THE "HALF-LIFE" OF SOME SCIENTIFIC AND TECHNICAL LITERATURES

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ABSTRACT

A consideration of the analogy between the *half-life* of radioactive substances and the rate of obsolescence of scientific literature. The validity of this analogy suggests the possibility of more accurate prognostications concerning the period of time during which scientific literature may be used and hence might help to guide the planning of library collections and technical information services.

The concept of *half-life* is most familiar to the physicist and nuclear engineer who employ it to describe the decay of radioactive substances. Recently, however, the expression has been used by documentalists, some librarians, and other information "officers" to describe a totally different measure in a manner which implies a rather rigid analogy. The term was much in evidence at the International Conference on Scientific Information meetings in Washington in November, 1958. Unfortunately, unlike the physicists' use of the expression, which is bounded by a precise definition, the documentalists' use has been imprecise, unverified by evidence, and generally subject to criticism. It is the purpose of this paper to examine the applicability of a *half-life* analogy to scientific literature, and to provide at least a small amount of data on which to base certain conclusions.

The physical scientists' concept of half-life is that of a decay function wherein the degree of radioactivity, or the intensity of the radiation, is measured against time. To borrow the definition used in one of the standard references,(1) half-life is the "time required for disintegration of one-half the atoms of a sample of a radioactive substance." The plot of such a function, that for uranium 239, is shown in Figure 1. The half-life is 23.5 minutes.

One point of special interest is that the half-life periods are of equal duration. That is, at any given time, the half-life of the remaining material is the same as the half-life of the original mass.

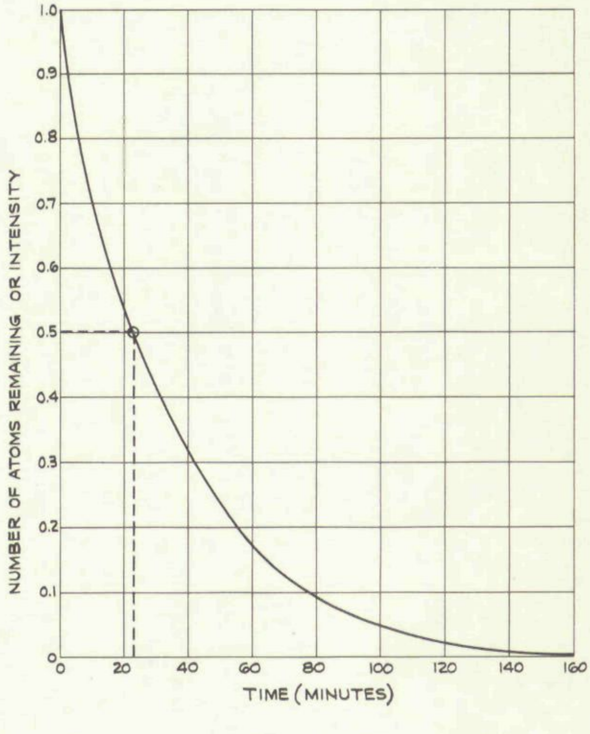

Fig. 1. Decay Curve for Uranium 239

The approach to the term *half-life* in relation to scientific literature is somewhat different. A working definition, closely analagous

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to radioactive half-life is that it is that time required for the obsolescence of one-half the currently published literature. Unfortunately, this obsolescence time cannot be precisely measured. Unlike a radioactive substance, which becomes something entirely different on disintegration, literature simply becomes unused, but *not* unusable. It is obsolescent, but not "disintegrated."

There are further difficulties. One could take a sample of scientific literature published this year and attempt, over the next two or three decades, to measure the rate at which it becomes obsolete. This could be done if agreement could be reached on a definition of "obsolete" and if one had the patience to wait thirty or forty years.

If, however, one redefines the use of *half-life* in this sense and if he describes what has occured in the past, he can obtain a useful measure of a quantity which resembles a *half-life* in many respects. The revised working definition then becomes *the time during which one-half of all the currently active literature was published.* This is saying, then, that one-half of all the active literature of a subject field was published not more than this time, $T_{1/2}$, ago. The determination of this quantity is possible and can be obtained with some reliability. Other studies,(2,3) particularly those on citations in periodical literature, have collected data which can be used for the determination. A generalized curve for this second definition is given in Figure 2. Figure 3 is a generalized curve of the type in Figure 1 as it would apply to literature, i.e., in accord with the first definition, the rate of obsolescence. For the work in this paper curves shall be used of the type in Figure 2, as they are a more descriptive representation of the data actually used.

Nine engineering and scientific fields have been investigated in this paper. Three engineering fields utilized data in the paper by Burton(4) and six science fields used data in Brown's book.(5) Zoology and entomology, which were included in the Brown study, were not used here because the nature of literature use in these areas seemed to need more study. The nine areas studied were chemical engineering, mechanical engineering, metallurgical engineering, mathematics, physics, chemistry, geology, physiology, and botany. The present paper is concerned with only the longevity of periodical literature.

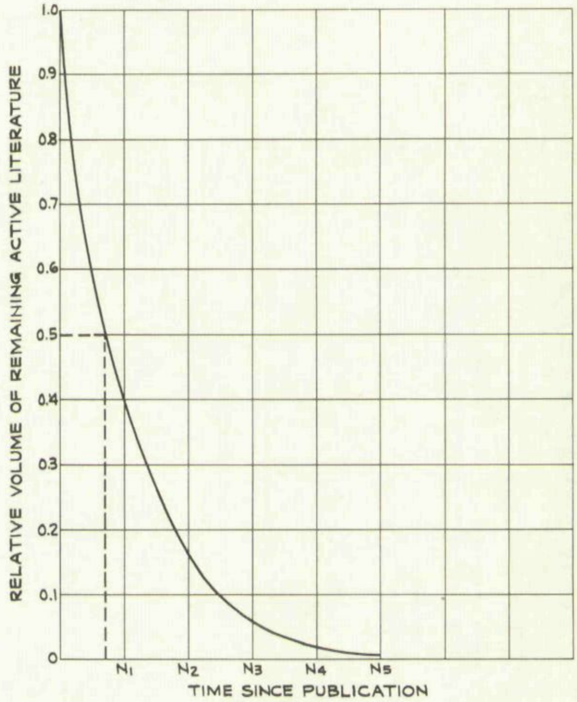


Fig. 2. Generalized Active Literature Curve

Both Burton and Brown collected data based on citation counts in selected source journals. The citations were distributed in various ways, one of which was time. Both studies utilized ten year periods and, while the periods selected are not the same, the data are comparable.

The data, which in the original studies showed the percentage of citations which fell within a particular decade, were reworked to show the cumulative percentages which fell in the ranges of one decade, two decades, and so on. For example, in the field of chemical engineering 75% of all citations had been published within the last ten years and 13% in the previous ten years. Thus 88% of the references had been

Table 1

Cumulated Citation Percentages

Field	Decades 1	1-2	1-3	1-4	1-5
Chemical Engineering	75	88	96	-	-
Mechanical Engineering	72	87	94	-	-
Metallurgical Engineering	82	93	97	-	-
Mathematics	48	77	89	94	98
Physics	76	92	98	99	100
Chemistry	58	77	87	91	95
Geology	42	68	84	90	94
Physiology	62	84	94	97	99
Botany	50	79	90	94	97

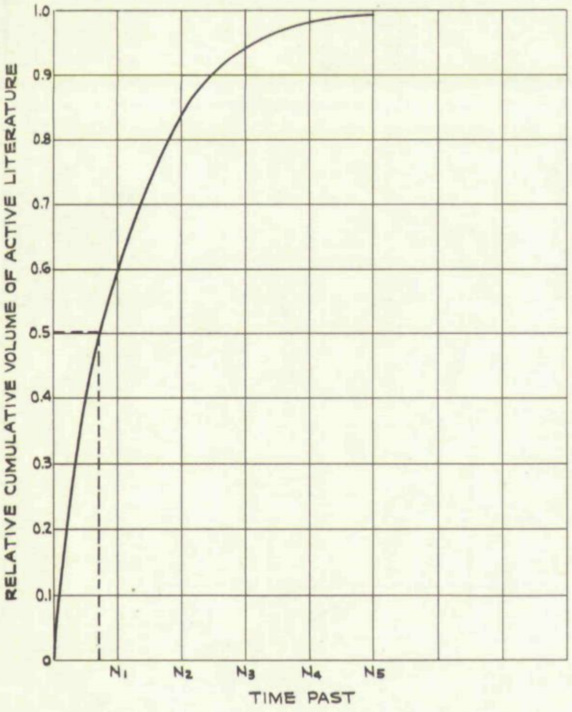


Fig. 3. Generalized Literature Obsolescence Curve

published in the last two decades. The complete cumulated percentages are given in Table I.

The next step in the determination of a literature half-life for the fields considered was to plot curves similar to that given in Figure 2 for each set of data. It was immediately observed that the curves were very similar and were exponential in character. An attempt was made, therefore, to determine the best exponential type curve for each field, so that half-lives could be calculated, as well as determined from observation. The authors found that the following type of curve fitted the experimental data.

$$y = 1 - \left(\frac{a}{e^x} + \frac{b}{e^{2x}}\right)$$

where $a + b = 1$; y = cumulated percentage expressed as a decimal; x = time in decades.

The curve also satisfied the boundary conditions of $x = o$, $y = o$ (citations are not made to references not yet published) $x = \infty$, $y = 1$ (all citations are included in all references published)

Curves were fitted to the data in each of the nine subject areas, and *x* value corresponding to $y = 0.5$ was calculated. The results of these calculations are shown in Table II and the curves are shown in Figs. 4-12.

Table II

Literature Half-Lives

Chemical Engineering	4.8 years
Mechanical Engineering	5.2
Metallurgical Engineering	3.9
Mathematics	10.5
Physics	4.6
Chemistry	8.1
Geology	11.8
Physiology	7.2
Botany	10.0

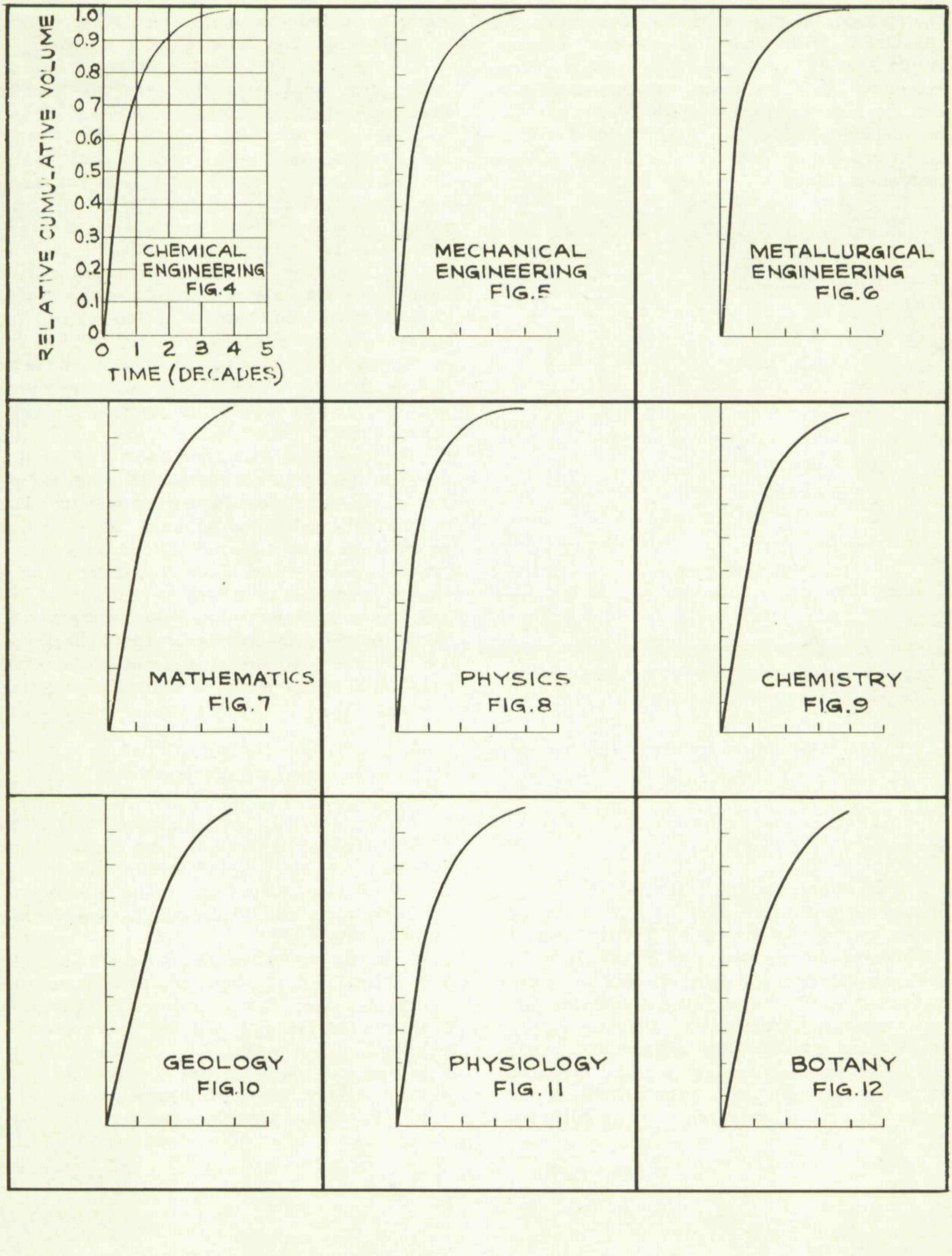
Because of the necessity of using a function with two exponential terms in order to describe the data, the half-lives calculated at points greater than $y = 0.5$, for example, at $y = 0.75$, 0.875, and so on, did not agree with the half-life calculated at $y = 0.5$. This disagreement arises from the nature of the data, but an analogy with radioactive half-lives still can be drawn.

Given a sample of radioactive material made up of two or more radioactive substances, the physicist finds that the decay curve is actually compounded of a series of components of varying half-lives.(6) Some components may have very short half-lives and others very long half-lives. The result, of course, is a curve in which the half-life periods vary.

It is possible that the periodical literature of a subject field is similarly composed of two or more distinct types of literature each having its own half-life. There is, for example, in most fields, a body of literature which is referred to as the *classic* literature. Presumably this classic literature has a relatively longer half-life than so-called *ephemeral* literature such as is found in weekly *news* publications. Certainly this problem should be more thoroughly investigated.

In drawing some of the curves using the raw data, it was suspected that the curve would move upwards rather slowly in the range of 0-3 years. This is simulated in Figure 13. If this is, indeed, true, the principal explanation is probably to be found in the fact that there is a necessary lag in the time between the publication of an article and the earliest possible publication of a reference to it. It might prove interesting to investigate the extent of this lag.

The usefulness of data concerning the half-life of scientific and technological periodical literature is to be found primarily in the areas of administration of literature collections or libraries. If, for example, 75% of the *useful* physics literature was published within a ten


RELATIVE CUMULATIVE VOLUME
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5
TIME (DECADES)
CHEMICAL ENGINEERING
FIG.4
MECHANICAL ENGINEERING
FIG.5
METALLURGICAL ENGINEERING
FIG.6
MATHEMATICS
FIG.7
PHYSICS
FIG.8
CHEMISTRY
FIG.9
GEOLOGY
FIG.10
PHYSIOLOGY
FIG.11
BOTANY
FIG.12

year period, the size of working collections (as contrasted to historical collections) may be rather sharply decreased. One must, however, remember that additional studies may show that certain journals contain abnormally or unexpectedly high proportions of *classic* references and, hence, will require longer storage than other titles.

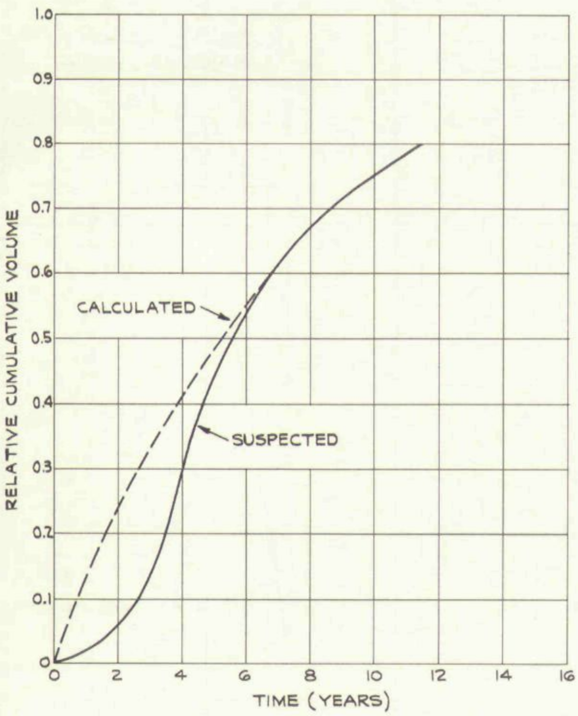


Fig. 13. Active Literature Curve Showing Suspected Lag in Early Years

It is interesting to note that the growth pattern of a subject field can be described rather well by half-life data. The literature of the *stable* sciences show longer half-lives than do those undergoing major changes in content or technique. Consider, for example, the contrast between mathematics and physics, or geology and metallurgical engineering. Similarly, those subject areas which are dependent on fresh data because of new problems, i.e. applied fields, will also show short half-lives while those fields which are more theoretical or fundamental may show longer half-lives.

A short half-life, which is equivalent to rapid obsolescence, is the result of rapidly changing techniques or interest within a subject field as has been noted. To some extent, rapid obsolescence could be a result of poor quality of information. It is possible, and has been suggested, that many published scientific papers have a sort of *built-in* obsolescence, guaranteeing their rapid disappearance from the active literature. Indeed, some papers, it is said, never were a part of the active literature. A study of this point would be interesting, but appears difficult to accomplish.

Additional interesting studies could be done on book literature, which presumably has a long half-life, and on report literature, which presumably has a short half-life.

We have seen that the idea of a literature *half-life* analogous to the half-life of radioactive substances does have some validity. The writers believe that the choice of the term may be unfortunate because the half-life of a radioactive isotope is part of the nature of the substance, whereas in scientific literature the half-life in a subject area may change as the nature of the subject area changes. Still, the fact that the longevity of literature follows an exponential type function is in itself interesting and suggestive.

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2. R. E. Burton, "Citations in American Engineering Journals" *American Documentation* (to be published)
3. C. H. Brown, *Scientific Serials.* Chicago, Association of College and Reference Libraries, 1956.
4. Burton, *op. cit.*
5. Brown, *op. cit.* p. 161
6. For a good representation of this, see J. M. Cork, *Radioactivity and Nuclear Physics.* New York, Van Nostrand, 1947. p. 21.