An independent-particle model of $cientific $alaries

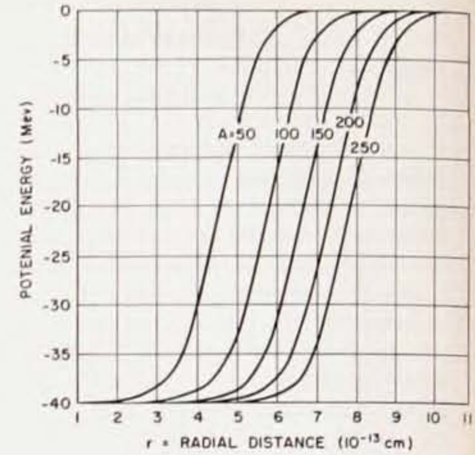

Fig. 1

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DURING recent years there has been a remarkable correlation or explanation of a wide variety of experimental nuclear data in terms of the so-called independent-particle model (IPM) of the nucleus. This model, which encompasses both the shell model and the optical model, views a nucleon which interacts with the many other nucleons in a complex nucleus as interacting with the nucleus as a whole via an IPM potential. For nucleon-nuclear interactions the potentials which have been inferred by phenomenologists from a vast amount of data have the general form shown in Fig. 1. Here the vertical scale represents the IPM potential of a nucleon interacting with the nucleus as a whole and the horizontal scale represents the radial distance (r) from the center of the nucleus. The curves shown represent IPM potentials used to represent typical nuclei with mass numbers $A = 50$, 100, 150, 200, and 250. A convenient and frequently used form function for representing nuclear potentials is the Saxon potential

$$f(r) = \{1 + \exp[(r - R)/d]\}^{-1}, \qquad (1)$$

where R represents the radial distance to the point at which the potential reduces in magnitude to 0.5 of its central value and d is a parameter which determines the diffuseness or surface thickness of the potential. Experimental data with beams of deuterons, alpha particles, other nuclei, as well as pions and K mesons, all scattered by heavy nuclei, seem to be accounted for quite readily in terms of the optical-model form of the IPM. The success of the IPM seems so broad that one might be tempted to apply it to a great variety of physical phenomena and even sociological phenomena.

The purpose of this article is to present an application of an IPM to a subject which may be of very considerable interest to many scientists—namely, to compensation schedules.

IN an attempt to find the order or regularity underlying the rapidly changing compensation picture for scientists in industry, the writer has made use of salary-distribution data accumulated by the Los Alamos Scientific Laboratory. A typical set of data may be graphed as distribution functions in a form shown in Fig. 2. Here the vertical scale represents the percentile; the horizontal scale represents the rate of pay. The various curves represent the distribution functions for $A = 5$, 10, 15, where A represents the years which have elapsed since the BS degree. The curves presented are typical of nonsupervisory scientists with the PhD degree, as well as supervisory scientists with the PhD degree. To a personnel expert looking at such a distribution function, these curves would undoubtedly suggest the integral-error function. However, the writer's immediate response to seeing such curves was to think of the potential functions used in the nuclear-shell and optical models. For the purposes here it is convenient to represent the distribution function using the Saxon form with the equation

$$1 - p = \{1 + \exp[(r - R)/d]\}^{-1}, \qquad (2)$$

where R represents the pay rate for $p = 0.5$ (i.e., the 50th percentile) for a given age and d is the width parameter which characterizes the spread of the distribution function. If one inverts this function one finds that the pay rate is given by

$$r(A, p) = R(A) + d(A) \ln[p/(1 - p)]. \qquad (3)$$

The problem of representing the two sets of distribution functions, one for supervisory PhD personnel and

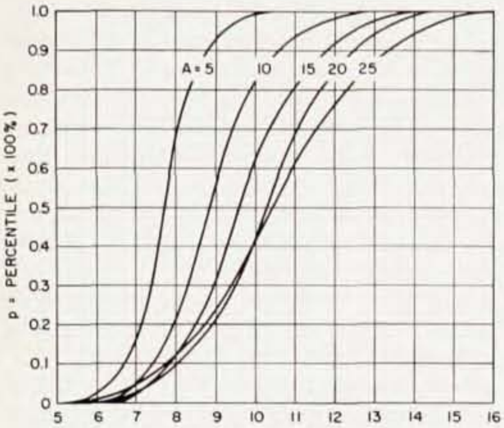
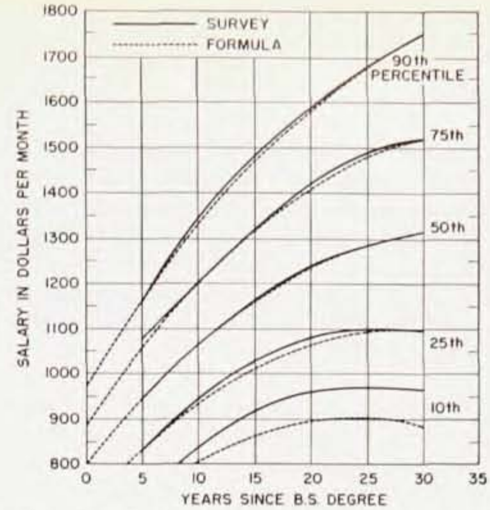
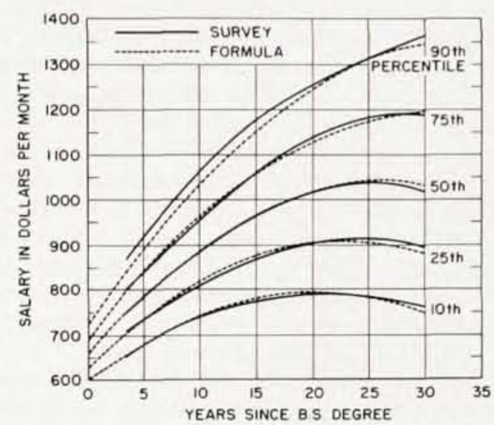


Fig. 2



SALARY CURVES FOR SUPERVISORY DOCTOR'S DEGREE

Fig. 3



SALARY CURVES FOR NON-SUPERVISORY DOCTOR'S DEGREE

Fig. 4

one for nonsupervisory PhD personnel, thus becomes a straightforward process of identifying the functions $R(A)$ and $d(A)$. The $R(A)$ function, which in the nuclear case goes as $A^{1/3}$, was found in the compensation case to be representable quite well by a quadratic function. Unlike the nuclear case, where the surface width d is approximately a constant independent of A, detailed examination shows that the compensation case requires an increasing $d(A)$. Again, a quadratic function is found satisfactory.

To a nuclear phenomenologist, it is highly distasteful to use two distinct sets of functions for the two types of entities (i.e., a supervisor and a nonsupervisor). Since these undoubtedly must be states of a single fundamental entity, it seems appropriate to introduce a dichotomic variable σ, which like the nuclear spin can take on two possible values, $\sigma = +\frac{1}{2}$ representing an upspin state (i.e., a supervisory state), and $\sigma = -\frac{1}{2}$ representing a downspin (i.e., nonsupervisory state). With this new variable, it was found that a single formula could be used to represent the 1959 distributions of salaries for PhD level scientists in industry:

$$\begin{aligned} r = {} & 726.5\,(1 + .0412\,A - .00070\,A^2) \\ & + 143\,(1 + .214\,A + .000314\,A^2)\sigma \\ & + 54\,(1 + .070\,A + \sigma)\ln[p/(1-p)]. \end{aligned} \tag{4}$$

In this equation, the first line represents the progression function for the 50th-percentile scientist. The second line represents the supervisory (or spin) correction and the third line represents the correction for departures from the 50th percentile which presumably reflects how high up the ladder the scientist stands, i.e., which orbit he is in. The last term in the third line thus corresponds to the "spin-orbit" interaction of nuclear potentials.

The results of the model in relation to the more conventional forms of the 1959 salary distribution functions are shown in Figs. 3 and 4. One sees that in the $\sigma = -\frac{1}{2}$ state, the fit is quite good except possibly at the highest percentiles for young scientists. For the $\sigma = +\frac{1}{2}$ state, the fit for the most part is also quite good, except at the very low percentile levels. This latter difficulty, which probably suggests that our model might be oversimplified, is really of no great concern, since no industrial firm would admit that its supervisory personnel come from the lowest ranks of scientists.

One considerable advantage of an analytical (in comparison with a graphic) representation of salary data, is the ease with which one might handle intermediate values of the independent variables. For example, there is a growing suspicion among persons engaged in scientific management that the dichotomy, supervisor vs. nonsupervisor, is not really a meaningful one. Indeed, to many minds entering freshly upon this age-old problem, it would appear that scientists are usually found in intermediate states between these two extremes and, accordingly, that σ is a continuous variable rather than a discrete one. The fact that, among the 14 533 PhD-level scientists represented in the Los

Alamos survey, the ratio of nonsupervisory personnel (10 674) to supervisory personnel (3859) was only 2.75 to 1, suggests that the term "supervisor" is used fairly freely, and it must indeed be true that most PhD-level scientists should be assigned σ values intermediate between the extremes $\sigma = \pm \frac{1}{2}$. The formula provides a linear interpolation between the extreme states for any intermediate value of σ.

WE may conclude that the analytic formula given by Eq. 4, which has many of the characteristics of the potential functions used in the nuclear-IPM concept, provides a compact and quantitative summary of the general trend of the large mass of data on compensation accumulated by the Los Alamos Scientific Laboratory.

An examination of the breakdown of the data collected by Los Alamos Scientific Laboratory suggests that salary-distribution functions depend significantly on other variables such as the particular industry, the geographic region, the size of the industrial establishment, the particular scientific field, the academic degree of the scientist, etc. Furthermore, comparative data from year to year suggest a time dependence of scientific salaries (they are going up!). One might reasonably expect that to a first approximation these local fluctuations and time changes might be handled simply adjusting the numerical coefficient in front of each parenthesis on the three lines of Eq. 4.

The data presented in the 1959 LASL survey concerns scientists in industry up to the middle managerial levels. The compensations for scientists, functioning in top managerial positions, as independent consultants, or as entrepreneurs, are not embodied in Eq. 4. For many reasons we may view Eq. 4 as presenting the analogue of the IPM for bound states, i.e., the shell model. With this correspondence we might regard the as-yet-unsurveyed data for top managerial help, consultants, and entrepreneurs as corresponding to the unbound states of the IPM to be embodied in an as-yet-unformulated optical model. With the large body of personnel experts involved in the determination of scientific salaries, it is not surprising that regularities should exist in such data (although it is rather surprising that analytic representations are not utilized). The very existence of personnel who consult with their counterparts elsewhere provides a feedback mechanism for the development of a self-consistent salary structure. It will be most interesting to follow the variations of the coefficients in Eq. 4 with time to see whether the distributions are converging.

One might raise the question as to what corresponds to the imaginary part of the IPM potential which is needed for excited bound states as well as for the unbound states. As it arises in nuclear problems, this imaginary part represents those interaction processes which lead to decay of the excited states, or which lead to outgoing particle waves which are incoherent with respect to the incoming particle waves. Income taxes are proposed as an analogy with the imaginary part of the nuclear-optical-model potential, since they certainly represent one of the more incoherent aspects of modern life. One can hardly call such money real income, hence it might reasonably be called imaginary income. Furthermore, the form function which might be used to represent income taxes clearly corresponds to a surface phenomenon in that the income tax losses are peaked at the high end of the distribution functions. In this peak, however, large fluctuations can be expected which will be directly correlated with the deduction dexterity of the individual. In any event, investigation directly dealing with income tax payments (inelastic processes) must be carried out to determine the best representation of the imaginary part of the optical model for scientific salaries.

In view of the success of this IPM representation of scientific salaries, the emphasis of further study might now properly shift towards work on fundamental sociological theory which might account for the type of interaction of a scientist with society represented by Eq. 4. Of course, scientists primarily interact with other people in pairs. Somehow in the course of the many two-body interactions (scientist and personnel man, scientist and manager, scientist and scientist, scientist and contract monitor, etc.) some sort of over-all average interaction of a scientist with society results which seems to be describable by a distribution function. We leave it, however, to the sociologist to develop this fundamental theory. The success of this intermediate IPM representation of the experimental information suggests that any theory which would account for this model would have a deep underlying significance.

In presenting these brief results, we must acknowledge that we have only scratched the surface of the potentialities of the IPM representation of scientific salaries. We have yet to explore the influence of velocity dependence, spheroidal distortion, the influence of charge, the exclusion principle, or to look into the problem of decay or transitions. Undoubtedly, these have their counterparts in various sociological factors such as salesmanship, organizational responsiveness, sex, organizational inbreeding, loss of scientific productivity, job transfer, etc. It would appear that the nuclear phenomena are so rich and varied, and hence require such complex models for their description, that these same models might be broad enough to encompass facets of human society.

The writer would like to express his appreciation to many scientists for discussions which have been helpful to this study. In particular, he would like to acknowledge his indebtedness to Drs. B. Lippmann and D. Saxon for their assistance in investigating the unbound states (i.e., the optical model), to Dr. K. A. Brueckner for calling attention to the large rearrangement term in the distribution function, and to Dr. J. B. Marion for help in exploring the diffuse tail of the distribution function. The writer would also like to express his thanks to Los Alamos Scientific Laboratory for permission to use the 1959 survey data.