

some explained later, including the recent military restriction on publication. Our dates of counting leave out most of the strictly war years. In general all the indices powerfully confirm each other's significance.

[67] Next, for comparative and general purposes, but not for construction of any index of invention, we have plotted on chart 1 the courses of population in the U.S., and of U.S. patents granted to American residents,²⁷ (chemical patents to all are on chart 2⁸⁹), and productivity⁴⁴ per man-hour, in Mining and in All Manufacturing. Productivity, as we said (§ 51) reflects the cumulative effect of all pertinent past inventions still used, and many other factors.

[68] Now to combine on chart 4 our various indices, to obtain sub-totals by class, and indices of input and output. By the averaging principle each successive average should have more valid significance than its constituents singly. But first any average, or any index, implies a system of *weighting*, even if the constituents be assigned equal weights. Weighting must be done by a judicious preferential combination among the four principles which must guide it, viz:

[69] 1. The principle of Simplicity, which calls for saving the time of the scientist and his readers, and also avoiding the appearance of perversion of the results by manipulation of the weights (although more or less of manipulation is also indispensable for securing truth).

[70] 2. The principle of Potency, which calls for giving more weight to those factors more influential at producing the result inquired into. Thus we should give more weight to Engineering in the early days, and to Chemistry as times goes on.

[71] 3. The principle of Typicality, or Representativeness. Anticipating our findings, we may conclude that one index, say the total research professional staff, should be a better index of inventive effort than the others are.

[72] 4. The principle of Diversity of Approach. If two or more indices reflect more or less the same factors, we should weight each less, to reduce duplication, and to favor the quite different approaches. It is a principle of science that when a new or uncertain concept can be come at by quite different evidence, like the various ways of figuring the age of the earth, or divining what minerals may lie below a certain location, by the many diverse methods of geology and geophysical prospecting, then if we discover some agreement between the findings by our various approaches, we are much reassured.

[73] Applying these four principles, therefore, first to obtain the subtotals of chart 4, and taking first of all the Abstracts, our measures of Inventive Output, it seems well to weight all these papers equally,⁹⁰ which will automatically give preponderance at first to Engineering, but as time goes on will increasingly weight Physics and Chemistry. The abrupt check which the publications suffered at 1940 would naturally be caused by the large entry of military secrecy; so we have continued by a dotted line to 1960 the remarkably straight slope which this graph had followed since 1920 (§ 83).

[74] As for the memberships in the professional societies, we should according to principle 4⁹¹ load the weighting of the chemists

⁹¹ We also recall under principle 2 of Potency, that larger percentages of the Physicists and then of the Chemists are engaged in industrial R&D, than of Engineers, as per § 61.