A ROLE OF THE HYBRID SCALE IN RADIATION PROTECTION

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ABSTRACT

The hybrid scale, first introduced for the purpose of reasonable control of occupational exposure, has been expanded to generally apply it to various subjects in radiation protection. The merit of using the hybrid scale is discusssed so as to control radiation risks as best as possible. New graph papers derived from the hybrid scale are systematically presented and their potential apllication is suggested.

INTRODUCTION

Both linear and logarithmic scales are widely used in radiation protection. The former is apt to describe variations of the same order of magnitude, e.g. levels of natural gamma radiation by time, while the latter is apt to describe variations of the different order of magnitude, e.g. levels of workplace radiation varied by operation of a nuclear facility. In radiation protection, however, there is another type of variations which consists of both the different order of magnitude in the lower range of variations and the same order of magnitude in the higher range. This type of variations needs a new type of scale of hybridizing a logarithmic and a linear scale in various ratios.

The first example of the scale for the hybridization was the variate coordinate axis on hybrid lognormal probability paper[1]. The scale, termed a hybrid scale, was developed to be given the meaning of variations of individual doses controlled by radiation protection practices[2, 3]. The hybrid scale seems to be useful for assessing not only the control of dose to workers, but also the control of other quantities in radiation protection. Especially it is important to discuss how degree the system of radiological protection recommended by the ICRP needs the hybrid scale.

The 1990 ICRP Recommendations provide detail background information on biological effects of ionizing radiations. Some of the biological effects can be displayed more properly on hybrid graph paper than on linear or log graph paper[4, 5]. Therefore the new graph papers using the hybrid scale are systematically presented to explore the potential application in radiation protection.

METHOD

The standard hybrid scale is defined $y=hyb(t)=\ln(t)+t$, where the scale has marks of t at distances of y apart. This is the same as the log scale $y=\ln(t)$ or the linear scale $y=t$. The

hybrid scale approaches the log scale for $t \ll 1$ and the linear scale for $t \gg 1$ because the function is $hyb(t) \fallingdotseq \ln(t)$ for $t \ll 1$ and $hyb(t) \fallingdotseq t$ for $t \gg 1$. If the log term is equal to the linear term, that is, $y=0$, the value of t is about 0.567143.

Suppose a quantity x is of the different order of magnitude in the lower range of x and of the same order of magnitude in the higher range of x, a procedure to use the hybrid scale for x is as follows:

1) find a proper positive value of ρ having the reciprocal unit of x so that the value of $y=hyb(\rho x)$ should be of the same order of magnitude over the substantial range of x,
2) calculate the value of $t=\rho x$ and plot it on a hybrid scale of t, or plot x directly on a hybrid scale of x which has marks of x calculated by t/ρ for a fixed proper value of ρ at distances of y apart.

Thus the locations of quantities x plotted on a hybrid scale represent the distances coresponding to the values of $y=hyb(\rho x)$. The value of $x_c = 0.567143/\rho$ is coresponding to $y=0$ and is termed a "critical point" between log and linear regions.

APPLICATION OF THE HYBRID SCALE TO DATA

The variations of annual dose to workers must reflect the effectiveness of a system of radiation protection. Analyzing the 1988 data of occupational exposure in Japan, we have the mean 1.7 mSv, $\rho = 0.3249$ mSv^{-1}, and $x_c = 1.7$ mSv for nuclear industry the mean 0.4 mSv, $\rho = 0.0293$ mSv^{-1} and $x_c = 9.4$ mSv for medicine. Figure 1 shows quite different hybrid scales between nuclear industry and medicine. However a similar hybrid scale is applicable for each occupation over years.

The variations of annual collective dose per reactor must also reflect the ALARA efforts through regulatory activities. The 1983 data of annual collective dose to workers per reactor of PWRs licensed by the USNRC, was analyzed; $\rho = 0.0790$ (person-Sv/reactor)$^{-1}$ and $x_c = 7.2$ person-Sv/reactor, where the minimum, mean and maximum are, respectively, 0.7, 6.2 and 18.8 person-Sv/reactor.

The variations of radioactive concentration must reflect some controlled or planned procedures. Those of foods contaminated by the Chernobyl accident but inspected in Japan, and those of contaminated metals due to the decommissioning of JPDR are examples of applicability of the hybrid scale.

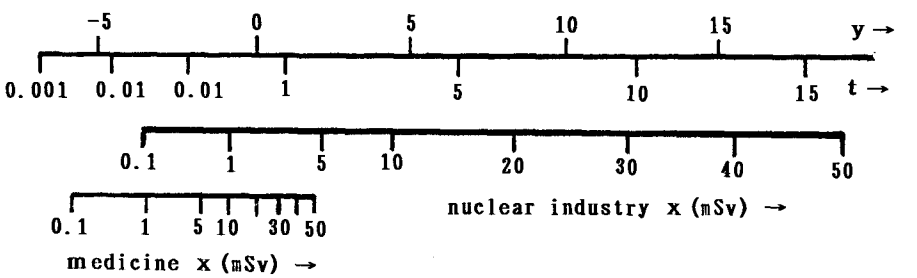

Figure 1 Examples of standard and actual hybrid scales

Another application of the hybrid scale is for the shouldered survival curves and low-LET radiation dose-response curves. The former is to plot surviving fractions on a hybrid scale with a positive parameter ρ estimated against doses on a linear scale[4] and the latter is to plot effects on a log scale against doses on a hybrid scale with a positive parameter ρ[5]. These facts suggest to need new types of graph papers.

Figure 2 shows a hybrid hybrid paper which consists of both hybrid scales on a horizontal and on a vertical axis. A hybrid hybrid paper approaches a log log paper near the left lower corner of it, a section paper near the right upper corner, a semilog paper near the left upper corner or the right lower corner. In general a system of hybrid graphs is defined as follows:

(log linear)	(hybrid linear)	(linear linear)
(log hybrid)	(hybrid hybrid)	(linear hybrid)
(log log)	(hybrid log)	(linear log)

The key point of using the hybrid scale is to find an area, on a hybrid hybrid paper, with variations of the same order of magnitude in terms of y-value by selecting ρ parameters. Thus a way to implement a system of radiological protection must be to select a proper control space or area on a hybrid hybrid paper.

CONCLUSION

The hybrid scale has been developed to systematically formulate a quantitative feature of risks controlled by a system of radiological protection. However, as the hybrid scale is applicable for some biological effects of ionizing radiation but repaired by biological protection mechanisms, the hybrid scale is explicitly in future studies.

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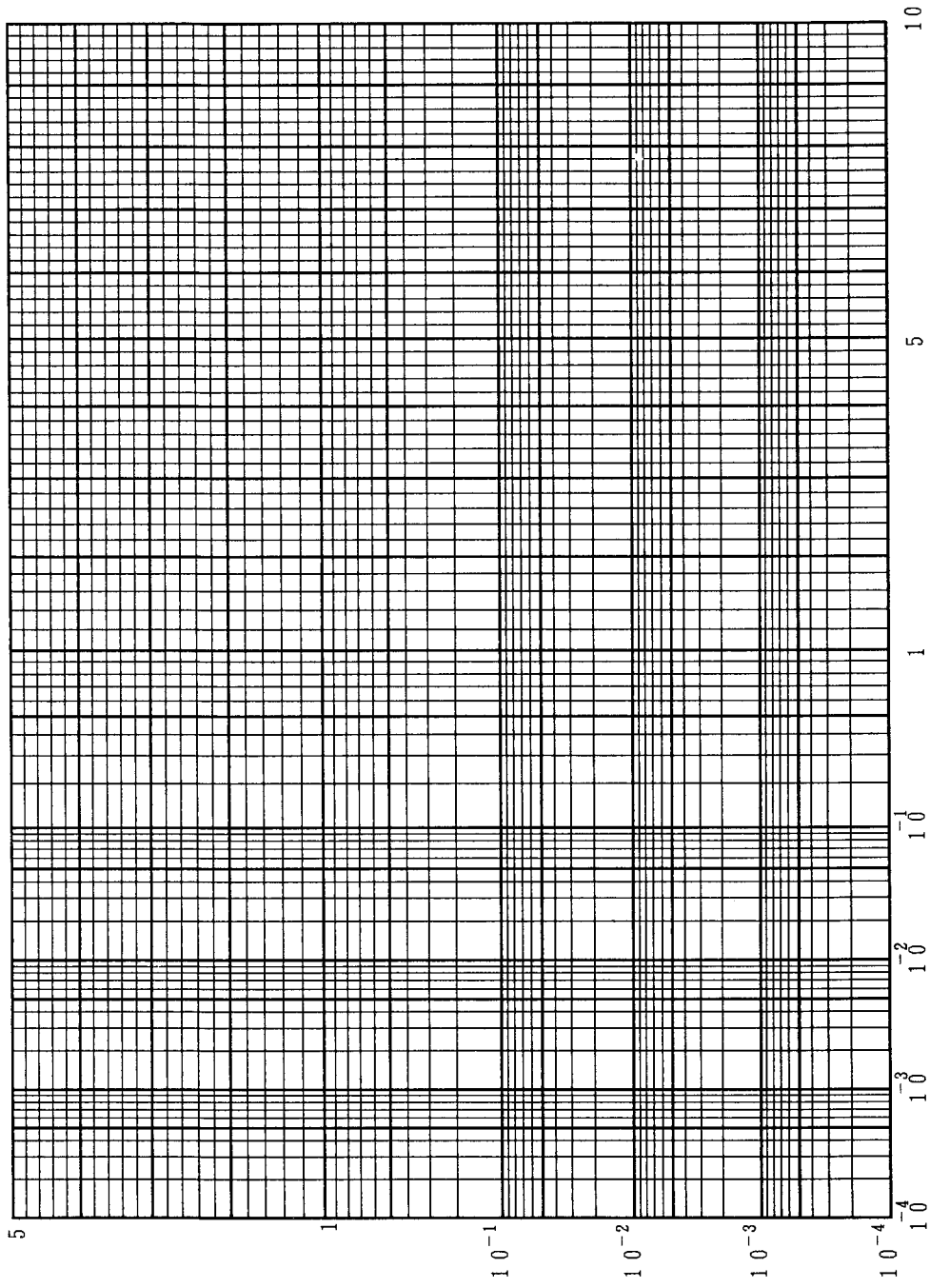

Figure 2. A hybrid hybrid paper