

NRC AIP CONFERENCE on

The demand for more men and women with specialized knowledge is felt generally in the sciences and other disciplines as well. In few is it so acutely felt as in physics. The problem of immediate concern to the physics profession is that far more emphasis needs to be placed on the study of mathematics and physics in our schools if the nation's growing requirements for physicists are to be satisfied.

SOME months ago, at the initiative of the Division of Physical Sciences of the National Research Council, plans were set in motion for a small gathering of physicists, educators, and representatives of industry and government to consider what concerted action might be taken to strengthen physics education in the United States as a means for improving both the quality and the quantity of physicists. The resulting Conference on the Production of Physicists, sponsored jointly by the National Research Council and the American Institute of Physics, took place from March 31st through April 2nd at the Greenbrier Hotel in White Sulphur Springs, West Virginia.

In view of the diminishing emphasis placed on science, and particularly on physics, in the thinking and training of secondary school students, it was agreed that the conference discussion should center on those problems facing physics education at the high school and first-year college levels. Many of the problems revolve around the numbers and training of science teach-

ers. It has been evident, even during a period of relatively low enrollments, that there is need for more and better high school science instruction, and the promise of increased enrollments in the near future serves to underline the importance of early action. It has been estimated¹ that the number of high school graduates will increase from 1.25 million in 1953 to 1.75 million in 1960 and to perhaps as many as 2.5 million in 1965. In the colleges, an increase from about 272 000 graduates in 1955 to 326 000 in 1960, 454 000 in 1965, and 591 000 in 1970 is expected.

The "background" phase of the conference agenda consisted of seven papers delineating the problem, followed by a panel discussion and four additional papers defining the regions in which practical measures might be taken to meet the problem. The broad range of interests of those who took part can be seen from the

¹ *America's Resources of Specialized Talent, The Report of the Commission on Human Resources and Advanced Training*, by Dael Wolfe, Harper & Bros., New York, 1954, page 172.

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appended list of the thirty-three conferees,² but it might also be noted that the physicists present included members of the Physical, Optical, and Acoustical Societies, together with several who are active in the American Association of Physics Teachers.

The immediate intent of the conference was to develop a set of workable recommendations, and to that end the group was divided into four committees chosen respectively to formulate specific proposals for remedial steps to be taken by government, industry, education,

and the physics profession. The recommendations of the committees were considered in detail at the last session by all of the conferees before being approved by the conference as a whole.

IN the absence, because of illness, of George R. Harrison, the scheduled chairman of the conference, Paul E. Klopsteg served as chairman and read Dean Harrison's summation of the central aims of the conference. Starting with the premise that there is now a shortage of physicists that is not likely to be relieved for a decade or longer, Dean Harrison suggested that it has occurred because of the rising demand for men with professional training and because the college education of a professional physicist is coming increasingly to require seven or eight years. Together, he said, these two facts introduce a transient as a result of the greater time needed for production. Also, the relative numbers, and in some cases the absolute numbers, of persons electing professional careers in science are decreasing. The relative drop is apparently greatest in physics, and in its case there is now an absolute drop as well.

Enrollments in high school physics and mathematics courses, as W. C. Kelly has made clear in the March 1955 issue of *Physics Today*, have failed to keep pace with rising total enrollments. In 1895 more than 95% of all students graduating from high schools had taken a course in physics; in 1952 this was true of only about one high school graduate in five. "Many college teachers of freshman physics," Dean Harrison observed in this connection, "will say that this does not matter, because they can detect no apparent increase in ability to study physics as a result of a high school course. What does matter is that a smaller proportion of students is likely to be made aware of the possibility that they might be interested in a scientific career. However, we must be careful not to jump to conclusions, for it is necessary to separate effects arising from the increasing size of the age stream from those related to the fact that as increasing fractions of the age stream tend to complete a secondary school education, the average IQ of high school students must inevitably diminish, and the fraction capable of success in science is likely to diminish also." In terms of absolute magnitude the physics enrollment situation appears even worse than is suggested by the relative figures, for physics has become far more important than it was 65

² Conference on the Production of Physicists, List of Participants.

Paul E. Klopsteg (Acting Chairman)	National Science Foundation
R. B. Brode	Professor of Physics, University of California
J. W. Buchta	Professor of Physics, University of Minnesota
R. H. Carleton	National Science Teachers Association
J. S. Coleman	Division of Physical Sciences, National Research Council
S. W. Cram	Kansas State Teachers College, Emporia, Kansas
Wm. L. Duren, Jr.	Professor of Mathematics, Tulane University
V. E. Eaton	Professor of Physics, Wesleyan University
N. H. Frank	Professor of Physics, Massachusetts Institute of Technology
Glenn W. Giddings	General Electric Co., Schenectady, N. Y.
W. W. Grigorieff	Oak Ridge Institute of Nuclear Studies
Robert E. Hopkins	Institute of Optics, Rochester University
J. A. Hutcheson	Westinghouse Electric Corp., E. Pittsburgh, Pa.
Keith Johnson	Science Supervisor, District of Columbia Board of Education
Philip Johnson	School of Education, Cornell University
Harry Kelly	National Science Foundation
R. B. Lindsay	Dean of Graduate School, Brown University
R. C. Maul	National Education Association
J. R. Mayor	Chairman, Dept. of Education, University of Wisconsin
R. W. McNamee	Union Carbide & Carbon Corp., New York
H. A. Meyerhoff	Executive Director, Scientific Manpower Commission
W. C. Michels	Professor of Physics, Bryn Mawr College
Brian O'Brien	Vice President, American Optical Co., South- Bridge, Mass.
L. O. Olsen	Professor of Physics, Case Institute of Tech- nology
R. S. Shankland	Professor of Physics, Case Institute of Tech- nology
H. B. Templeton	Science Supervisor, New York State Depart- ment of Education
M. H. Trytten	Director, Office of Scientific Personnel, Na- tional Research Council
Wallace Waterfall	American Institute of Physics
A. T. Waterman	Director, National Science Foundation
B. B. Watson	Operations Research Office, Johns Hopkins University
Fletcher Watson	Graduate School of Education, Harvard Uni- versity
Harold E. Wise	Graduate College, University of Nebraska
Dael Wolfe	American Association for the Advancement of Science

George R. Harrison, Dean of Sciences, Massachusetts Institute of Technology, was Chairman of the Conference, but was unable to attend because of illness. Others who had participated in the activities of the Conference Planning Committee, but who at the last minute were unable to attend, were H. A. Barton, American Institute of Physics, and W. G. Pollard, Oak Ridge Institute of Nuclear Studies.

years ago. "Modern technology, to say nothing of science and medicine, is coming to depend more and more on the physics discovered since 1890," he continued. "Wipe this out and you remove a large part of our social wealth. Yet, as Kelly points out, in the high schools of 1890 physics was only one of nine subjects, while today it is one of 274."

A key factor in the problem to be considered by the conference, Dean Harrison indicated, would be the high school science teacher. Many teachers, because of the relatively unattractive life offered by the public schools, are being drawn away from teaching into industrial and government positions, while others, because of the shortage of teachers, give science courses although they were primarily trained in other subjects.

FUTURE supplies of physicists are flexible and can to some extent be controlled in size, the conference was told by Dael Wolfe, the second speaker. There is no one level or pattern of intellectual traits characterizing the physicist, he said; on the contrary, physicists differ markedly from one another and their abilities often overlap those of other specialists. Thus, in a kind of "statistical game" to consider what fraction of the nation's students might have the needed qualifications and aptitudes to become physicists of some degree of competence, it is sufficient to know that on the intelligence scale nearly all persons who earn bachelor's degrees in physics rank in the top 20 percent of the total population, that nearly all who earn PhD's rank in the top 8 or 9 percent, and that the best half of the PhD's rank in the top 3 percent. At these intelligence levels, roughly half of the people having the intellectual ability required of a physicist do not finish college, and of the 50 percent who do, about 1 percent major in physics and 10 percent major in the natural sciences. To carry the picture further: of 10 000 boys and girls who are bright enough to become physicists, about 5000 finish college but only 50 have majored in physics and 450 in one of the other natural sciences; of the 50 physics graduates, 12 become junior physicists or technicians, 14 enter closely related fields such as electrical engineering, chemistry, or school teaching, and 15 enter graduate school and later, after getting a master's or doctor's degree, become physicists.

Last spring, Dr. Wolfe reported, nearly 2000 physics students graduated from college and almost 500 received PhD's in physics. College graduating classes can be expected to double within 12 or 15 years, and assuming that the same percentage of graduates will be in physics, we can look forward to perhaps twice as many physics graduates even if nothing is done to increase interest in careers in physics.

"In each generation," he concluded, "there is a satisfactorily large number of boys and girls who, at least potentially, possess the intellectual interest, habits, and abilities required of a physicist. We do not want all of them to enter physics, but we do want more than we can expect if we simply let nature take its course. Through scholarships and other devices we can prob-

ably increase the supply moderately and within a few years. More slowly, but also more constructively, we can increase the supply by improving the quality and increasing the quantity of high school instruction in science and mathematics. Again more slowly, and again more constructively, we can increase the supply by identifying more of the boys and girls of potentially high ability and by encouraging, motivating, educating, and rewarding them so that more of the most gifted will seek higher education. The supply of physicists can be increased by any of these means. The latter ones have the additional virtue of increasing the supply for all fields, of giving the nonscientists of the next generation a better knowledge than their parents had of how a scientist works and what he contributes to the world, and of providing increased opportunities to intellectually gifted young people to develop and use their talents more fully and effectively."

SSECONDARY school science teachers, said Fletcher Watson in his discussion of their availability and qualifications, are diminishing in numbers while many are inadequately prepared to encounter the quantity of students that soon will reach the high schools. As most of the country's high schools are small, with total enrollments under 400, the teacher, who usually teaches two or more subjects, has to be a "one-man band". Those science teachers who take part in college summer programs in order to qualify for higher degrees, Dr. Watson suggested, would ordinarily choose to do their graduate work in science. But unless they have already fulfilled the necessary undergraduate requirements for a particular major (which is rarely the case) they are not permitted by the science department to take graduate courses in science for credit. As a result they do their graduate work in education rather than in the science they often want and need.

There are about 65 000 teachers in the country actually teaching high school science, but there appears to be no direct means of communicating with them. One recent survey has shown that a third of those polled belong to no professional organization at all. There is real need for better communication with high school science teachers, Dr. Watson declared, if for no other reason than to insure better comprehension of such opportunities as funds and scholarships that are available in the colleges.

Because a sequential grounding in elementary mathematics is necessary for later science study, the "time of decision" for a potential science student is often the 8th grade when electives are selected for the following year. Here the key influence is the high school teacher, who must serve as the "cutting edge" in advising the child on his future study program. Unless the teacher's sources of information are adequate, the value of his advice is open to question.

As every scientist knows, Dr. Watson continued, the fields of science have fuzzy borders, which lends strength to the argument favoring general courses in secondary schools on science as a whole rather than

separate courses for each field. An exciting, stimulating, significant sequence of courses called "science", including all sciences, would provide an opportunity, he suggested, for removing "labels" in the early years of study and thereby avoiding the danger that over-specialization encouraged in the student's high school program will lead to frustration in college.

QUOTING from statistics assembled by the National Education Association, Ray C. Maul noted that the total number of this year's college graduates prepared to teach in high school has dropped 41 percent since the all-time high of 1950 and the class of 1956 is expected to produce even fewer potential teachers than did any of the last seven years of college graduates. In September 1954, he reported, the high schools employed some 2759 "new" full-time science teachers (where a "new" teacher is one who did not teach regularly the preceding year but is not necessarily a recent college graduate) and 5415 to teach science and one or more other subjects. At the end of the 1953-54 year some 3641 college graduates with majors in science completed the requirements for the high school teaching certificate, and of these only 47 percent, or about 1730, entered teaching last September.

WORKING conditions and salaries, according to John R. Mayor, chairman of the AAAS Cooperative Committee on the Teaching of Science and Mathematics, are the most important factors prompting teachers to leave the teaching profession and causing young people of ability to hesitate before entering. There are many opportunities for advancement in secondary school teaching that are not widely enough appreciated, but it should be recognized, he added, that they are mostly opportunities for advancement in "professional growth" rather than advancement in salary.

Among the factors contributing to the undesirable working conditions of teachers are problems involving the sizes of classes, the spread of teaching load, and the availability of appropriate teaching aids. A less tangible factor is the relatively low status of the teacher in the community, caused in part by his low economic position and in part by the heavy work load which he carries in his profession.

Throughout the country most school systems have a fixed salary schedule in which increases in salary are based only on length of service, with no provision for advancement beyond the fixed limits in recognition of merit in the teaching profession. Even though the fixed schedule has the support of most teachers' organizations, Dr. Mayor said, it seems that the time is at hand when leadership must be provided for a movement to allow recognition of merit in teaching through advancement beyond the fixed salary limits. In Wisconsin new teachers with bachelor's degrees and without experience are accepting positions for next fall at salaries ranging from \$3400 to \$4200. Although these salaries do not compare unfavorably with those earned by new graduates of the University in other professions, the diffi-

culty is that teachers in the best schools in Wisconsin, with twenty years' experience or more, and with the master's degree, will in many cases not earn as much as \$6000 in the next academic year. [It was recognized, however, that the salary situation in many states is even less favorable. A recent survey,³ for example, noted that whereas in 1938 teachers were in the top third of the income groups of the country, only ten years later they were in the bottom third. "Despite the rare community that pays its teachers adequately," the report stated, "by 1952-53 the national average salary of all school teachers had risen to \$3400."]

IN a critique of teaching objectives in secondary schools, Harold E. Wise had some things to say of the field of professional education which has "mushroomed" along with enrollments since 1900. The influx of large numbers of pupils not preparing for college and "who, all too often, did not measure up in mental ability to the previous standards of high school pupils" created as yet unsolved problems of adjustment, he indicated, and has led to a system of formal teaching objectives which "seem to have disavowed, for the high school, any responsibility for preparation for college and to have excluded, or at least minimized, the importance of knowledge or plain old-fashioned subject matter in the secondary schools". Furthermore, he continued, rather than showing any inclination to help in developing the potential ability of outstanding students, education theorists now seem to place the most emphasis on "the common needs of youth which in the older or subject-matter-centered high school were assumed to be concomitant outcomes of the work of the school, the church, and the home".

The academic preparation of teachers, however, has had a more crucial effect on high school instruction than have all of the formal statements of objectives that have been written. It is essential, he said, for the teacher to have the respect of his students if he is to have any influence in their development, but one of the first essentials to such respect is a knowledge of the subject matter of his teaching. Although there are many able, well-qualified, and underpaid teachers of science who are doing the best they can under difficult circumstances to do a good job of teaching, there are factors that have impaired the over-all quality of secondary school science education. Most high school teachers must teach in two and frequently three subject matter fields and "if they are to be prepared during four years of college work some compromise must be made either in the time devoted to general education, to special preparation in the subjects to be taught, or to professional education. A glance at minimum requirements for certification and the standards established by accrediting associations will reveal that the compromise is not in the professional aspect of the training program." As a result, Dr. Wise said, it is

³ *Critical Years in Science Teaching*, the report of a conference on nationwide problems of science teaching in the secondary schools, Harvard University Printing Office, 1953.

not uncommon to find high school teachers attempting to give instruction in subjects in which they have had little or no college preparation, and such teachers are often assigned to teach general science at the junior high school level where they may lead many boys and girls to have a real aversion to anything called "science".

Turning next to three outstanding "maladies" affecting our public schools, Dr. Wise cited the practice of "curriculum dilution" by gradually removing those high school subjects which are difficult, an action often followed by the introduction of a new course "designed to meet the needs of youth" which is little else than a reorganization of the superficial elements of one or more of the deleted courses. A second problem has to do with the notion that there should be no failures in high school, a practice defended by educators with the explanation that it is "essential to personality development for the boy or girl to experience the feeling of success". Item three deals with the "disproportionate emphasis" on the importance of the program of extra-curricular activities: "it is not uncommon to observe that the new high school building in a small community is not a class room building at all but a combination gymnasium auditorium."

Even the best trained science teachers must have reasonably adequate laboratory facilities in order to do a good job of teaching, Dr. Wise said, but the trend in science instruction has been away from the quantitative and technical during past years with the result that less emphasis and less time have been given to laboratory work. "The virtual elimination of the individual laboratory in the science classes in many high schools is in principle exactly opposed to the tendency toward more individual pupil activity in most other phases of high school work. Evidently many school administrators are convinced that the slogan, 'We learn to do by doing', does not apply to science students."

Emphasis, he concluded, needs to be placed on the better training and supervision of high school mathematics and science teachers; the continuing tenure of these teachers should be insured by their employment on a 12-month basis at salaries approximately the equivalent of those paid in professions requiring comparable ability and preparation; and the organization of science and mathematics instruction should be stabilized. To those ends, he proposed, high school science and mathematics teaching should be recognized by federal legislation somewhat similar to that establishing the Smith-Hughes program,⁴ and the administration of such a program for science should include provision for at least advisory services by a board representative of the nation's leading scientists.

[N. H. Frank's critique of teaching objectives in col-

leges, which followed the paper by Dr. Wise, can be read in full on page 19 of this issue.]

APPARATUS for the laboratory, which is an important factor in capturing and holding the interest of students in physics, need not be expensive and need not be capable of high precision, V. E. Eaton told the conference, but it should be easily available. The fact is, he reported, that no new apparatus for teaching purposes has been developed in the United States since before the war, and for reasons of labor economics there is apparently no plan to bring out new equipment.

The American Association of Physics Teachers, Dr. Eaton said, has named a special committee on scientific apparatus for educational institutions to explore the matter. An effort will be made, by means of a questionnaire to AAPT members, to discover what types of apparatus are most needed, and the committee is already busy studying various aspects of the rather involved problem of whether domestic manufacturers can be persuaded to fill the need for equipment used as teaching aids or whether it will be necessary to depend on imports from abroad.

It has been suggested that the problem might be partially solved if unused scientific apparatus stored away in warehouses by certain government agencies and industries could be made available to high schools and colleges. Another partial approach has to do with simple demonstration and laboratory equipment that might readily be constructed by the teacher, if he could be told how, by using materials that are inexpensive and easy to obtain. Here the chief difficulty is that of getting in touch with the high school teacher, for no single organization or journal reaches more than a small fraction of the nation's teachers.

TEXTBOOKS are another form of teaching aid inviting attention, according to Walter Michels, and in the light of many of the introductory physics texts now in use one can hardly blame students if they put all physics into two categories: "the understandable, complete, and closed system of classical physics comprising one category; and an esoteric subject known as modern physics, suitable only for genius, comprising the other". One reason for the heavy emphasis on classical physics and comparative neglect of modern physics in the treatment of college texts, he suggests, has to do more with the necessity in elementary courses for providing a sound basis of classical physics for engineering students than with the need for a realistic introduction to physics as it now exists. It is possible, he continued, that our textbooks are a symptom rather than a disease. "If more of us would try to bring more modern physics into our teaching, not as an addendum but rather as a new way of thinking, we may find ourselves producing new and better textbooks within the next ten years."

The high school textbook situation, he indicated, is no less disturbing. While certain "old stand-bys" still

⁴The Smith-Hughes Act (1917) and later supplementary acts of Congress were enacted for the purpose of developing and promoting vocational education of less than college grade under a cooperative arrangement between the government and the various states. The acts provide annual appropriations for use by the states and territories for vocational education in agriculture, home economics, and trades and industry.