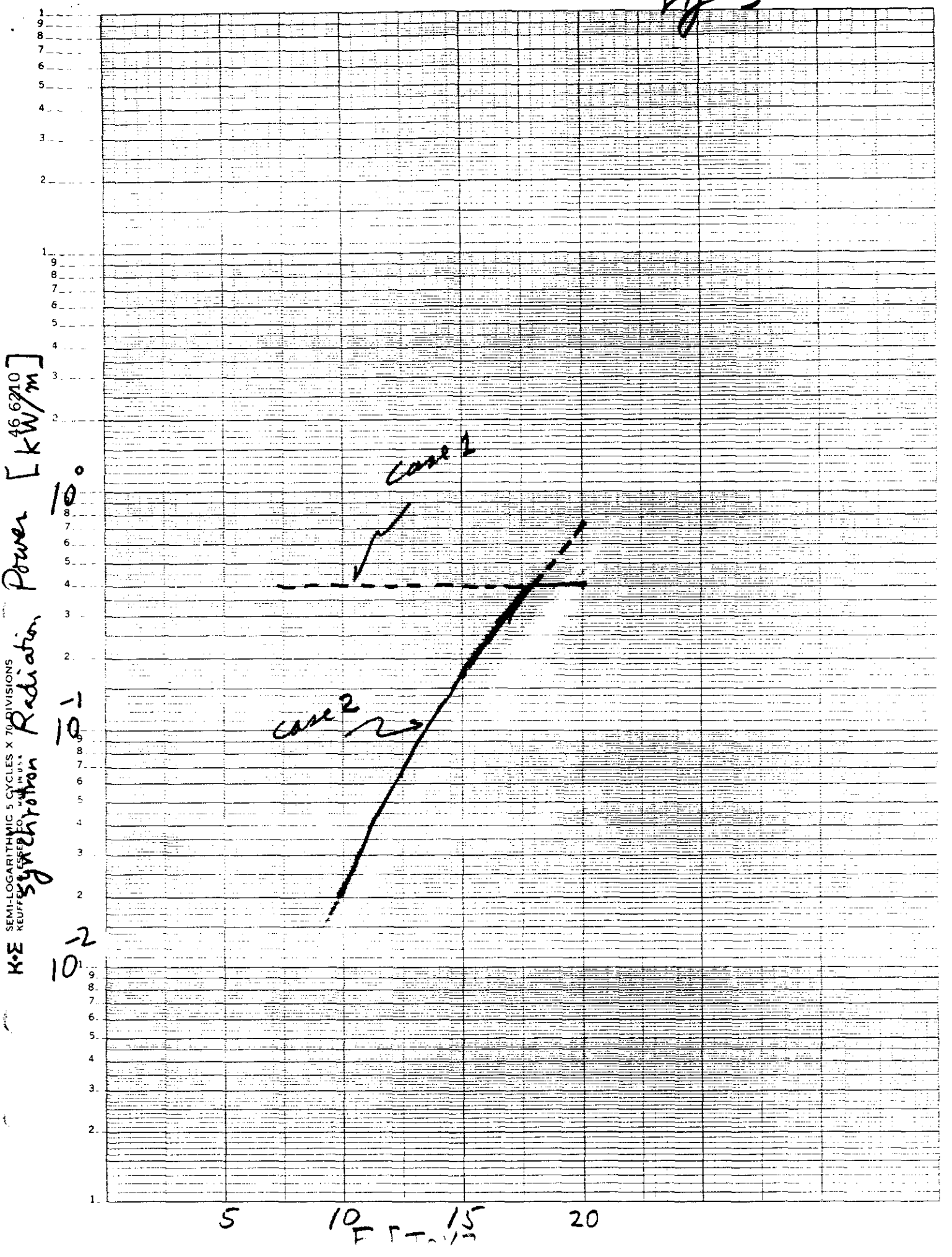
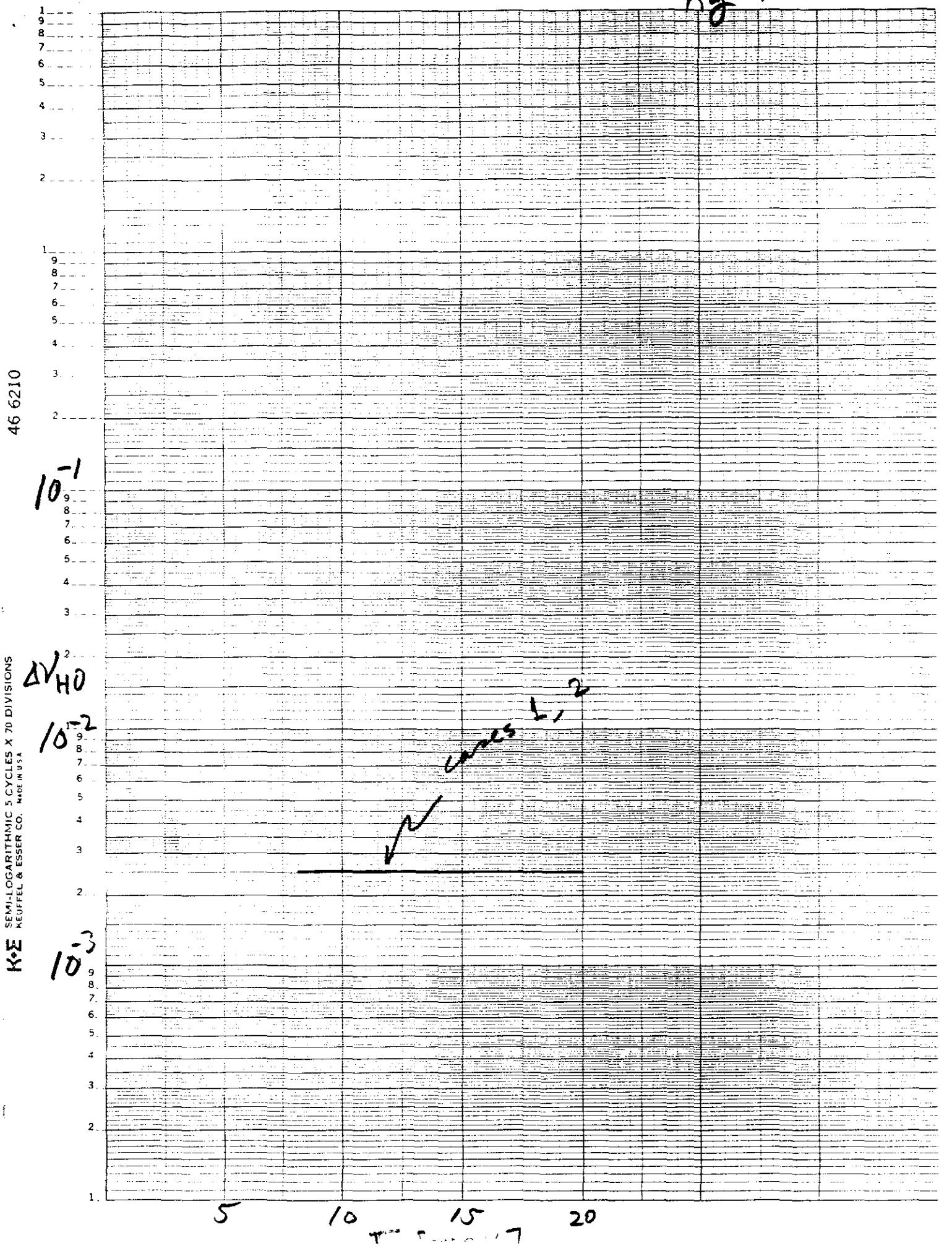
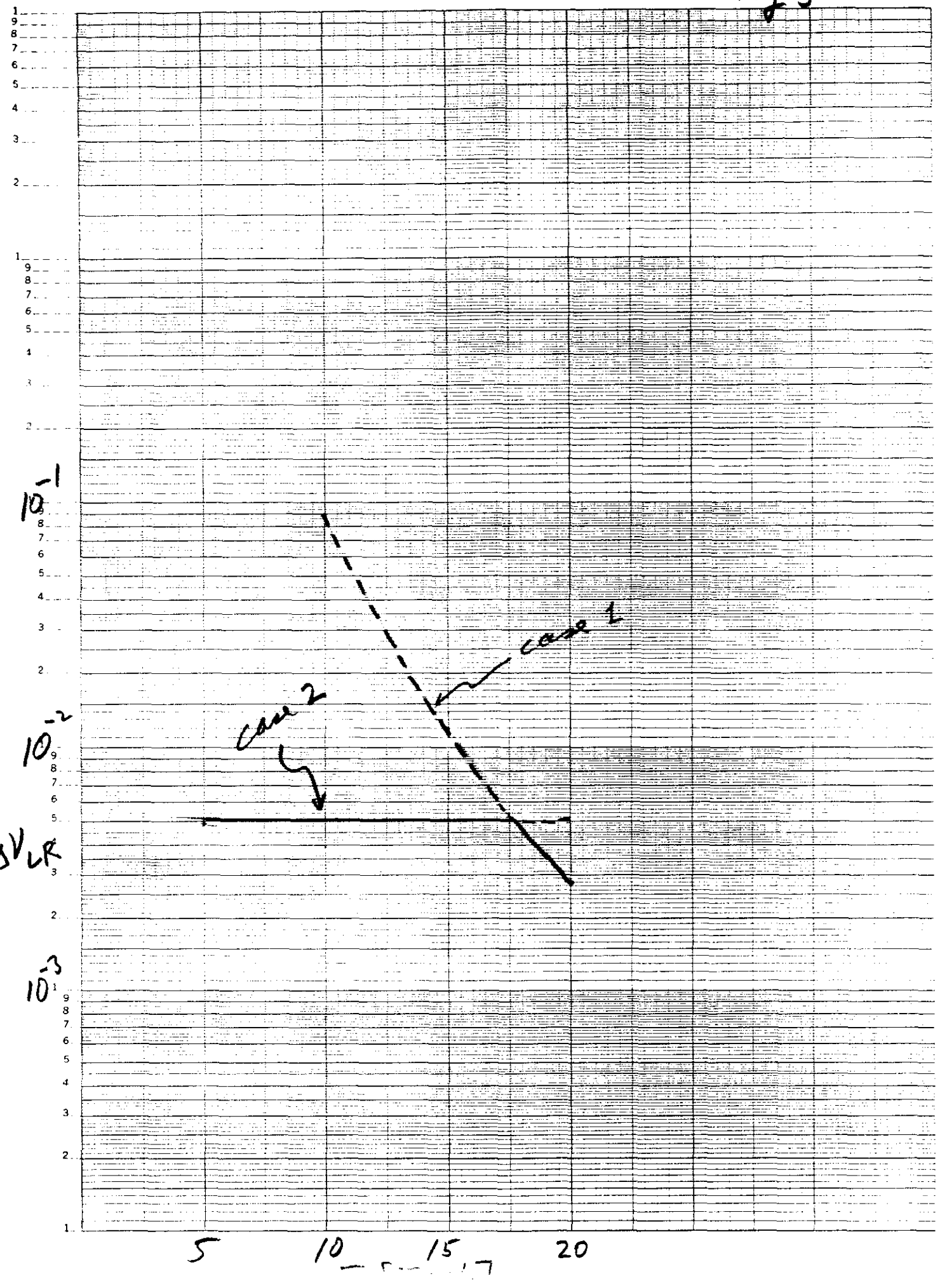

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
Synchrotron Radiation Power [kW/m]
10^0
10^{-1}
10^{-2}
case 1
case 2
5
10
15
20

Fig 4



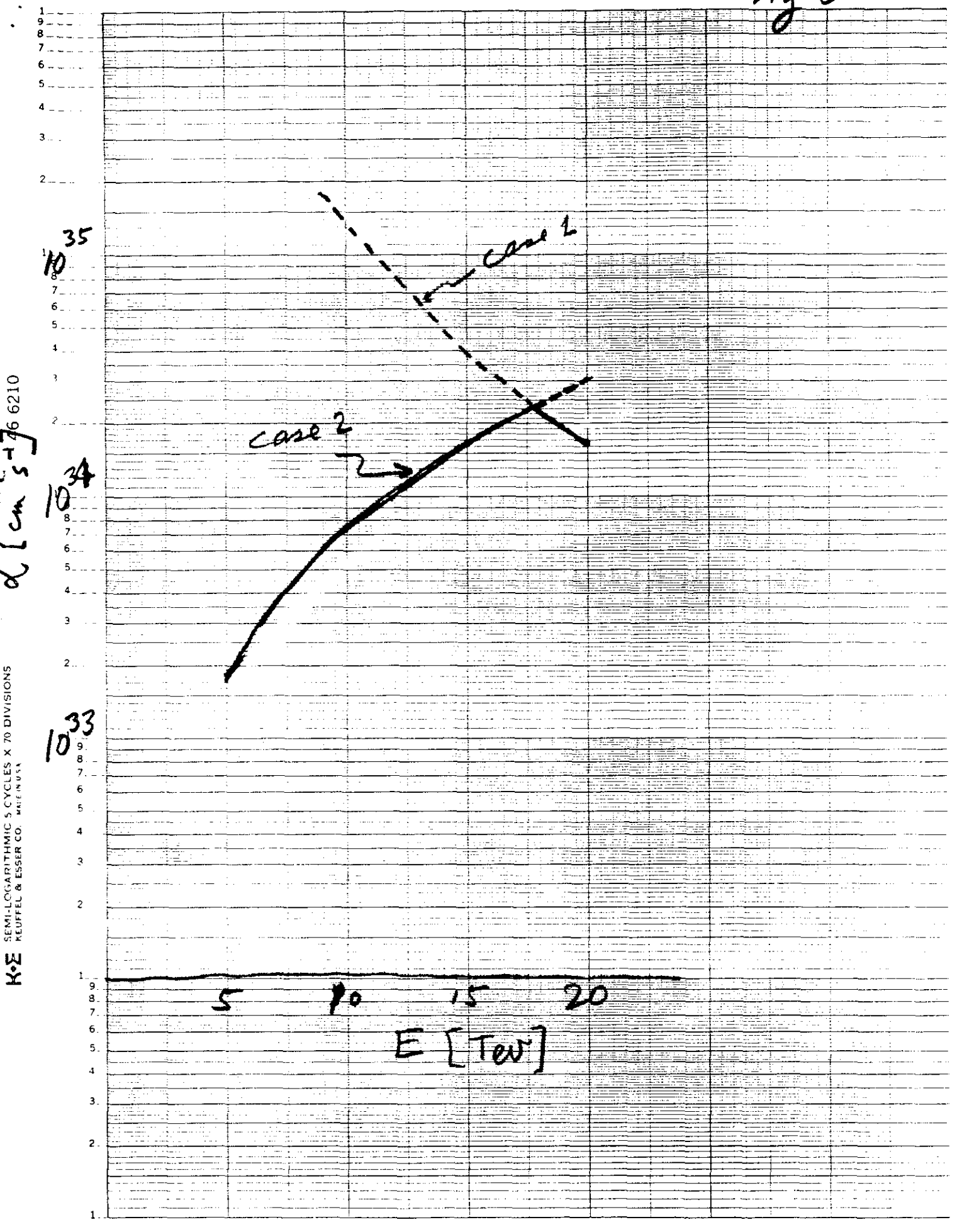
10^{-1}
$\Delta\nu_{HO}$
10^{-2}
10^{-3}
cases 1, 2
5
10
15
20
46 6210
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Fig 5



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6210

Fig 6


case 1
case 2
10^{35}
10^{34}
10^{33}
$\mathcal{L}\,[cm^{-2}s^{-1}]$
5
10
15
20
E [TeV]
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6210