RADIATION PHYSICS NOTE #16

RISK PROJECTION USING FILM BADGE REPORTS

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One of the topics discussed in the MORT course is risk projection using standard statistical methods. This note will describe two of those methods and show how they can be applied to our film badge data.

It is claimed that two things can be learned from such exercises; the degree of "control" on the system and a forecast of how frequently an accident will occur with the existing controls. As taught in the MORT course these techniques are used when investigating an accident in an attempt to answer the question "would an event this serious have been expected in terms of normal system behavior?" Obviously, if the answer is yes, the event could have been predicted which means the accident was not an "abnormal" event. Then it is the "control system" which needs attention not an isolated event.

Rather than wait for an accident to ask the above question, it is perhaps more appropriate to ask "with the given operating conditions and given set of controls how often should we expect a Type C (> 3 rem/quarter) or Type B (> 5 rem/quarter) incident?"

The purpose of this note is to bring these tools to your attention and give an example by applying them to our film badge data. As much as possible I will refrain from drawing conclusions from the examples. That will be left to the reader.

Frequency - Severity Distribution

This method is the simplest to use but, as is usually the case, the least amount of information is obtained. It has the advantage of making use of the entire spectrum of past events i.e., from trivial to severe, and thus has a larger data base.

Figure 1 shows a frequency - severity plot for the year-to-date exposures for Accelerator Division (AD), Meson Lab (ML), Neutrino Lab (NL and BC), and the Proton Lab (PL) added together. The "line of balance" is used as follows. If a line fit to our data is parallel to the line of balance it means a single 1 rem exposure is controlled as effectively as 10 exposures of 100 mrem each. Our data has a steeper slope which means we control the single 1 rem exposure "more effectively" than the 10 exposures of 100 mrem. That means we are normal: the same is true (we were told) for all ERDA contractors. The steep slope can be interpretated two ways. Either we should get a pat on the back for doing so well controlling high exposures or a kick in the ---- for not controlling low exposures better. From a purely health physics view you can see why the latter interpretation leads to emphasis on ALRA.

For the data above about 500 mrem a line can be fit (dashed line) parallel to the line of balance. If all of our data were to fall on that line the total exposures for these accounts would be about 10% lower. That is to say, if we controlled all exposures as effectively as we control "high" exposures we could reduce the total Lab exposures by about 10%!

Another way to plot the same data is shown in Figure 2 where dose (ordinate) is plotted against "per cent under" i.e., the percentage of persons with doses less than the ordinate. (Note the lowest point is the minimal catagory.) In this figure the individual operating areas are shown separately. The data for each area have three distinct regions showing three catagories of exposure control. That is, intermediate exposures (50 to about 500 mrem) are controlled better than low exposures (less than 50 mrem) but not as well as high exposures (greater than 500 mrem). Furthermore, within these catagories (at least the intermediate and high levels) exposures are controlled nearly logarithmically and more surprisingly these lines have nearly the same slope. The individual areas show some distinction in these catagories but the difference would be difficult to quantify in a meaningful way. The biggest differences seem to be where the break between the intermediate and higher catagories begin. This is, at least partially, a reflection of the amount and level of hot work which is done in each area.

Extreme Value Projection

The main difficulty in using the frequency - severity approach is that most of the data occur in the low severity ranges. That means the statistics are poor in the higher ranges, where the interest is highest, "the tail wags the dog". The extreme value technique is said to have the following advantages:

1. Lesser quantity of easily obtainable data is needed.
2. It is self-testing as to applicability.

(At this point I must disclaim more than an engineer's knowledge of the technique. That is, I don't yet know how or why it works. I am trying to get a monograph which tells how and why.

The method involves:

1. Select a period of homogeneous operation - i.e., a period where operation was not affected by sudden increases in residual dose rates, changes in procedures, etc.
2. Break the period down into appropriate time intervals; for exposures, monthly intervals are appropriate.
3. Obtain the most severe event (highest film badge reading) for each interval.
4. Plot the worst case events on special "extreme value paper" in accordance with certain rules - in MORT text.

5. Test for applicability - data should fall on a straight line.

Figure 3 is such a plot for the four operating areas for the period January through October, 1976. The ordinate (vertical axis) is the worst case exposure in mrem. The abscissa (horizontal axis) of interest is at the top - return period in months. The graphs are used as follows. Select an exposure (remember these are monthly exposures to an individual) on the ordinate. Then go across to the line which represents the area of interest. Then go up to the abscissa to obtain the return period - i.e., how frequently you expect such an exposure to occur. For example you should expect a 450 mrem exposure in the Neutrino Area every two months. It is interesting to note that with the possible exception of the Meson Lab, the data for each Lab fall very nearly on a straight line. There are obvious reasons for the Meson Lab data not fitting so well.

It is interesting that the lines for the different areas tend to converge in the nieghborhood of 400 to 700 mrem with a return period of about 4 to 6 months. This is perhaps related to Lab wide shut-downs - long M&D periods?

Another interesting question to ask is how frequently will an exposure occur which exceeds 3 rem or 5 rem in one month (not a necessary but a sufficient condition for Type C and Type B incident respectively)? The periods are marked in the figure and indicated in the table below.

Area	Return Period (months)	
	Type C	Type B
AD	110	300
PL	250	700
NL	1000	5000
ML	35	60

A note of caution! The actual values of the numbers should not be taken too seriously. These numbers do not necessarily indicate that the Accelerator Division is ten times more likely to have a Type C incident than the Neutrino Department. Ignoring the Meson Area, for the moment, it can be said that there is no indication of serious undercontrol of exposures. The Meson Area is an exception because the high exposure data came from a train change and a hot job upgrading the switchyard for 400 GeV. Other than those jobs they have very low exposures. Perhaps intervals of interest for that area should be "hot jobs" or "train changes". There is not enough data available to make a useful plot that way. Another interpretation is that the data is accurate and that the highest potential for an accident (high beam-off exposure) is in the Meson Area.

Figure 4 is another plot of the same data for the Proton Area but with 68% confidence interval lines shown by the dashed lines. These can be used as follows. The return period for a 0.95 rem exposure is about 25 months. However, there is a 67% probability that a 0.95 rem exposure will occur within the time interval 8<T<77 months. That is, such an exposure occurring more frequently than every 8 months or less frequently than 77 months is "unlikely". In fact such an exposure did occur in November, 1976. It would seem that it was not an unusual or unexpected event. In the same way there is a 67% probability that a Type C event will occur in the time interval 66<T<714 months.

An interesting exercise is to see if this projection technique would have "predicted" the Type B incident in the Meson Area. Figure 5 is a plot of the relevant data from July 1973 to June 1974. (Recall the incident happened in May 1974.) Note first, that there seem to be two straight lines. One line involves train change work and the other doesn't. Looking at the line through the higher exposures you see the return period for a 5 rem exposure is about 6 months. (Perhaps this should be interpreted as 6 months of work involving train changes.) Even if you ignore the point which represents the actual incident it appears that an incident was <u>very</u> likely.

Another period of interest is January, 1975 to December, 1975 in the Proton Area - a period when high exposures were occurring there. That data fits a straight line nicely as is shown in

Figure 6. For this data Type C and Type B incidents have return periods of about 11 and 20 months respectively. As Figure 3 shows "things are better" now.

Caveat

I do not claim high accuracy for my data. I did check our files on the higher exposures to see if they had been reduced. I took no great care to add in late badges or check for multiple badges.

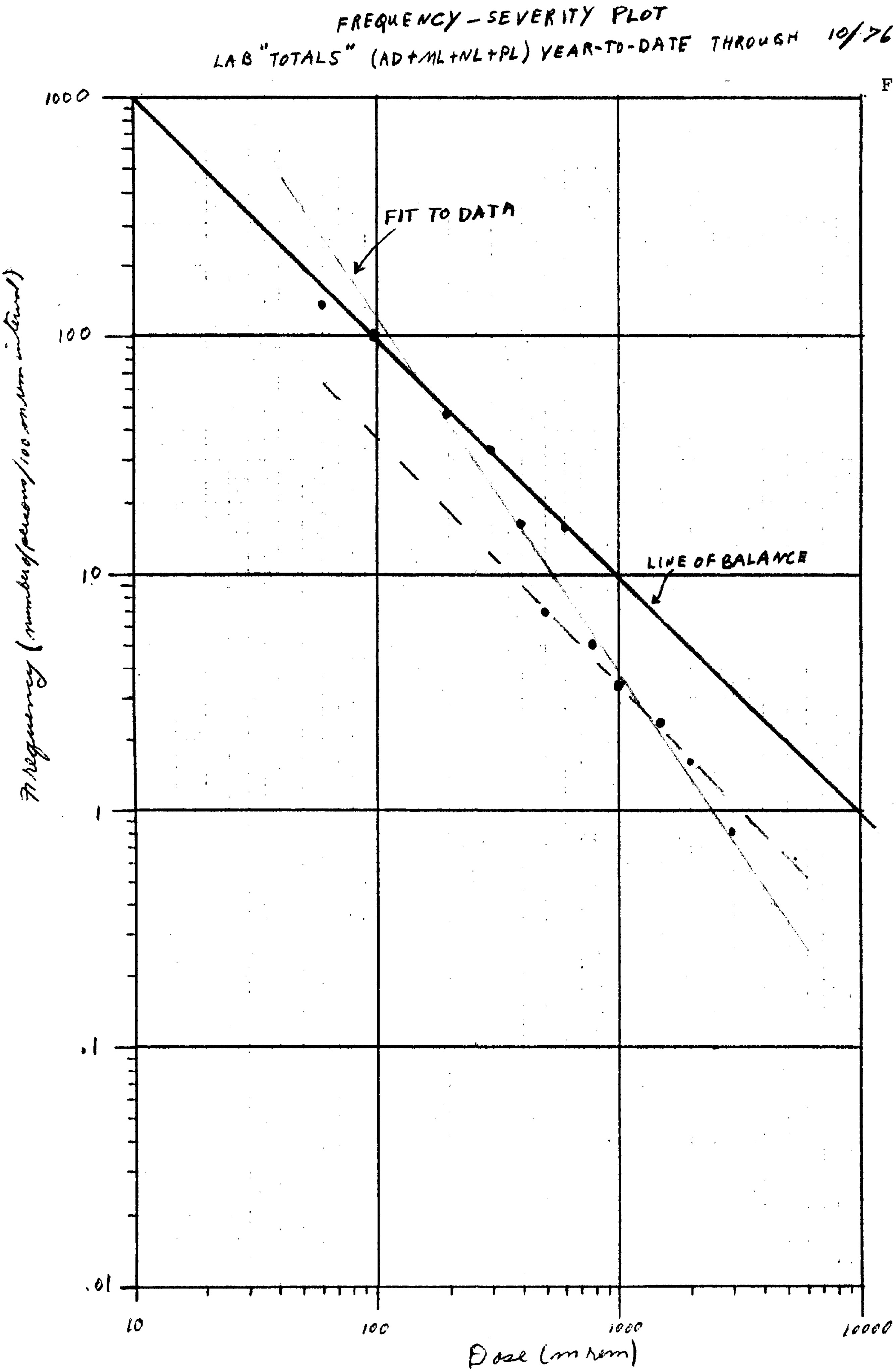
These are obviously beam-off exposures. Therefore, they are of no value in predicting disasters where high beam-on exposures present a significant problem.

Type B and C incidents can easily occur in ways other than to get 5^+rem or 3^+rem on a monthly badge. For example if film badge reports for an individual for a quarter were 1.2 rem, 1.3 rem and 2.6 rem that is obviously a Type B incident but would not show up as an incident using this technique. A better way to predict incidents would be to use quarterly totals - not monthly reports.

These risk projection techniques, of course, may be used on other than film badge data. The convenient thing about film badge records is first they exist, second, we have a relatively large amount of data and thirdly, it is easy to quantify (unlike interlock failures, etc.).

Two more cautions about using these techniques are in order. First, as with any statistical analysis, the results can be misleading. The actual numbers derived should not be taken as absolute, but only as relative indicators of risk. Secondly, the results only apply to the period of time the analysis covered. Projections are no good if unbalanced changes occur in the system.

Figure 1

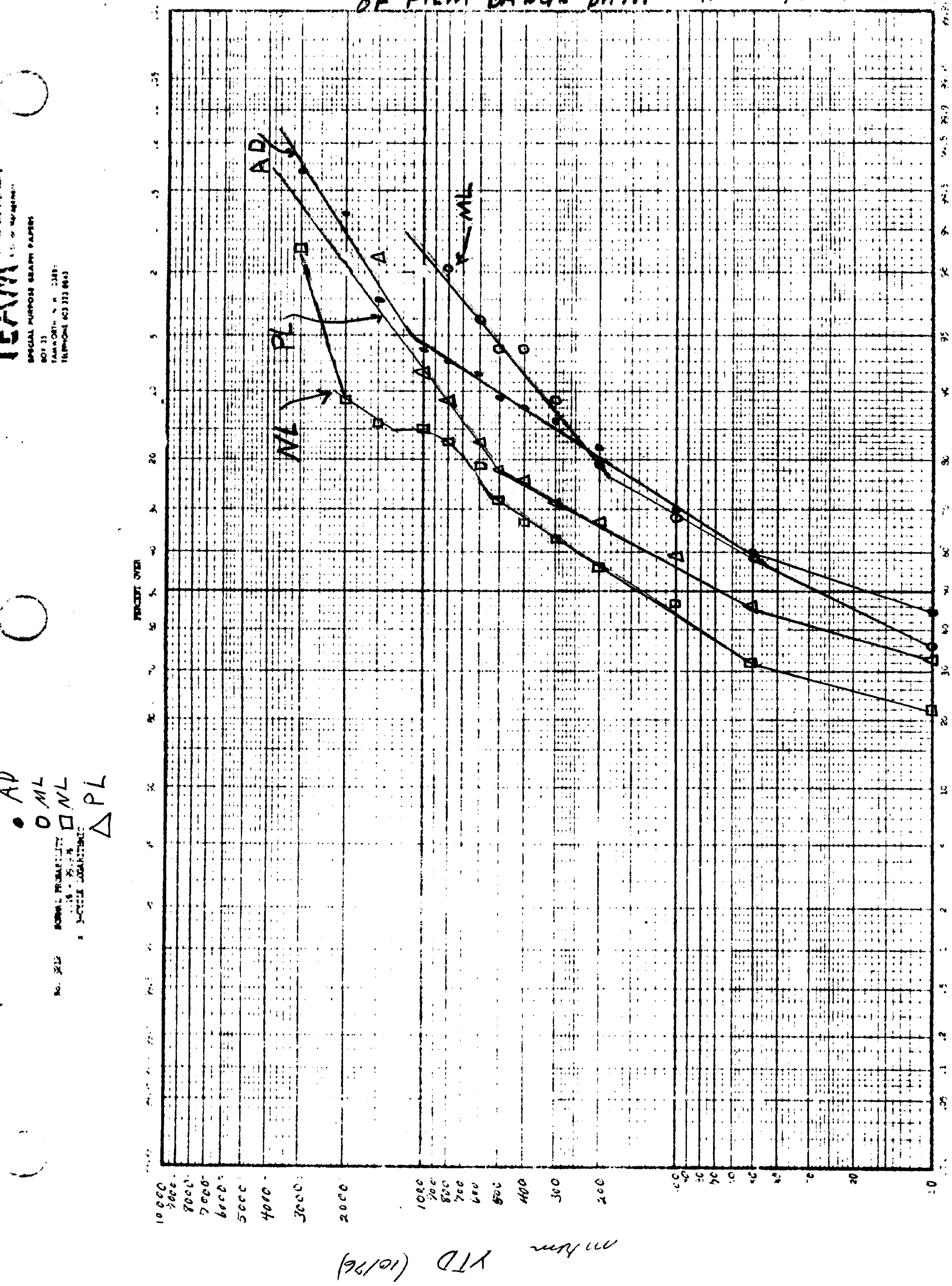


FREQUENCY – SEVERITY PLOT
LAB "TOTALS" (AD+ML+NL+PL) YEAR-TO-DATE THROUGH 10/76
1000
100
10
1
.1
.01
FIT TO DATA
LINE OF BALANCE
10
100
1000
10000
Dose (m rem)

FREQUENCY-SEVERITY PLOT OF FILM BADGE DATA

Figure 2

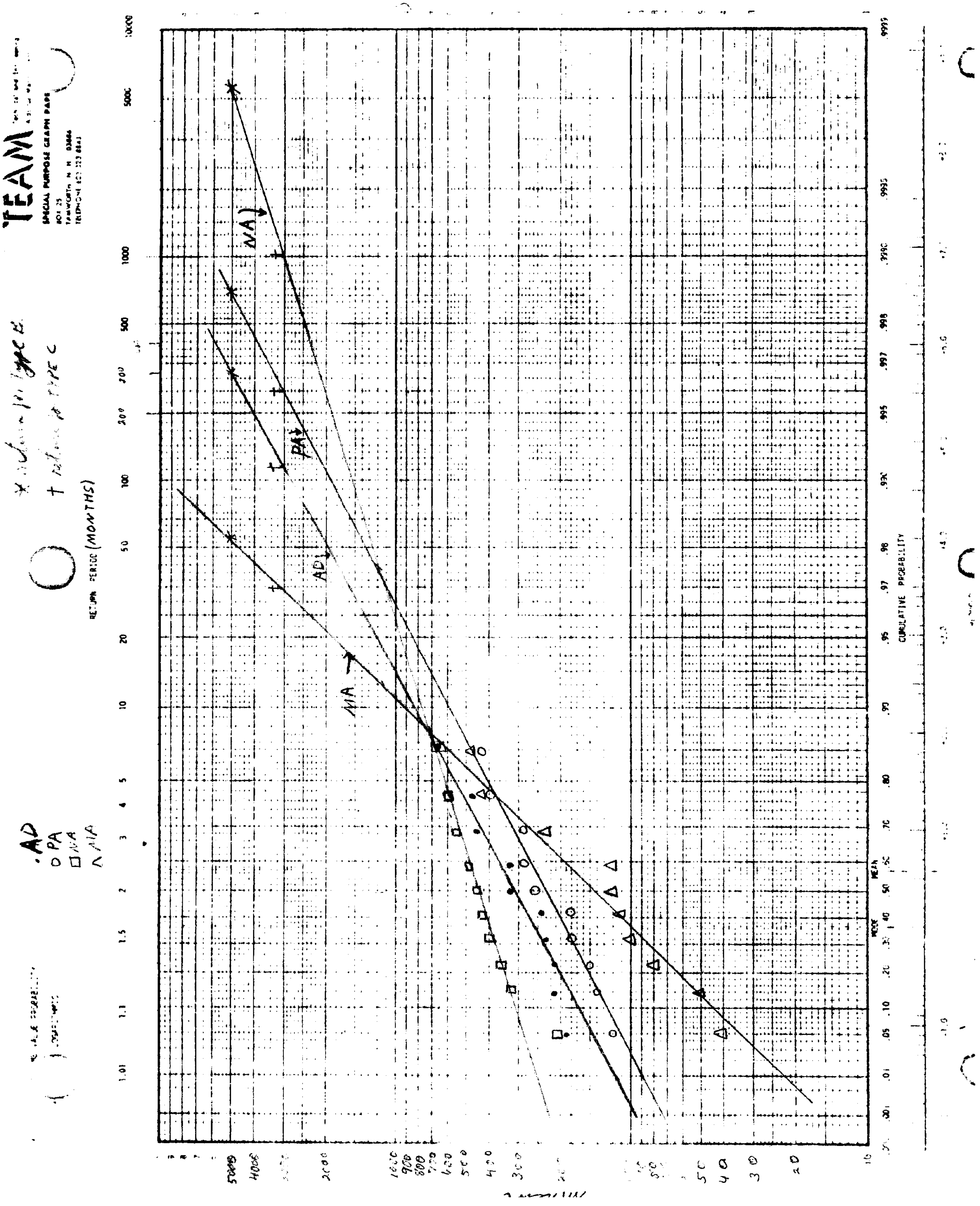
DATA IS YTD 1→10/76



EXTREME VALUE PROJECTION

FILM BADGE DATA FROM 1→10, 1976

Figure 3



EXTREME VALUE PROJECTION

FILM BADGE DATA FOR PROTON AREA

DATES 1→10, 1976

Figure 4

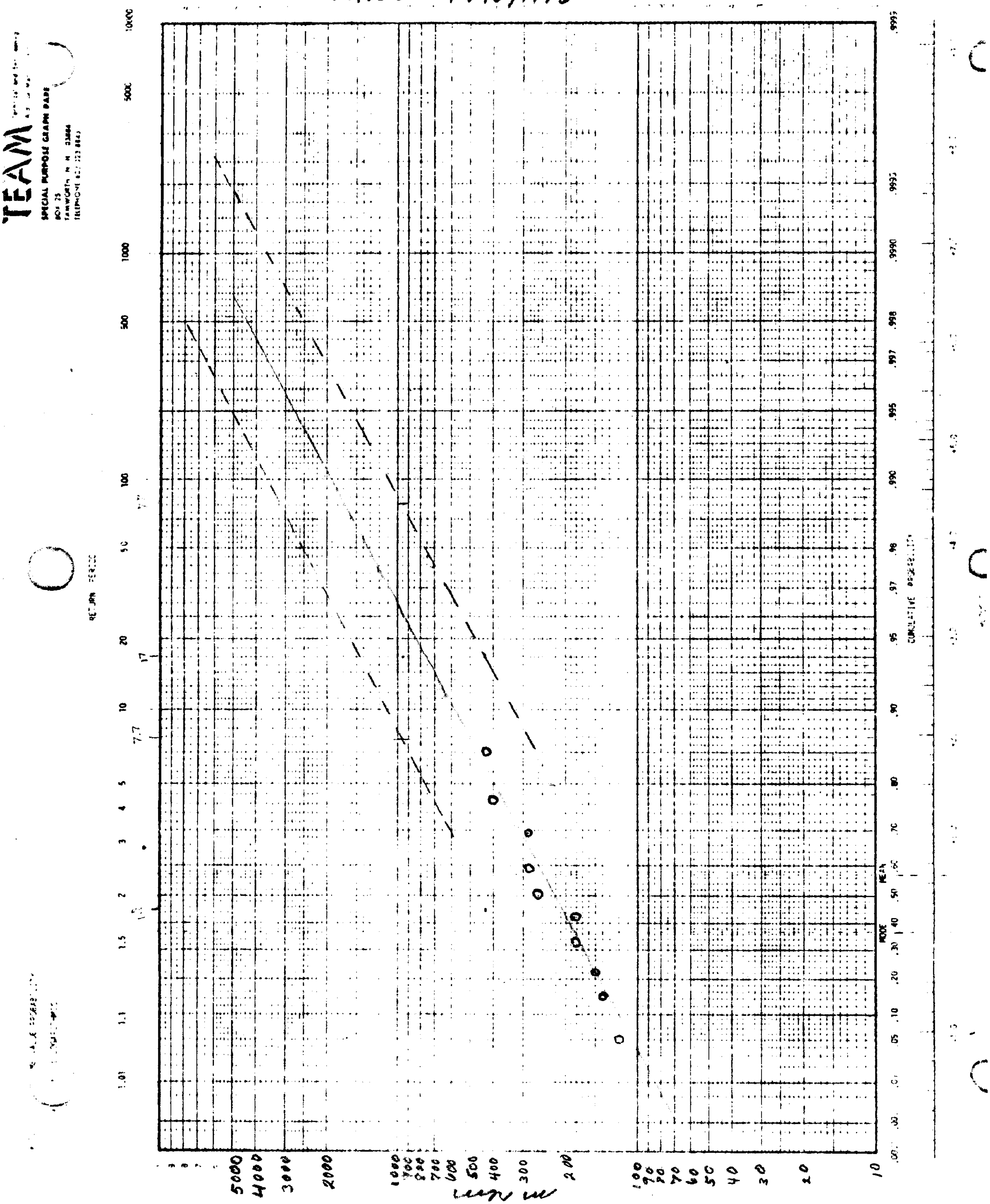


Figure 5

EXTREME VALUE PROJECTION
MESON FILM BADGE DATA FROM 7/63 → 6/74

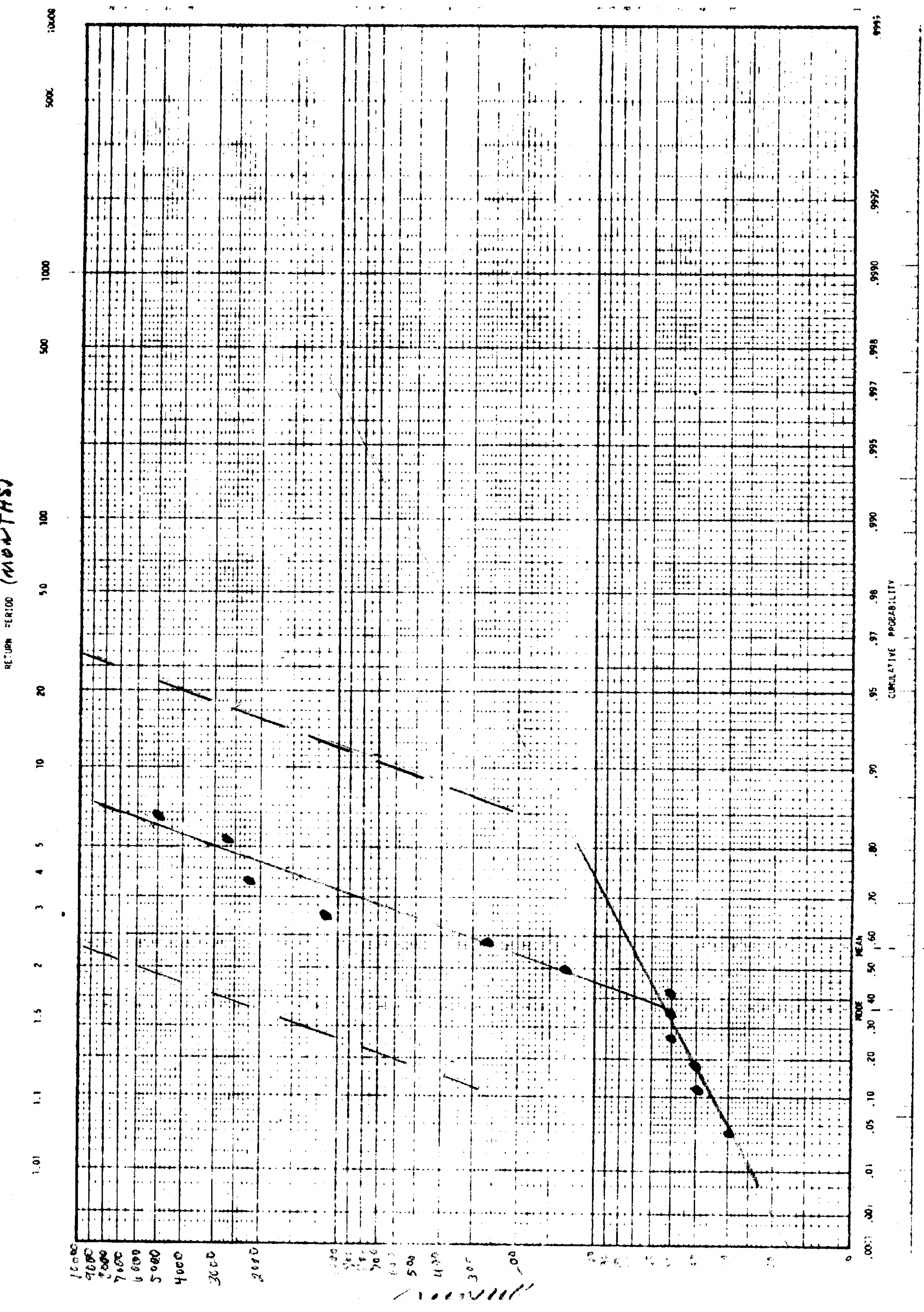


Figure 6

EXTREME VALUE PROJECTION
PROTON FILM BADGE DATA FROM 1/75 → 12/75