ITR-21

CALIBRATION OF 4-INCH LOW BACKGROUND BETA COUNTING SYSTEMS FOR COUNTING AIR FILTERS

By
R. E. Jaquish

Southwestern Radiological Health Laboratory

U.S. Department of Health, Education and Welfare
Public Health Service
Consumer Protection andEnvironmental Health Service
Environmental Control Administration
Bureau of Radiological Health

May, 1969

ABSTRACT

The 4-inch low background beta counters were recalibrated and alternate methods of preparing standards were studied. It was concluded that the placement of a standard solution directly on a 4-inch stainless steel counting planchet is an acceptable approximation of activity on the surface of an air filter.

LIST OF TABLES

LIST OF FIGURES

In January 1969 a recalibration of the beta systems used for counting 4-inch glass fiber filters from the Air Surveillance Network was initiated. The objective was to determine the effect of the resultant difference, if any, between the current method of calibration by placing a known amount of activity directly on a 4-inch stainless steel planchet and an alternative method of depositing the activity on a filter. This recalibration was performed with three types of samples as follows:

a. The standard solution was uniformly distributed directly over the surface of a 4-inch stainless steel planchet.

b. The standard solution was uniformly distributed over the surface of a 4-inch glass fiber filter attached to a 4-inch stainless steel planchet.

c. The standard solution was uniformly distributed on the surface of a 4-inch glass fiber filter coated with acrylic lacquer attached to a stainless steel planchet.

1. Sample Preparation

All samples were prepared by pipetting a standard solution directly onto the planchet and filter, as specified with an Eppendorff micro-pipette. The volume of the solution used was either 500 or 1000 depending on the activity of the standard. The range of activity on the samples at the time of count was between 10,000 and 100,000 transformations/min. The solution was placed on the sample in small droplets from the center out to the edge of the sample in a spoke-like pattern.

The samples with a filter on the planchet were prepared by spraying the planchet with spray adhesive and placing the glass fiber filter directly on the planchet. The filters used were Gelman Type E glass fiber filter with an area of 81 cm^2.

The coated filters were prepared by spraying the filter with an acrylic lacquer from a pressurized can. The filters were allowed to dry under a heat lamp before the solution was pipetted onto the coated filter. Four of the filters were weighed before and after the acrylic coating was applied to determine the weight of the acrylic applied. The average weight of material on the filter was 2.7 mg/cm^2. This thin film was considered to be essentially zero and the added backscatter material would have practically no effect.

When the standard solution was placed on the coated filter, the solution beaded-up on the filter and did not soak into the filter during the entire drying time.

The standards used for the recalibration were:

Nuclide	Max. Beta Energy (MeV)
^{14}C	0.156
^{99}Tc	0.229
^{185}W	0.429
^{137}Cs	0.559
^{36}Cl	0.714
^{204}Tl	0.766
^{90}Sr-^{90}Y	1.41
^{89}Sr	1.463
^{32}P	1.710

All of these are pure single beta emitters except the ^{137}Cs and ^{90}Sr-Y. Pure beta emitters were used whenever possible to eliminate the problem of conversion electrons. The beta counter is very insensitive to gamma radiation with less than 1% of the photons being detected.

For the ^{137}Cs the value used for conversion electrons was 9.5%; therefore, 1.095 betas/transformation was used. The energy distribution of the betas from ^{137}Cs is:

1.180	MeV	4.8%
0.518	MeV	95.2%
0.662	MeV	9.5%

The average maximum energy for ^{137}Cs is 0.559 MeV. This average is not exact since the beta values for the 1.18 and 0.518 MeV betas are maximum energies with an average energy of about 1/3 the maximum. The 0.662 MeV conversion electrons are monoenergetic.

For ^{90}Sr-Y the energy distribution is:

^{90}Sr - 0.526	MeV	100%
^{90}Y - 2.27	MeV	100%

The average maximum energy for ^{90}Sr-Y is 1.41 MeV.

2. Counting

All samples were counted for five minutes on each of the three beta systems.

3. Data

The data from the counting of standards are listed in Tables I, II,

III. The activity added is as of the time the sample was counted.

4. Calibration and Conclusions

Calibration curves for each system indicating the three geometries are shown in Figures 1, 2, and 3. For all three systems the calibration curves are similar. At the lower energies there is greater self-absorption in the filter; therefore, the efficiency values show a wider difference. The calibration with the solution placed directly on the stainless steel planchet and the activity of the coated filter are very similar.

Figure 4 shows the average maximum beta energy for mixed fission products as a function of time after fission. Accordingly an average value of 1 MeV could be assumed at anytime between two and 100 days after fission. Also shown is the average maximum beta energy for plowshare devices with a predominance of tungsten components. Note that the average maximum beta energy is somewhat lower, being constant at 0.5 MeV after 10 days.

The efficiency used for beta emitter on the three counters is 50%. This efficiency is an acceptable value as it lies between efficiency for beta emitters from Plowshare devices and pure fission devices. The efficiency for 1 MeV beta particle is 54% and for 0.5 MeV betas is about 47%.

For all three counts the calculated efficiency for the ^{36}Cl was high. The activity of the solution was checked by having an aliquot 4π beta counted and the resulting count was less than 3% different from the calibration from the supplier. On previous calibrations the ^{36}Cl was also high. The ^{204}Tl is low. This could be due to the fact that there is a disagreement on the half-life of ^{204}Tl in the references and this standard was several years old.

Figure 5 shows the calibration curves for each system for the coated filter geometry. It is felt that this geometry is most representative of a filter sample with activity deposited on its surface. It is noted that all three systems respond nearly identically.

Table I

BETA CALIBRATION

System #1

Nuclide	B Energy (Max.)	Half-life	dpm Activity Added	Date of Count	CPM Planchet	CPM Filter	CPM Coated Filter	% Eff. Planchet	% Eff. Filter	% Eff. Coated Filter
^{14}C	.156	5730y	24,400	1-9-69	3,671	-	-	15.0	-	-
"	"	"	"	"	-	-	2293	-	-	9.4
"	"	"	"	"	-	514	-	-	2.1	-
^{99}Tc	.292	2.12×10^5y	1.12×10^5	2-14-69	40,992	-	-	36.6	-	-
"	"	"	"	"	-	21,499	-	-	19.1	-
"	"	"	"	"	-	-	35,262	-	-	31.5
^{185}W	.429	75 d	2.40×10^5	3-27-69	115,800	-	-	48.2	-	-
"	"	"	"	"	-	71,000	-	-	29.6	-
"	"	"	"	"	-	-	95,900	-	-	40.0
^{137}Cs	.514	30y	23,700	1-30-69	11,377	-	-	48.0	-	-
"	"	"	"	"	-	9,326	-	-	39.3	-
"	"	"	"	"	-	-	11,003	-	-	46.4
^{36}Cl	.714	3×10^6y	16,400	1-9-69	10,356	-	-	63.1	-	-
"	"	"	"	"	-	-	9,592	-	-	58.5
"	"	"	"	"	-	8,971	-	-	54.7	-
^{204}Tl	.766	3.81y	12,500	1-9-69	6,226	-	-	49.8	-	-
"	"	"	"	"	-	-	5,684	-	-	45.5
"	"	"	"	"	-	5,087	-	-	40.7	-
^{90}Sr-Y	1.41	27.7y	25,610	3-10-69	-	-	14,580	-	-	56.9
"	"	"	10,250	"	-	5,185	-	-	50.6	-
"	"	"	25,610	"	14,460	-	-	56.5	-	-
^{89}Sr	1.463	50.4d	31,350	2-12-69	18,340	-	-	58.5	-	-
"	"	"	"	"	-	17,228	-	-	55.0	-
"	"	"	"	"	-	-	17,912	-	-	57.1
^{32}P	1.710	14.28d	32,000	1-28-69	19,202	-	-	60.0	-	-
"	"	"	"	"	-	-	19,240	-	-	60.1
"	"	"	"	"	-	18,873	---	-	59.0	-

Table II

BETA CALIBRATION

System #2

Nuclide	B Energy (Max.)	Half-life	Activity Added	Date of Count	CPM Planchet	CPM Filter	CPM Coated Filter	% Eff. Planchet	% Eff. Filter	% Eff. Coated Filter
^{14}C	.156	5730y	24,400	1-9-69	3,157	-	-	12.9	-	-
"	"	"	"	"	-	-	2409	-	-	9.9
"	"	"	"	"	-	476	-	-	2.0	-
^{99}Tc	.292	$2.12x10^5y$	$1.12x10^5$	2-14-69	40,273	-	-	40.0	-	-
"	"	"	"	"	-	21,414	-	-	19.1	-
"	"	"	"	"	-	-	34,710	-	-	31.0
^{185}W	.429	75d	$2.40x10^5$	3-27-69	119,100	-	-	49.6	-	-
"	"	"	"	"	-	73,000	-	-	30.4	-
"	"	"	"	"	-	-	98,800	-	-	41.2
^{137}Cs	.514	30y	23,700	1-30-69	11,460	-	-	48.4	-	-
"	"	"	"	"	-	9,368	-	-	-	-
"	"	"	"	"	-	-	10,786	-	39.5	45.5
^{36}Cl	.714	$3x10^6y$	16,400	1-9-69	9,805	-	-	59.8	-	-
"	"	"	"	"	-	-	9,855	-	-	60.0
"	"	"	"	"	-	8,649	-	-	52.7	-
^{204}Tl	.766	3.81y	12,500	1-9-69	6,173	-	-	49.4	-	-
"	"	"	"	"	-	-	5,818	-	-	46.5
"	"	"	"	"	-	5,074	-	-	40.6	-
^{90}Sr	1.41	27.7y	25,610	3-10-69	-	-	14,888	-	-	58.1
"	"	"	10,750	"	-	5,422	-	-	52.8	-
"	"	"	25,610	"	14,764	-	-	57.6	-	-
^{89}Sr	1.463	"	31,350	2-12-69	17,481	-	-	55.8	-	-
"	"	"	"	"	-	17,358	-	-	55.3	-
"	"	"	"	"	-	-	18,097	-	-	57.7
^{32}P	1.710	14.28d	32,000	1-28-69	19,096	-	-	59.7	-	-
"	"	"	"	"	-	-	19,390	-	-	-
"	"	"	"	"	-	18,949	-	-	59.2	-

Table III

BETA CALIBRATION

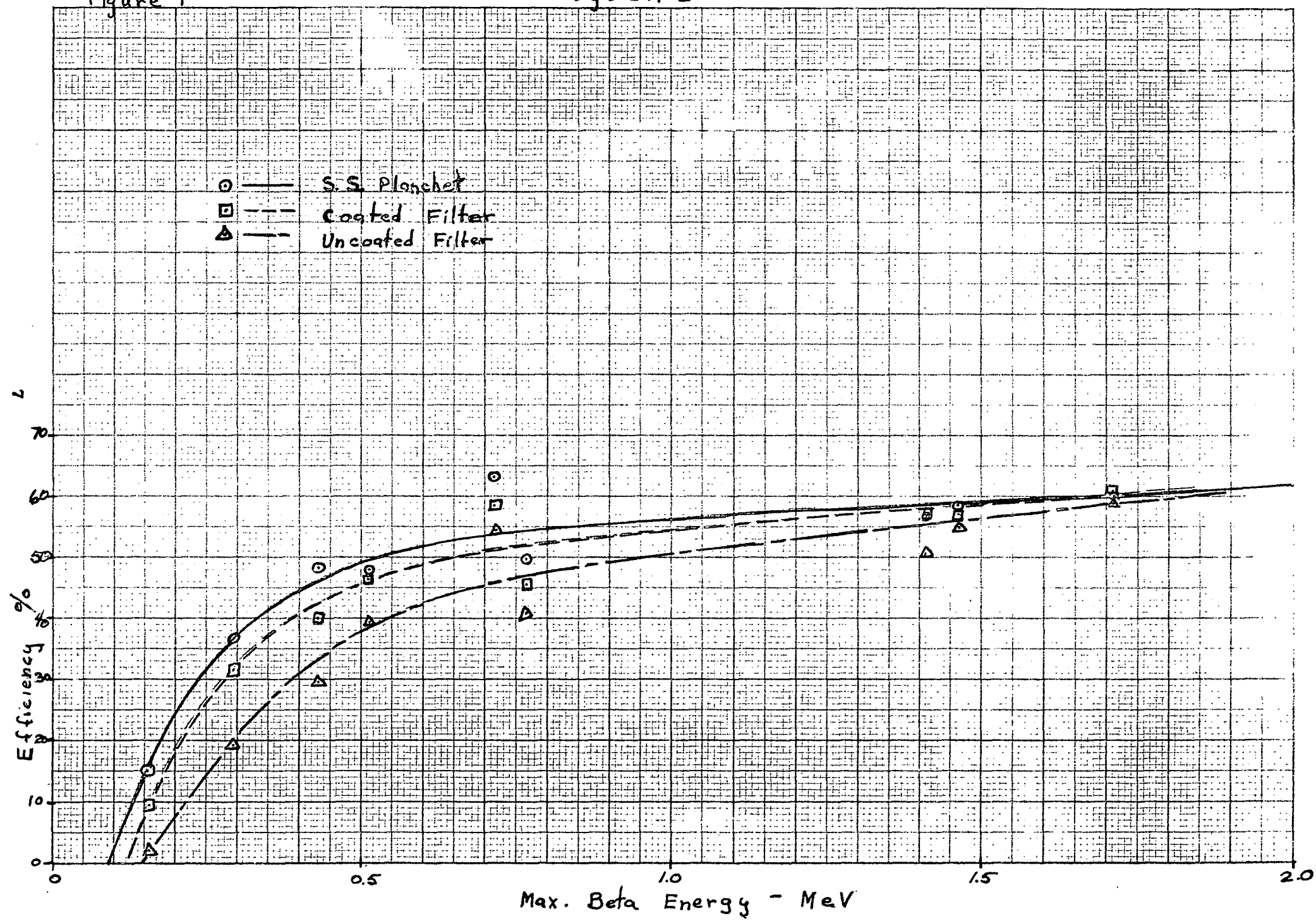
System #3

Nuclide	B Energy (Max.)	Half-life	Activity Added	Date of Count	CPM Planchet	CPM Filter	CPM Coated Filter	% Eff. Planchet	% Eff. Filter	% Eff. Coated Filter
^{14}C	.156	5730y	24,000	1-09-69	4,568	-	-	18.7	-	-
"	"	"	"	"	-	-	3,445	-	-	-
"	"	"	"	"	-	636	-	-	2.6	-
^{99}Tc	.292	2.12×10^5y	1.12×10^5y	2-14-69	47,984	-	-	42.8	-	-
"	"	"	"	"	-	24,310	-	-	21.7	-
"	"	"	"	"	-	-	41,530	-	-	37.1
^{185}W	.429	75d	2.40×10^5	3-27-69	137,600	-	-	57.3	-	-
"	"	"	"	"	-	80,100	-	-	33.4	-
"	"	"	"	"	-	-	112,300	-	-	46.8
^{137}Cs	.514	30y	23,700	1-30-69	12,296	-	-	51.9	-	-
"	"	"	"	"	-	9,853	-	-	41.6	49.9
"	"	"	"	"	-	-	11,830	-	-	-
^{36}Cl	.714	3×10^6y	16,400	1-9-69	10,244	-	-	62.5	-	-
"	"	"	"	"	-	-	10,421	-	-	63.5
"	"	"	"	"	-	8,867	-	-	54.1	-
^{204}Tl	.766	3.81y	12,500	1-09-69	6,655	-	-	53.2	-	-
"	"	"	"	"	-	-	6,454	-	-	51.6
"	"	"	"	"	-	5,319	-	-	42.6	-
^{90}Sr	1.41	27.7h	25,610	3-10-69	-	-	15,223	-	-	59.4
"	"	"	10,250	"	-	5,295	-	-	51.7	-
"	"	"	25,610	"	15,036	-	-	-	-	-
^{89}Sr	1.463	5014d	31,350	2-12-69	17,826	-	-	56.9	-	-
"	"	"	"	"	-	17,670	-	-	56.2	-
"	"	"	"	"	-	-	18,504	-	-	59.0
^{32}P	1.710	14.28d	32,000	1-28-69	18,936	-	-	59.2	-	-
"	"	"	"	"	-	-	19,161	-	-	59.9
"	"	"	"	"	-	18.557	-	-	58.0	-

Beta Calibration System I

Figure 1

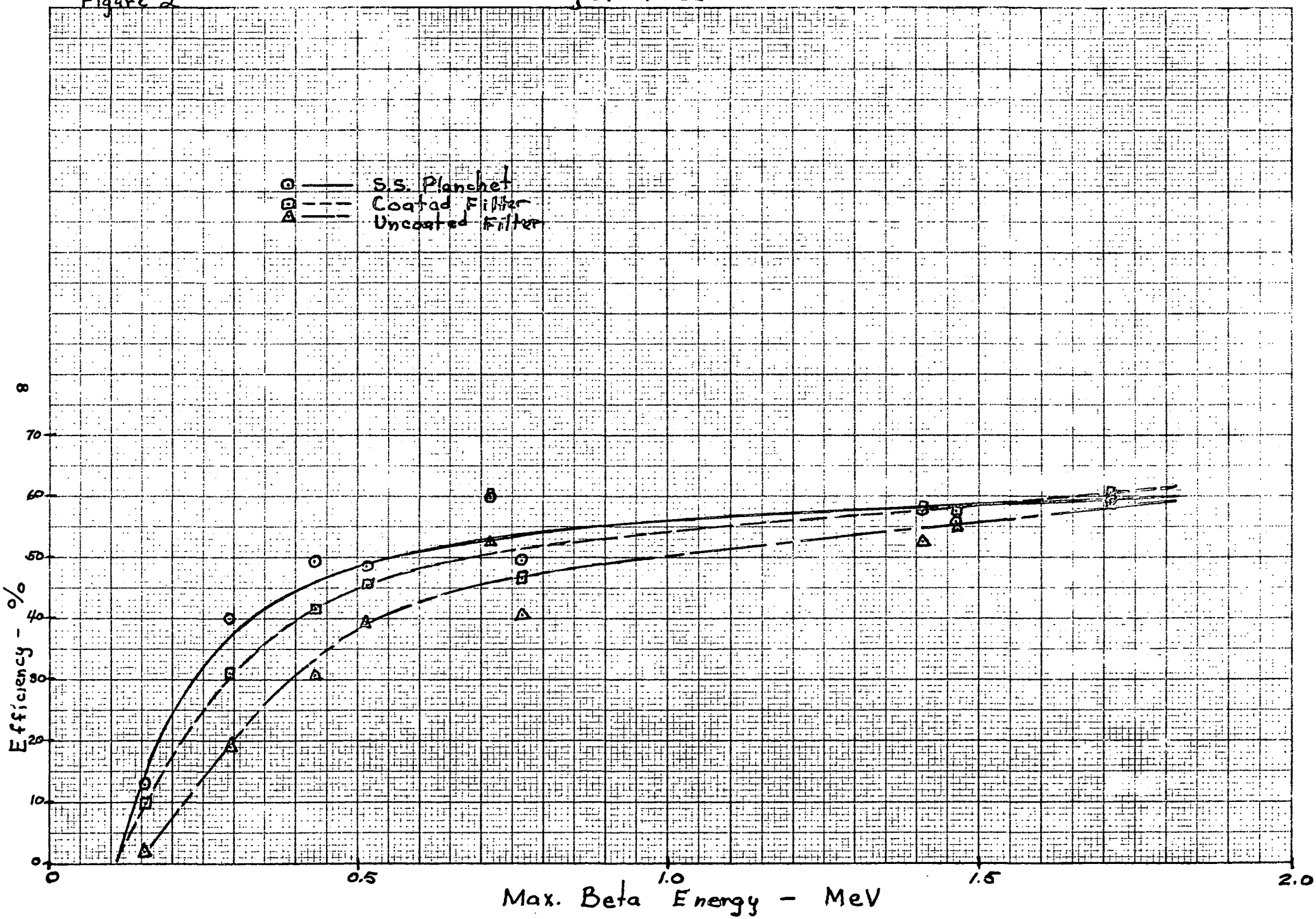
February 1969



Beta Calibration
System 2

February 1969

Figure 2



Beta Calibration
System 3

Figure 3

February 1969

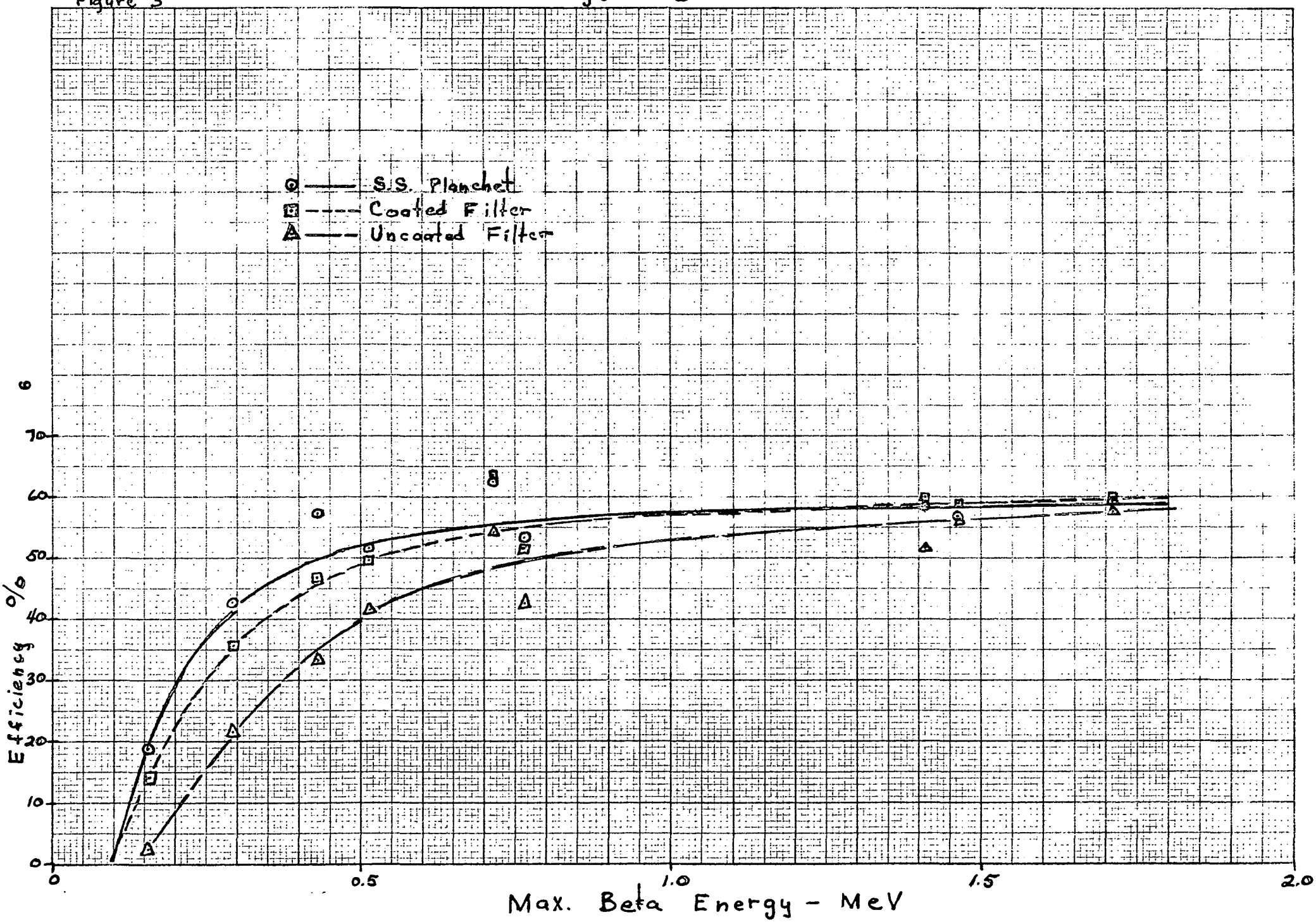


Figure 4

FISSION PRODUCT - AVE. MAX. BETA ENERGY VS. TIME AFTER FISSION

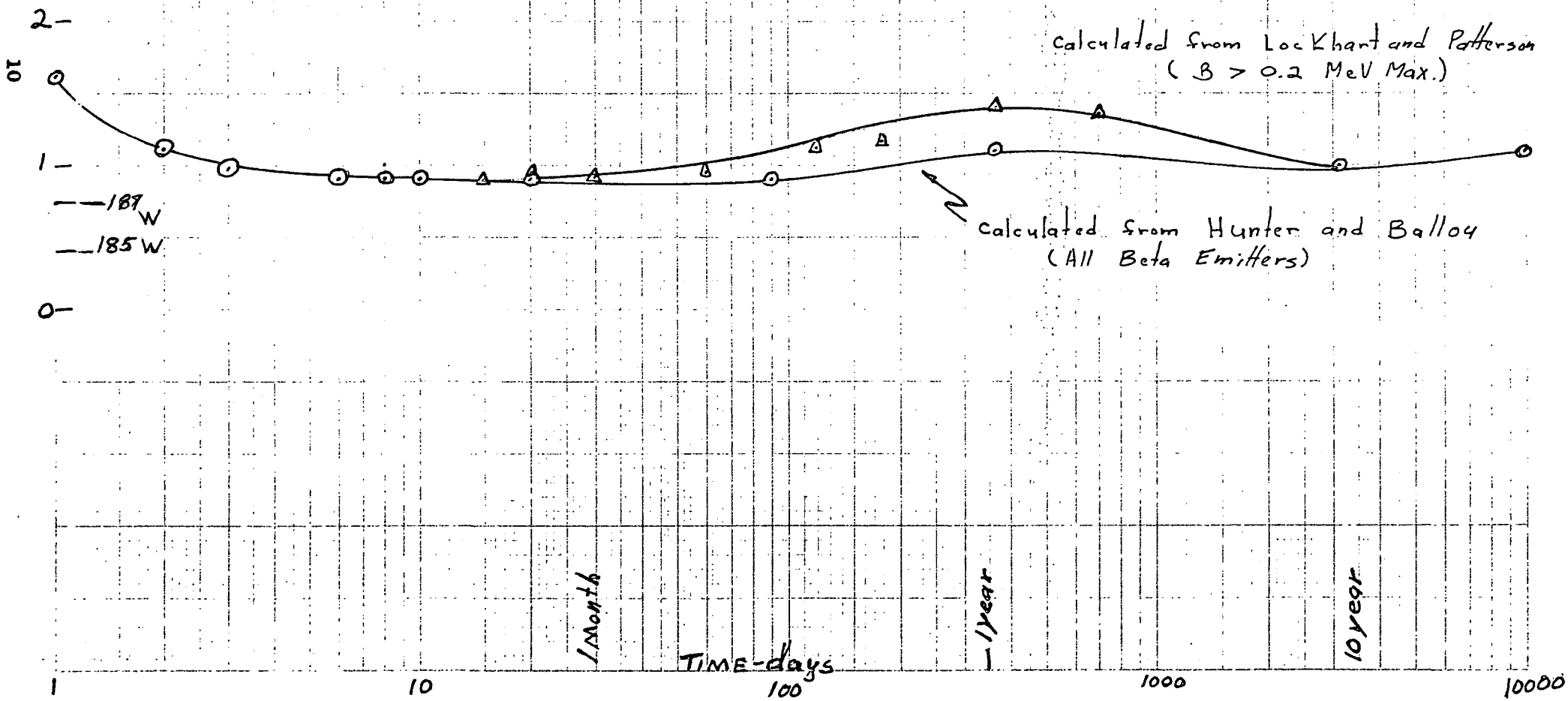


Figure 5

Beta Calibration
Coated Filter

FEBRUARY 1969