Some Contributions of Physical Science to Military Efficiency.

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The technical and popular press has of late been offering much valuable material which shows the contributions of the physicist and the research laboratory to war problems. Moreover before these Proceedings are printed and circulated it is certain that much more information along the same line will be released. It is not the purpose of this paper to give a complete catalog of the achievements of physical science in the war, nor to set forth in detail the devices which have been developed and applied. It is, however, my purpose to sketch briefly some of the general lines along which the physicist gave aid to the military forces, and to point out some of the valuable results which have followed from the large activities and generous appropriations which were called out by the pressure of war conditions.

It will undoubtedly appear that instances are rare where war-inspired research has resulted in the discovery of any distinctly new principle or law. The lay public, keenly alert for some wonderful invention or discovery, which should overwhelm the opponent as by a great cataclysm, frequently voiced the question why our active scientists were not bringing forward this all-important achievement. But the hoped-for result did not come about. Rather the achievements of physical science in the war consisted in the application of already well-known principles, but with a *refinement* and a *precision* heretofore not realized. The careful consideration from the standpoint of theory of the lines and balance of a shell, of the form of its ends, and of the proper width and thickness of its copper band resulted in the addition of miles to its range and increased the accuracy of gunfire manyfold. Such precision studies, often highly theoretical in nature, growing in numbers to scores or hundreds, all contributed to an increased efficiency of the military forces, and their full value cannot at this time be realized.

Studies similar to the above resulted in our becoming free from European markets in the matter of high-grade optical glass. Precision methods of glassworking, amounting almost to quantity production, were developed, and lenses and prisms large and small, and plane parallel plates were turned out in large numbers with an exactness heretofore hardly thought possible. In photography, in the great development of

photographic map making, ray filters were devised for eliminating the effects of haze. By means of these, landscape details were clearly delineated, while without them the plates revealed little more than a bank of clouds.

In the development of suitable instruments for giving the aviator information as to his position, altitude and speed, and for enabling the accurate dropping of bombs upon assigned target areas, the combined skill of many specialists brought results of surprising value. With a dynamo-generator attached to the frame of the airplane, driven by the air stream and with a control so perfect that in spite of the inevitable large variations in speed practically a constant voltage could be maintained for the radio equipment, the aviator was enabled to signal or talk with ground stations, with other aircraft or with his companions in the same machine.

In the science of acoustics many old and well-known principles have been revived, extended and applied in a variety of ways. Of especial value were those applications to sound-ranging, for locating positions, and even determining caliber of enemy guns. Moreover the observer is enabled to distinguish between sounds due to discharge, flight and bursting of the shell. Highly developed listening devices gave invaluable information in locating enemy aircraft, in detecting mining operations, and in submarine detection. The widely used methods of ground telegraphy, invaluable in communication, recall the early experiments long antedating modern radio.

Meteorology has taken its place as essentially a new department of physical science, and a careful study of the earth's atmosphere has led to results of the highest importance in determining wind conditions before and after gas attacks, in correcting data for artillery fire, in revealing favorable conditions for the aviator, in foreseeing conditions which will aid or hinder transport service and in predicting fog and rain.

In the field of electricity the vacuum tube or electron relay has demonstrated its indispensability for countless uses; telephonic and other communication devices have been perfected to an astonishing degree; the dangers of electrostatic charges on balloon fabrics have been studied and methods of control devised; and the quality of small portable batteries has been much improved and their life increased. In radio communication, already highly developed before the war period, startling results have been realized. Closed coil reception has proved successful in the absence of large antenna installations, and has made possible satisfactory work in uni-directional sending and receiving, in triangulation and in receiving on submerged submarines even at transatlantic distances. Without the vacuum tube much of this important work would have been impossible.

Finally, however, the student of the scientific achievement of the war period, whether in applications of known laws and perfection and refinement of existing devices, or in pure research, cannot but be impressed by the large body of knowledge and experience which has come as a by-product of the study of war problems. During the war both government and private laboratories left no promising clue untraced, and no suggestion was ignored if it seemed to contain any germ of expectation. Although a large part of this activity did not result in devices or processes directly useful or applicable to war problems, nevertheless out of it all is sure to come a wealth of results of value to our scientific and industrial life. Now that the immediate need for high pressure research is at an end, there should be no decline in the research spirit. Now, more than before, the effort should be made to maintain and advance the effectiveness of all existing organizations and agencies which encourage and promote diligent research in physics.

One outgrowth of the intense activity in physical research has been a growing interest in physical science and its applications. Our students have been keener and more alert and the instructor has before him a wealth of illustrations with which to enrich his classroom and laboratory work. Also in the popular press, setting aside the purely sensational, there has been given to the reading public much stimulating material, and the people at large have been brought to a wider appreciation of scientific laws and facts.