tubes has only to study his book entitled "The Grand Fleet." The alloy used is a tin-brass containing 1 per cent. of tin, 70 per cent. of copper, and 29 per cent. of zinc. Nearly ten years ago the institute took up this very problem with the view of solving it, and has been assisted since its inception by Sir Henry Oram and Sir George Goodwin at the Admiralty. As a result, tests are now being carried out, in one of his Majesty's vessels, of a process devised by the committee's investigators, which, it is hoped, will go a long way towards solving this particular difficulty. In its work the committee has had no better friend than Sir George Goodwin, and there is a singular appropriateness about his choice as president of the Institute of Metals. H. C. H. C.

The Investigation of Grain Pests.

By DR. A. D. IMMS.

FEW lines of biological research at the present time are of greater moment than those which are likely to contribute towards the maintenance of our food supply. Information comes from trustworthy sources that there is a considerable reduction in the available wheat of the world, and it is therefore more than ever incumbent upon us to reduce any preventable losses to a minimum. The damage sustained by stored grain through the inroads of insect pests is heavy, and we welcome a further series of the Royal Society reports [1] which are directly concerned with problems connected therewith. Prof. Dendy and his colleague, Mr. Elkington, have carried out much-needed observations of a more exact nature than has hitherto been attempted. Embodied in their reports is a good deal of both biologically and economically valuable information relating to some of our most destructive grain pests. In dealing with the phenomenon known to the trade as "webbing," they point out that it is due to the wandering of great numbers of larvæ of the moth *Ephestia elutella* over the surface of heaped grain in warehouses. Each larva trails behind itself a silken thread and, when very abundant, the whole surface of the grain may become infested with a reticulum of these threads. The superficial 12 in. of the grain are affected, and become fouled by fæcal and other larval débris. Actual injury to the grain itself does not appear to be serious, and it is probable that much of the contamination would be effectually removed during the cleaning processes to which the grain is subjected. It is, however, scarcely likely that any advantage can be derived from allowing these webs to remain, on the strength of a suggestion that weevils are destroyed through getting entangled therein. The safest and surest method is to eliminate the pest as the authors advocate, and it is noteworthy that a wide range of other food products is susceptible to the attacks of this species.

In the same report (No. 4) Prof. Dendy also deals with the occurrence of live insects in presumably sealed tins. His observations show that it is an evident fallacy to conclude that they can survive indefinitely when once the original oxygen is completely used up. The main point is to ensure that the sealing of the tins has been really efficiently carried out before the latter are relegated to the store. Directly connected with airtight storage is the question of "heating." Two experiments conducted by Prof. Dendy indicate that this process, which is due to fermentation, is prevented when the grain is stored in hermetically sealed vessels. Whether anaerobic fermentation is a factor likely to occur does not appear to have been studied. In connection with the investigations, it was noted that when a vessel is only half filled with grain attacked by *Calandra oryzae*, all the insects may become perfectly motionless in twenty-four hours. When 273·5 c.c. of air are present to 100 grains of wheat, only three insects remained alive out of thirty-nine (including all stages) at the end of fourteen days at 30°–31° C. At room temperature nineteen insects out of forty-three remained alive after thirty-two days. In both experiments the percentage of carbon dioxide had gone up to between 18 and 19, and the oxygen diminished to less than 2; and the authors express themselves as being quite certain that the insects would have succumbed soon afterwards.

It is evident from these experiments that further research under varied conditions and degrees of infestation is still desirable. If airtight storage provides ready sterilisation, without previous application of heat, we have a fact of first-rate economic significance. An important factor is the moisture content of the wheat. Above a certain point the production of carbon dioxide by wheat increases very greatly. This critical point varies with the temperature, and in the cases investigated it lies between 13·25 and 16·95 per cent. Above this critical point of moisture content wheat in airtight storage speedily renders itself immune to insect attack; below it a longer time elapses. It is noteworthy that pure (moist) carbon dioxide acts almost instantaneously as a narcotic to Calandra, but is less fatal in its effects than when mixed with a small quantity of oxygen.

The seventh report deals with points in the bionomics of *Calandra oryzae* and *granaria*, and also of *Rhizopertha dominica*, which are three of the most serious grain pests. It was found that the

[1] Royal Society. Reports of the Grain Pests (War) Committee. No. 4: "On the Phenomenon known as 'Webbing' in Stored Grain." By Arthur Dendy and H. D. Elkington. "Note on the Occurrence of Live Insects in Tins supposed to be Hermetically Sealed." By Arthur Dendy. No. 5, 1919: "On the Prevention of Heading in Wheat by means of Air-tight Storage." By Arthur Dendy and H. D. Elkington. No. 6, 1920: "Report on the Effect of Air-tight Storage upon Grain Insects," Part iii. By Arthur Dendy and H. D. Elkington. No. 7, 1920: "Report on the Vitality and Rate of Multiplication of certain Grain Pests under Various Conditions of Temperature and Moisture." By Arthur Dendy and H. D. Elkington.

optimum temperature for the breeding of Calandra is about 82° F., but somewhat higher for Rhizopertha. *C. oryzae* may increase 700-fold in sixteen weeks, which makes it a more dangerous pest than *granaria,* which has a slower rate of multiplication. On the other hand, adults of the latter species were found to survive the winter in this country at ordinary room temperature, whereas nearly all those of *oryzae* were killed off. Rhizopertha succumbs after three minutes' exposure at about 146° F., while 120°-130° F. is the lethal temperature for both species of Calandra.

As the consequence of information accumulated in the laboratory, tests along commercial lines need to be carried out in order to ascertain the practicability or otherwise of the knowledge thus obtained. We strongly urge that large-scale tests should be inaugurated with as little delay as possible. If such tests confirm the conclusion that the most satisfactory method for the storage of grain in bulk, over lengthy periods, is in air-tight silos or granaries, the Grain Pests Committee is to be congratulated upon a notable achievement. The construction of such receptacles would involve a high initial cost, but probably not excessive when the annual loss from weeviling is recounted. As the authors point out, by such a method of storage we should be provided with a means of maintaining a reserve of cereals in the event of war or crop failure, and, we may add, of economic or financial difficulties.

Some Applications of Physics to War Problems.

IN an address to the Physics Section of the American Association for the Advancement of Science, delivered at the St. Louis meeting in December last and published in *Science* for March 5, Prof. Gordon F. Hull describes the work done by a number of American mathematicians and physicists in elucidating the various problems that arose during the war in connection with long-range and anti-aircraft gunnery. It may be of interest, therefore, to record the efforts of a number of British men of science, made at a much earlier date during the war, on which (and on the work of the French) the developments of American scientific gunnery as described by Prof. Hull were largely based.

Up to the spring of 1916 the developments of British ballistic science had come largely through the Ordnance Committee at Woolwich, which during the war was fortunate in having an officer of considerable mathematical attainments as head of the ballistic office. The mass of work, however, and the extraordinary variety and difficulty of the problems that arose, especially in connection with the new science of anti-aircraft gunnery, made it necessary for the Ordnance Committee to seek help from outside; and from 1916 onwards the investigation of problems in "external ballistics" devolved largely on the Anti-aircraft Experimental Section of the Munitions Inventions Department. The A.A.E.S., as it was called, consisted of a number of mathematicians and other men of science, mainly fellows and scholars of Cambridge colleges, some from the Patent Office, one from Oxford, and three fellows of the Royal Society—some in military, some in naval, and some in civilian clothes.

The work of this group was undertaken at H.M.S. *Excellent,* Portsmouth, at Rochford Aerodrome, at the National Physical Laboratory, at University College, London, and at a variety of other places. It consisted largely of trials with anti-aircraft guns, shells, and fuses, recording the positions of shell-bursts at heights up to 33,000 ft., observing and calculating the effects of winds and of pressure and temperature abnormalities, developing the mathematical theory of ballistic calculations, and investigating the behaviour or the causes of failure and irregularity of fuses. In addition to this, work of considerable mathematical and physical interest was done, some of which will be published, on the general dynamics of shell flight (such problems as the stability of shells, the effects of rotation of the earth, "drift," the "twisted trajectory of the shot," etc.), and on the pressure distribution on the head of a shell in flight. The solution of some of these problems, undertaken originally in connection with anti-aircraft gunnery, had, in the end, a considerable bearing upon the theory of gunnery in general.

The A.A.E.S., in addition to its main work in investigating the problems of gunnery, did a large amount of routine computing of range tables in conjunction with the staff of the Galton Laboratory, and performed a number of interesting and important trials on time-fuses in co-operation with the Engineering Department of University College, London. It carried out far-reaching experiments on the use of sound-locators for the detection of air-craft, and in conjunction with the R.E. and the Air Force on the co-operation between such sound-locators and searchlights; the military equipment and methods finally adopted were based directly on these experiments. It tested both the theory and the use of a number of instruments required for anti-aircraft work, such, for example, as range-finders, height-finders, and "predictors" (instruments for predicting the "future position" of the target at the moment the shell bursts); and finally it had what was known familiarly as a "travelling circus," which moved about in Great Britain and France recording the results of practice anti-air-craft shoots, and investigating the performance of guns and instruments.