ENGINEERING COLLEGES AND THE WAR.

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Anyone who during the last few years had followed closely the developments of armaments could have predicted that, as has actually happened, the next great war would be essentially an Engineers' War, and that the engineering aspects of the war would not be confined to the old distinctions which separated military from civil engineering. These conclusions were inevitably pointed to by the developments which have taken place in mechanical transport, terrestrial, aerial and naval, both on the surface and under the sea; in ordnance and other implements of war for naval and field operations necessitating workshop tools and trained engineers; in telegraphy and telephony with or without interconnecting wires; and in all kinds of new optical aids.

It was therefore a national duty from the military and naval, as well as from the educational, point of view that the equipment and
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staffing of Engineering Technical Colleges and their organization should be brought to a high state of efficiency as a preparation for national defence, if need be, against the contingency, which was not very remote, of this country having to face a European War.

On the outbreak of the war it was inevitable that the work of the technical colleges in relation to it should be put upon its trial, and that the colleges should be asked to prove that the large, though insufficient, sums of money spent on their equipment and staffing were justifiable from the practical engineering as well as from the purely educational point of view.

The object of this Paper, however, is not to examine the whole of the general questions which obviously suggest themselves in this connexion, but to deal more especially with what is being and can now be done by the technical colleges to assist the country in its endeavours to win through. The Authors, therefore, venture to bring before the Institution the present Paper dealing with such matters and with the distinct object of raising questions for discussion. They venture to hope that the opinions and suggestions of practical engineers and of expert engineering teachers, the expression of which may be expected to follow the reading of the Paper, will prove of considerable value towards the attainment of the end which all have in view.

For convenience of reference, the Paper is divided into the following sections and sub-sections, though it may be said at once that close water-tight divisions between the different parts are not possible nor perhaps even desirable:—

1. *Munitions Work in Technical College Workshops:—*

- (i) Equipment available.
- (ii) Personnel: staff, students and others.
- (iii) Conditions under which the College Workshops should be utilized.
- (iv) Kind of work which can be undertaken.
- (v) Organization of this work.
- (vi) Work actually undertaken in the College Workshops.

2. *Training of Munitions Workers and War Workers generally :—*

- (i) Summary of what is being done at present in Technical Colleges.
- (ii) Training carefully selected hands on the direct production of munitions under manufacturing conditions.
- (iii) Whether, and under what circumstances, the manufacture of munitions is preferable to training munitions workers.

3. *Other Engineering War Work in Technical Colleges.*

1. MUNITIONS WORK IN TECHNICAL COLLEGE WORKSHOPS.

(i) *Equipment available.*—Many of our best technical colleges have well-equipped workshops provided with valuable modern tools of precision, such as universal grinding machines, tool-makers' machines, capstan and turret lathes, universal milling machines, gear-cutters, etc. Where such equipment is available, there can be no doubt that the best use to which it can be put is in the manufacture, either directly for Government Departments or through the local Munitions Committees, of munitions of all kinds, including the very numerous ancillary details necessary for the completion of the equipment of the Navy and the Army as fighting forces.

Many practical engineers and some engineering professors have in the past looked with disfavour, almost with contempt, on the college workshop, and have doubted whether any serious work or instruction of real value can be given in it from a practical engineering point of view. This doubt, we are sorry to say, is in many cases the result of the amateurish workshop equipment and instruction given in a number of technical schools, excluding those referred to in the preceding paragraph. Owing to the fact that they have gone on year by year installing cheap examples of old types of machines, fit only for the rough machine operations established long ago in the days of James Watt and of the machine developments inaugurated by Whitworth, the assistance which these schools can give

to the country in the present crisis is necessarily different from that which can be given by the better equipped colleges which have suffered largely from these ill-advised and pretentious attempts of other institutions at teaching so-called engineering workshop practice.

This, however, is neither the time nor the place to deal with the position of the college workshops in their several educational aspects; but it is of urgent importance that their equipment and staff should be utilized to the best advantage in the service of the country during the present national crisis, irrespective of educational, personal, or even of local considerations. In this utilization, the type of the equipment which has been accumulated in the past must necessarily be a determining factor as to the special work to be undertaken.

As regards the amount of equipment available of one type or the other, it may be noted that the number of technical colleges and schools in the United Kingdom comprised in the membership of the Association of Technical Institutions is ninety-six. The list is nearly but not quite exhaustive, for it does not include the University Engineering Schools in London, and similar schools in some of the provincial Universities. There may also be some minor technical schools not included. Altogether, not fewer than 112 educational engineering workshops or sets of workshops are in existence, and of them about 25 fall into the higher category referred to above as being more or less well equipped with modern productive tools.

(ii) *Personnel: Staff, Students and Others.*—As regards personnel, there are on the staffs of many of these engineering colleges and schools, including some of those which may be poorly equipped with modern tools, skilled instructors and workmen trained in good commercial workshops and familiar with and capable of operating modern up-to-date tools. There are also large numbers of skilled and semi-skilled engineering students who may be employed, and these may be and are in many cases supplemented by any outside skilled workmen obtainable.

(iii) *Conditions of Utilization.*—The question of immediate importance is under what conditions and in what manner the workshops of our engineering colleges can be made of use to the Naval and Military Authorities. This, as remarked above, depends to a large extent upon the equipment of the particular workshop under consideration.

Where there is already a collection of modern tools of precision as well as of the other tools suitable for the roughing out and finishing of parts of munitions and military apparatus, the Authors have no doubt but that the best course to pursue is not to attempt to combine educational work with production, but to organize the workshop as a factory workshop, and staff it under the direction of the well-trained staff which in such a case will be available on the spot, employing also such students as are available and are likely to be useful in the work. In addition, skilled workmen should, whenever possible, be imported from the outside, if such workmen can be found, but the experience of the last few months shows that it is difficult to obtain many of this type of workmen, namely, those who can work to the highest degree of accuracy required in finishing inspection gauges and in other high-class productive work. The available supply appears to have been quickly absorbed in the early days of the present development of munitions works.

An alternative method in large centres would be to assemble a selection of tools from the different colleges in the area under one organization, and at a convenient centre for the purpose, rather than to distribute the work amongst the colleges, no one of which may be competent to deal with it on broad lines. The object of this centralization would be the carrying on of the best type of work mentioned in the next sub-section. Undoubtedly also, much can be done by grouping and concentrating special tools in large areas for the manufacture of some special work, such as shell bodies. If, for example, the Education Authorities in a large area were to concentrate the heavier lathes, certain furnaces, presses and other suitable plant in one centre, together with the necessary staff, it would be quite possible to obtain an output of from 200 to 600 shell-bodies a week, and that with tools which in many instances would

otherwise be doing relatively unimportant work or be lying entirely idle.

In another centre, furnaces, pyrometers, and the suitable staff may be concentrated to deal with the special hardening operations for gauges before the final finishing work, such as grinding and lapping, is done. Many manufacturing engineering firms, as well as some technical colleges, on first undertaking the manufacture of gauges, have found considerable difficulty in dealing successfully with the hardening of cast or tool steel for gauges, resulting in large waste of material, and, what is more valuable, time. Gauge-makers will realize the great importance of the above suggestion in the case of firms or institutions taking up gauge manufacture for the first time.

Then, again, educational institutions, have an Artistic Crafts Department with special craftsmen on the staff. These departments might usefully be employed as centres for the stamping or engraving of gauges and other work. The Authors can state from direct experience that this work can be carefully and expeditiously done by such a department.

Where, owing to the unsuitability of the equipment or for other reasons, the technical college authorities are unable to engage in the manufacture of munitions or to employ suitably the valuable tools under their charge, they should be required to hand over such tools, either on loan or purchase, to Government Departments or "Controlled" Munitions Works urgently requiring them.

In all cases in which the equipment utilized has been largely derived in the past from the expenditure of public money, that is where the college workshops are being directly utilized as recommended or where there is a centralization scheme, the conditions under which work can be undertaken appear to the Authors to be fairly obvious.

In the first place, the work undertaken should be on orders received directly either from the Local Munitions Committee or from Government Departments. The conditions under which it should be undertaken should be the charging to the Government of actual out-of-pocket expenses, including such wages as are directly paid in connexion with this work, but excluding the full-time

salaries of the expert members of the staff who are engaged upon it. Incidentally, it may be remarked that these full-time members of the staff should, if the work is to be effective, be giving to this commercial production a number of hours per week largely in excess of the hours required for educational work. This extra time, which is not less than from ten to twenty hours per week, has up to the present in some institutions been voluntarily given by the engineering staff, who have fully realized that, not being charged against munitions, it is a fair equivalent of the time which would under ordinary teaching conditions be employed by them in preparation work outside of the scheduled time for routine college work. Any students engaged on the work should be paid such wages, representing the commercial value of their work, as may be determined by the expert opinion available. These wages would usually be on an hourly basis, though, when the nature of the work allows of it, piece-work rates should be fixed and the work done should be paid for per piece with the view of obtaining an increased output at a reduced cost. Students who have had some or no previous commercial workshop experience are, of course, of the grade of apprentice learner or improver from the shop point of view, and are not to be regarded as skilled workmen.

Under these conditions it is submitted that the total cost of production chargeable to the Government should not, for all the college workshops considered together, be in excess of the cost in well-equipped commercial factories; but it is obvious that if this method of charging for the work be adopted, then no orders should be taken from private firms, as this would lead to the exploitation of public property for private profit.

(iv) *Munitions Work which can be undertaken by the College Workshops.*—Assuming a well-equipped workshop and a capable engineering staff assisted by students and additional workmen with good workshop experience, the kind of manufacturing work which can be done in sufficient quantity to be of real war value may next be considered.

Taking first the highest type of college workshop equipped with

modern automatic tools and representative precision machines, together with the necessary gauges and ultimate standards of measurement, perhaps the most useful work at the present time from the war point of view is the manufacture of gauges—both inspection gauges and shop gauges—for which there is a very pressing need. As in the manufacture of these gauges the limits of error allowed vary from, say, ± 10.000 inch to ± 10.000 inch, depending on the type of gauge, and special operations such as annealing, hardening, stamping, grinding and lapping—all necessitating special skill—are required, it is vital, if wasteful expenditure and disappointment are to be avoided, that what is meant by a “gauge” should be clearly understood. As a workshop operation, even this degree of accuracy is eclipsed in the case of gauges for small-arms, and gap-gauges which are worked to simple check gauges, where a small fraction of 10.000 inch can be detected by the skilled worker.

The first criticism which will at once suggest itself to a casual reader is, “Yes, it is all very well to talk about gauge-making in the technical college workshop, but how will you obtain the skilled workers, who must be of the highest type, when there is such a great and unsatisfied demand for gauge-makers in the arsenals and munitions factories? Further, even many so-called skilled workmen can never be trained to be good gauge-makers, for it is a case of ‘many are called, but few chosen.’” Now, it must be granted at once, and will be shown more fully presently, that for the machine operations involving the use, say, of a universal grinder, or of a good lathe for screw gauge making, a highly-skilled man is required, thoroughly at home with the use of machine-tools, and possessing, in addition, the necessary temperamental faculty of perceiving by touch and gauge very small differences of dimensions. Quite a number of institutions have such men on their regular teaching staff, and not to use such highly skilled ability at the present time is a national sin. Further, many engineering students attending the technical colleges have had previous workshop training, and from actual experience it can be asserted that a few possessing the necessary faculty can, with a little instruction and close

oversight, be so trained that they quickly pick up the special grinding and lapping operations necessary in the final stages of gauge-making.

Then, again, there are very numerous details wanted for gun and small-arms work requiring not only the use of capstan lathes and operators, but of the higher type of workman able to use gauge and micrometer in milling, screw-cutting, grinding, etc., and for this kind of work also the well-equipped college workshop can be, and is being, made use of.

Turning next to somewhat poorly-equipped workshops, these can be utilized, provided the necessary tools of the ordinary type are available, with students to work them. They can be employed, for example, on rough machining for gun and carriage details, details for aeroplanes, such as plates, pins, bolts, stays, etc., and on many other operations requiring only somewhat crude workshop skill. Experience, however, up to the present has shown that this roughing work is difficult to obtain from the sources indicated, for the following reasons :—

First, the roughing and often the finishing in the arsenals and munitions factories are for the most part done cheaply on automatic and semi-automatic machines, and it is the finished article, worked very often to the thousandth or half-thousandth of an inch, that is required in quantity.

Secondly, few munitions firms, and certainly none of the Government arsenals, are able, owing to heavy pressure of work on the controlling staff, to place orders for simple roughing work to be returned for finishing, with an individual technical college of limited capacity whose output would be so comparatively small as to be almost a negligible quantity.

It is here that the Local Munitions Committee, or the Local Education Authority in the case of large areas with several technical colleges properly organized, can be of use even if it be considered undesirable to develop a centralization scheme such as has been recommended above. Orders for finished units of work in quantities should be freely placed with these authorities by the Government Departments. The authorities acting as distributing and collecting

agencies would then place orders and material with the various technical colleges for specific operations. Tools at one institution would be found capable of doing only the crudest of rough machining to ordinary callipers, and the institution should be required to do that work, which would then be collected and passed on to another institution capable of dealing with the somewhat finer and more skilled operations; finally, it would be finished at the one or two institutions capable of dealing with the most accurate workshop operations.

In the hope that it may be of assistance to the public bodies referred to and others, the Authors, in Appendix II (page 751), have scheduled in detail the chief particulars which should be ascertained as a basis for the decisions to be arrived at. So far as the Authors have been able to find out, this system, or some modification of it, does not seem as yet to have been adopted. For its proper working, the Munitions Committee or Education Authority would require to have a well-qualified and trained man, with a bed-rock knowledge of modern workshop methods, detailed for this special work, who could give his full time to its organization and administration, and not, as is sometimes the case, be employed on other work. Skilled advice through a large committee of local engineers is a great step in the right direction, but what is wanted in addition on these committees is the full-time organizer with executive authority and with full responsibility for seeing things put through expeditiously.

The question of cost for work carried out in this way, as compared with that produced by automatic machinery, does not bulk largely when it is remembered that the labour may be largely patriotic and unpaid, that many munitions factories cannot obtain nearly the full number of automatic machines they require, and that many institutions working together can produce by these less modern methods work of considerable value in a far from negligible quantity.

(v) *Organization of the Work.*—Dealing next with the question of suitable organization for the rapid production of munitions in college workshops, it should be first and chiefly insisted upon that only full-time work is of value. Nothing can be more lamentable,

or perhaps even ridiculous, than to attempt to undertake, as has unfortunately already been done in some places, the manufacture of munitions at odd times during a regular full-time course of engineering college work. The Education Authorities have to make up their minds that if this thing is worth doing at all, it is only worth doing well, and it is one of the sacrifices demanded by the stringency of the present crisis that at least some of the educational work, and from the conditions that of the higher type, has to be set aside for the present, so that the personnel, both students and instructors, as well as the material equipment, may be freed for national service. It may be remarked, parenthetically, that the lower type of educational work, such as the first year's day courses in the colleges, may be continued, since the young students fresh from school and under military age are rather a hindrance than a help in the workshops, and for the time, at any rate, their instruction may be undertaken by teachers who are not necessarily so well-versed in actual workshop operations as their more skilled colleagues. It is, of course, understood that workshop practice forms a small part of a first-year's course at a technical college, and can be given in other shops not used for munitions work. It being granted, then, that only full-time work is contemplated, it is essential that it should be organized in accordance with the practice which in some form or other now obtains in the best workshops.

In the first place, a reliable system of cost-keeping is essential, and although the various institutions will, perhaps inevitably, adopt methods suitable to their particular circumstances and differing in details, yet it is important that each institution should start on a clearly-defined system.

There will, in general, be several, and sometimes many, operations required to produce the finished article, and it is of the utmost importance, if the work is to be done as quickly and cheaply as possible, that the men should be properly grouped, and that each man should as far as possible be confined for a reasonable time to one operation only. Thus, for example, if numbers of a particular type of gauge are to be manufactured requiring, say, twelve operations, then if possible twelve men, each on a distinct operation, should be

employed. This system is, of course, quite the practice in a well-organized engineering factory, but in some university colleges and technical schools, attention to the business side of practical engineering and of modern workshop methods is conspicuous by its absence.

The records for the cost of such work are best obtained by some system of job-ticket and job-cost cards, which when completed will enable the costs of any or of all of the work turned out to be readily determined. An example of such a job-ticket, which may be a printed card measuring 6 inches by 4 inches, is shown on the opposite page, and an example of a job-cost card which may also be in the form of a card 6 inches by 4 inches is shown on the same page. These are so drafted as to form part of a good system, whereby the costs of all work may be arrived at.

A job-ticket should be issued to each workman on commencing a particular operation for a number of identical parts, and given up by him, with all the information filled in, when the particular operation is finished, together with the work done. He will then be given another job-ticket and other parts to be worked on the same (or another) particular operation. All the job-cards for a particular job-number, taken together, will give the cost of direct labour for the job in quantity. These labour costs will be transferred to the job-cost card for the several operations of the particular work.

In addition to direct labour, there will be the indirect charges or shop charges, which will include :—

Cost of power.

Depreciation of tools based on the life and scrap value.

Cost of small tools, oil, and the many other incidentals required.

Cost of light, gas, water, etc.

Establishment charges, which in ordinary engineering works form a not inconsiderable item, should not be charged, remembering that these charges would exist if no munitions work were undertaken, and have already been paid for from public funds. Moreover, the usually heavy item of drawing-office charges is most frequently eliminated by the necessary working drawings being supplied with the order. To charge any proportion of institute establishment charges

JOB TICKET

M.E.D. ORDER No. _ _ _ _ _

OFFICIAL REFERENCE _ _ _ _ _

WORKMAN _ _ _ _ _

CHECK No. _ _ _ _ _

DATE AND TIME ISSUED _ _ _ _ _

DATE AND TIME RETURNED _ _ _ _ _ TOTAL HOURS _ _ _ RATE _ _ _

NAME OF PART _ _ _ _ _ PART No. _ _ _ _ _

No. OF PARTS ISSUED _ _ _ _ _ No. ACCEPTED _ _ _ INSPECTED BY _ _ _ _ _

No. OF MACHINE _ _ _ _ _

OPERATION _ _ _ _ _ No. _ _ _ _ _ MATERIAL _ _ _ _ _

DATE	HOURS	DATE	HOURS	DATE	HOURS	REMARKS

NOTE.—This card to be handed in when the particular operation is complete, and must not on any account be taken away, but hung on the board required whilst the work is in progress.

JOB COST CARD

M. E. D. ORDER No. _ _ _		OFFICIAL REFERENCE _ _ _		NAME OF JOB _ _ _		JOB No. _ _ _					
OPERATION No.	OPERATION	HOURS		DIRECT LABOUR			SHOP CHARGES		MATERIAL		
		MACHINE	HAND	RATE	AMOUNT		RATE	AMOUNT	(FURTHER DETAILS ON OTHER SIDE)		
					£	s.	d.		£	s.	d.
											KIND _ _ _ _ _
											FINISHED WEIGHT / _ _ _ _ _
											ROUGH WEIGHT / _ _ _ _ _
											PRICE / _ _ _ _ _
											RATE / _ _ _ _ _
											MATERIAL
											D. LABOUR
											S. CHARGES
											+ %
											WORKS COST
											£ s. d.
											DATE _ _ _ _ _

to munitions would, under the conditions of the work, result in making the manufacturing price prohibitive, and is undesirable from other points of view.

In connexion with the question of the extent, if at all, to which the salaries of the engineering teaching staff should be charged to munitions work, we are glad to note that the Governing Bodies of some institutions feel it their duty to allow their staff, in time not urgently required for other work, to engage upon munitions work without charge to the cost of the work. If this were not done, the utmost that could be properly charged to munitions work, where the staff are engaged on this work, would be workshop value of the individual on similar work in a modern engineering factory. This workshop value will in some cases be more, but in many cases less, than the salaries paid for teaching work. There is then the difference, plus or minus, to be considered. Generally, where members of the teaching staff have joined the military forces, the Governing Bodies have, where army or naval pay is less than the institute salary, made good the deficiency. In cases where the teacher earns more as a worker on munitions, he should be allowed to keep the increase. On the other hand, where either whole or part salary is charged directly to munitions work, there must necessarily arise the question as to whether a corresponding reduction of grant to the institutions from public funds ought not to be made; for it is obvious that to charge salaries to munitions work without a corresponding reduction of grants from public funds would result in the taxpayers and ratepayers paying twice over. The simplest solution, and the one to which least objection can be taken, appears to be to allow engineering teachers in public institutions to engage upon munitions work without any charge for their services being made against the cost of such work. Exception may be made, however, where overtime is worked, for which the proper workshop value should be paid to the teacher. This procedure will simplify matters and avoid the cumbersome business (which must operate to the detriment of the rapid and urgent manufacture of munitions) of transfer and readjustment of grants as between the Imperial and

Local Education Authorities and the Governing Bodies of our Technical Colleges.

(vi) *Munitions Work actually undertaken in the College Workshops.*

—The Authors propose next to give some indication of the munitions work which is at present being done in the engineering workshops of the different Technical Colleges, together with some idea of the actual conditions under which such work is being undertaken. It is hardly necessary to state that it is inadvisable, for military reasons, to be too specific in details with respect to the exact kind of work or the precise locality in which such work is being carried out. To do so might bring the Paper under the ban of the Censor. Most of the London Polytechnics and the technical institutions under the direction of the Education Committee of the London County Council are either directly engaged in the manufacture of munitions, or are giving some form of training to munitions workers. The same holds in London and the provinces as regards some of the University Engineering Departments, the larger Technical Schools, and also some of the smaller ones.

Dealing with the London Educational Institutions first, and, in this section only, with munitions work, by far the most important of the work undertaken is the manufacture of numerous types of gauges which require to be finished with a very high degree of accuracy. The output in this respect is considerable, and would astonish some of those engineering critics who look with disfavour on the college workshop. In addition, both in London and the provinces, very numerous details are being manufactured for naval and military work of various kinds, such as shell-bodies, gun-mountings, parts for motor-lorries, aeroplanes, naval guns, fuses, adapters, *gaines*, details for small-arms, armourers' details, and much other work, all of which is being effectively carried out by these college workshops. In addition, some of the workshops are manufacturing small tools, jigs, etc., for neighbouring munitions factories. The particular type of work undertaken in any institution depends, as has just been shown, on its equipment and the conditions under which the work is organized and carried out.

An important question is the cost to the country at which this work is being done. Some institutions will no doubt be able to show that they can manufacture at a price which compares favourably with that of the outside manufacturer. In other institutions the cost price may well, because of the conditions, be greater than the proper market value. On account of urgency extra cost may be faced without misgiving, provided it is not unreasonable, as it is output which matters first and cost afterwards. It cannot be disputed that, if a college workshop can turn out work up to specification in sufficient quantities at a reasonable market price, then that workshop is doing good work under difficult conditions, and that if it be possible for one good workshop with good facilities to do such work, it is possible for others under proper organization to do likewise.

It will be worth while at this stage to consider how orders for such work are placed, and the kind of agreement arrived at by different authorities as to payment for work delivered. Orders for work are placed by Government Departments, either directly with the colleges which have inspired sufficient confidence to justify such a course, or with the local Munitions Committee who are acquainted with the full circumstances, and who can act as distributing agents for the Government Department concerned. Again, some institutions, both in London and the provinces, act as sub-contractors for details urgently required to the large armament firms or to smaller firms engaged in the manufacture of munitions. In another part of this Paper it is pointed out how undesirable this latter course is. The methods of charging for the work vary considerably, and depend upon whether the order is received directly from the Government Department, from the local Munitions Committee, or from one of the armament firms or other munitions works.

The most desirable conditions under which work has been accepted, whether that work is done for a Government Department or for the local Munitions Committee, is practically the cost price to the Governing Body of the work done, over and above any outgoings which would have been incurred if the work had not been

undertaken. This includes the cost of material, direct labour and shop charges, including the cost of power, lighting, heating, etc. Hitherto, in such cases, orders have not been accepted from private firms, and it is proposed not to accept such orders so long as the necessary work is forthcoming from the Metropolitan Munitions Committee, or one or other of the Government Departments. The objections to accepting orders from private firms are set forth above, but it must not be overlooked that munitions, wherever manufactured, are very urgently required.

Technical Colleges undertaking work for private firms must necessarily agree at the very commencement with respect to the financial conditions under which the work is undertaken. In some instances contracting parties have agreed on a definite price for each piece of work to be done. In other instances the cost price, with or without establishment charges, has been agreed to, but the conditions vary considerably in relation to the many technical institutions which have undertaken munitions work. Agreement to pay cost price, plus shop and incidental charges, necessarily implies a considerable amount of confidence by the Government Department or firm placing the order. The workshops of one large provincial institution are being run entirely by orders from a prominent firm engaged on munitions work, which agreed to furnish all material, pay the wages, plus other charges to the extent of 100 per cent. of the wages paid on the work, with the proviso that the agreement can be terminated at any time. Another very large provincial institution engaged on munitions work for a large armament firm is charging cost price in material and wages, but nothing for power or establishment charges. To meet some of the objections urged above, having reference to the danger of exploitation for profit by private firms, it may be argued that all these firms are "controlled" firms working with a limitation of profit for the end that all have in view. Thus, if costs are slightly reduced and work done cheaply in particular college workshops, the result will stand as a set-off against the cost, much higher than the market price, at some other institutions working on an actual cost price basis.

Reference has been made elsewhere in the Paper to the desirability of grouping and concentrating tools collected from the technical colleges in large areas in a suitable building, for the purpose of manufacturing munitions, and it is interesting to note that this has to some extent been done by the Education Department of the London County Council, and probably at some institutions in the provinces. Full details of the results of this work are not yet available, and a report to date, fully setting forth all the details and the difficulties encountered, as well as the effective work done, would be interesting and probably instructive.

The Authors have endeavoured, from statistics available, to form a rough idea of the extent to which technical colleges are dealing with the munitions problem, and have estimated that about one-third are employed on the manufacture of munitions in some form; another third have been training munitions workers; and some of the remaining technical colleges have dealt with the problem by the supply of their workshop tools to munitions factories.

2. TRAINING OF MUNITIONS WORKERS AND WAR WORKERS GENERALLY.

(i) *Summary of what is being done at present in Technical Colleges.*—A fair number of technical college workshops are being utilized for the so-called training of munitions workers, and the training given depends essentially on the type of workshop equipment, as well as upon the technical or teaching staff which can be set aside to deal with this work. As pointed out above, a very large proportion of these school workshops have facilities representing more the older type of engineering workshop and workshop practice, but the more modern colleges have in many instances modern tools of a high order of excellence with the necessary staff competent to use them.

The instruction courses given are remarkably varied, both in relation to the duration of the course and the quality of the work dealt with. Thus we find one technical college proposing to give instruction to intending munitions workers for a fee of 5s. for ten hours' instruction, and to train women for the measurement work in shell manufacture. Another technical institution has arranged

instruction courses in screw-cutting in connexion with the Amalgamated Society of Engineers, who supply eight of their members as instructors for lathe work. At another institution a mixed class of girls, youths, and men receives instruction on the ordinary types of machines, in the hope that they will be capable of employment by a munitions firm for the manufacture of shell-bodies after a fortnight's instruction. Longer courses of instruction of from four to six weeks are undertaken by institutions, large and small, for considerable numbers of workers in the expectation that they may be placed with munitions firms afterwards. Evening instruction is also being given to inexperienced men and girls, in the hope that they may be qualified for admission into a munitions works after anything over a fortnight's training.

These examples are sufficient indication of the fact that instruction courses are open to the general public for periods of time which in many instances are totally inadequate to produce any useful result. Comparatively few of the institutions working under these conditions are prepared to offer any guarantee of subsequent employment to those being trained, and the Authors believe that only a very small proportion of workers so trained at the outset ever saw the inside of a munitions factory. The fact was, that the terms "munitions work" and "munitions workers" were very elastic and excelled the word "Mesopotamia" as phrases to conjure with. A "munitions worker" apparently might be anything from one who is required to do routine work of such an elementary nature that skill and rapidity can be acquired in a few hours by anyone with intelligence and enthusiasm, to the most highly-trained workmen whose deftness and dexterity can only be acquired by long experience. A "certificate of proficiency" in munitions work may therefore mean little or much, and the proficiency certified requires to be very specifically defined. Better considered courses of instruction than those alluded to are, however, being offered and taken advantage of at Technical Colleges in London and in the provinces. The Education Department of the London County Council has undertaken a considerable amount of work in connexion with the training of munitions workers. Many of the tools and facilities at

the various junior technical schools under the Council have been transferred and centralized, and very definite instruction in workshop practice is being given to both sexes. It would be interesting in this connexion to have a report from the authorities as to the success of this scheme.

Apart from the instruction which is being given to inexperienced workers, a good deal is being done in connexion with the supplementary training of skilled and semi-skilled workmen. Courses of instruction are offered in London and various parts of the country to skilled mechanics, fitters, turners, etc., some of whom are members of trade unions and have been brought up on the old English workshop lines. We find at one large provincial centre a complete plant for the turning out of shells, and we understand that works in the district engaged on munitions send their workmen to see the process of manufacturing from start to finish. Another prominent institution, acting under the local Munitions Committee, has received thousands of names of persons, many of whom are semi-skilled and many unskilled, who wish to receive instruction in the use of modern machine-tools and measurements for shells and gun manufacture. Then again, more than one institution is combining instruction work with a certain amount of munitions manufacture, but it is doubtful whether, even given semi-skilled and skilled labour of a certain type, much training can be done concurrently with the effective manufacture of munitions.

It has recently been proposed by certain of the Educational Authorities to add to their present equipment various modern machine-tools of a very elaborate character with a view to training selected mechanics or others in the use of these particular tools. It is very doubtful whether such tools can be obtained from the manufacturers under present conditions in time to be of any use, and even if they could be so obtained, whether this is the best way to utilize them. All tool manufacturers and tool factors have received definite instructions from the Ministry of Munitions to hold such new tools, as they may make or obtain, for disposal to munitions works, which would of course include college workshops directly engaged on the manufacture of munitions. One of the best

of the technical schools in the country is giving definite instruction in capstan-lathe work, tool-setting on automatic machines, and the use of gauges. All these examples go to show that a very considerable amount of work is being done, and it is proposed to extend this work for the training of unskilled, semi-skilled, and skilled workers. It cannot be gainsaid that it is possible to do a considerable amount of useful work, providing such work is undertaken with a clear knowledge of the requirements, possibilities, and limitations, and given that a certain definite object is in view, and also given the certainty of immediately placing the men so trained in munitions works. This question is still further considered later.

(ii) *Training carefully selected hands on the direct production of Munitions under manufacturing conditions.*—There are, we believe, in the United Kingdom thousands of men with some training, more or less thorough, as fitters, turners, machinists, erectors, clockmakers, artistic craftsmen, etc., who are of various ages and who are not yet employed in the manufacture of munitions. These men have received their training and experience in the old-fashioned type of shop of the non-specialized kind, or in shops not requiring the costly and elaborate equipment of modern machine-shops. These are shops in which universal grinders, automatic machines, gear-cutters and even milling-machines are either few in number or are conspicuous by their absence. The workmen referred to have been earning, and have deserved to earn, fairly high wages before the dislocation caused by the war began to tell, but since then there has been some difficulty in finding work for some of them. It is obvious that such men should not be offered wages below those to which they have been accustomed, but the difficulty is to find the intermediate work at which such wages can be earned.

To explain how this very curious state of affairs has arisen, namely, the existence of a large body of skilled mechanics for whom, notwithstanding the present abnormal demand for engineering labour, there is difficulty in finding proper employment, a brief digression may not be irrelevant even for professional engineers, some of whom may not, in the rush of modern work,

have followed up this particular phase of engineering development very closely. The conditions under which mechanical engineering has been carried on in the past and the necessity for economic production have during the last two decades undergone remarkable changes, amounting to a revolution in workshop methods of manufacture, organization, and management. Machine operations have become more and more specialized to produce greater accuracy in dimensions and finish and greater output, and, by the use of the limit gauge system, interchangeability of parts.

Sir (then Mr.) H. F. Donaldson stated before this Institution on 15th February, 1901, in the discussion following the reading of a Paper by one of the Authors' predecessors at the Northampton Institute, that "The introduction of automatic machines was due to the high cost of labour and the absolute necessity of getting work done without having to expend more in wages than was necessary, and to allow of the manufacturer having the possibility of adopting more or less unskilled labour in many productions. . . . The result aimed at was to get as large and as cheap production as possible. . . . English machines had attained the character of a very high standard of excellence, but they required brains, not only to produce, but also to work them. . . . With the automatic machine brains were required to start it, but after that the attendance did not need to be of the same calibre as was required at the start; the watching, the keeping in order, and the feeding of the machine could be done by a less expensive man."

Thus the general trend of recent years has been to replace costly hand-finishing and the costly work done on the older types of English tools by machines which in time have become more and more automatic, with greater accuracy of the work done and with greatly increased output. Hence the developments in the manufacture of the many types of milling-machines (largely replacing shaping-, planing-, and slotting-machines and hand-labour), cylindrical and disk grinding-machines, turret and capstan lathes (replacing the lathe and skilled turner), jig work for increased and accurate productions, the use of limit gauges instead of the micrometer and calliper (making for interchangeability

and increased output, so important for the manufacture of guns and small-arms); these in their turn have led to the development of special tool-makers' machines and the modern tool-room equipment.

Some of the results of these developments have been :—

- (1) Largely to replace costly workmen by costly machine-tools.
- (2) To create two distinct classes of workmen—the cheap automatic-machine attendant and the very highly skilled precision worker required for the tool-shop and for gauge-making.

Thus it is found that in the highly organized and equipped factory there is little requirement for the ordinary type of skilled workman trained on the older workshop methods referred to above. And yet these developments are so recent that thousands of workshops are still of the non-specialized kind, and, including those in which specialization is being introduced with the gradual introduction of modern tools, are still training concurrently with the other two types, the older type of skilled workman accustomed to receive good wages. Thousands of such workmen were, we believe, quite recently available for employment on munitions, if they could be brought into use.

It might here be remarked that in times of peace much can be done by the technical college workshop, with a good representative and modern equipment, to minimize the evil to the workmen arising from a too narrow specialization consequent on these modern changes by the :—

- (1) Training of the automatic-tool attendant to become less automatic himself, and to give him instruction in the skilled and more general work of the old English type.
- (2) Training of the skilled worker, brought up in the old workshop methods, in the higher work required in setting automatic tools, and where ability is manifest, in still higher precision work, both hand and machine.

At the moment, however, the problem is to utilize this skilled labour, which, like Mahomet's coffin, would appear to be suspended between heaven and earth without visible means of support, in the production of the munitions which are so urgently required. The partial solution which has presented itself to the Authors is not to establish instruction courses for such men, but to find work for some of them on munitions in the lower type of technical college engineering workshop, where they would find the tools with which they are familiar, and in the use of which some of them, at least, are expert. It ought not to be difficult to give out to such workshops work which, owing to its nature or the limited quantities required, is not suitable for the more highly-equipped college workshop on the one hand or for the more cheaply operated labour-saving automatic-tool on the other.

There is next a class of men which should be utilized, and which consists of men with some practical engineering training, but who have for a longer or shorter period been following other types of employment, and have not been in contact with practical mechanical work for some time. Speaking generally, middle-aged or fairly young men who have been through an apprenticeship in the works of a mechanical engineer should be capable of profitable employment on shell-work in a factory. Even if years have elapsed since their contact with practical work, skill gained is never lost, and two or three weeks at a factory should be quite sufficient to enable such men to regain their manipulative skill with ordinary tools, either hand or machine. For such work no special training in the schools ought to be required, nor should the time of the schools be spent on them. Any man classed as a fitter, for instance, who has obtained reasonable proficiency as such, should readily adapt himself in the factory itself to work on a good machine such as a lathe.

Attempts are being made in some places, and are under consideration in others, to give supplementary instruction to selected men of these types, and it has been proposed to extend the facilities whereby such selected men may receive special instruction on modern tools and on modern workshop operations,

The problem of training these men, and the engineers previously referred to, to become efficient on modern high-class precision work is quite a different one, involving psychological problems as well as physical and physiological ones. This has been demonstrated during the past summer, for there have been cases where it has been found impossible to train successfully an otherwise admirable mechanic to be an efficient gauge-maker. The Authors have come to the conclusion that many efficient bench and machine hands cannot be trained to make good precision workers where high accuracy of work at machine or vice is required, say, to the $\frac{1}{10,000}$ th of an inch, as in gauge-work. All men have not the delicate touch nor the power to perceive or work to small differences of dimensions. It is, the Authors are convinced, quite as much a question of temperament and mechanical instinct as of training. A careful selection of suitable men for training as precision gauge-makers can only be made by actual trial of individuals under close supervision, and such work should be so arranged as not to retard the output of munitions.

Since the above was written, a scheme has been drawn up for training semi-skilled munitions workers in technical schools. This scheme has been drafted by the Ministry of Munitions in co-operation with the Board of Education, the Scotch Education Department, and the Labour Exchanges. In a memorandum* issued by the Ministry of Munitions special emphasis is laid on the condition that the training to be given must be thoroughly practical and that purely educational ideals must be subordinated to utilitarian methods. Thus there must not be too large a proportion of bench work, which educationally is very valuable, but reducing this to a minimum, the learner, no longer a student in any real sense, must be given as quickly as possible the "machine sense" and preferably be taught to use a definite machine-tool upon which he is likely to be employed, or better still, upon which he has been promised employment, in the factory. In fact, the training, from an educational point of view,

* An abstract of this Memorandum is given in Appendix I (page 748).

is to be pure "cram" work in engineering workshop practice of a strictly limited type.

(iii) *Whether, and under what circumstances, the direct manufacture of Munitions is preferable to training munitions workers.*—One of the most important and urgent problems at the moment is to decide quickly in every case what course to adopt in the very complex conditions revealed in the foregoing sections of this Paper. The first point to settle in each case will be as to whether it is better to arrange for the direct production of munitions or for the training of munitions workers. It is partly with a view to aiding the responsible authorities to decide this important point that much of what immediately precedes has been written, and that full references have been made to the questions involved in the various schemes which have so far emerged for the training of different types of candidates as munitions workers.

In connexion with all such schemes, however, there arises the important and complicated question as to whether it is justifiable to set on one side valuable and specialized machine-tools for instruction purposes, when they are so urgently required for the direct production of munitions. The schemes also involve the absorption of the time of skilled instructors who might otherwise be employed on productive work. There should therefore be seriously considered in connexion with the value of this work—

- (a) The diversion of large numbers of useful machine-tools and highly-trained mechanics (workshop instructors and teachers) otherwise directly employable in the manufacture of munitions.
- (b) The proportion of men so trained who afterwards find effective employment on munitions work.
- (c) The effect on the acceleration or retardation of the production of munitions by the employment of large bodies of short-trained, and therefore only at the best semi-trained, workers.

With regard to (a), the diversion referred to leads to reduction of the resources available for the immediate production of the

munitions which are so urgently needed, and the place of this production is to be taken by a production of problematical relative magnitude and importance at some indefinite future time.

With regard to (b), the proportion of men specifically trained as munitions workers who may afterwards find effective employment on munitions work will depend upon whether (i) before starting the period of training they had had any previous training in bench or machine-tool work, or (ii) were absolutely untrained except for what little skill they had picked up as amateurs.

Most of the workmen who would come under category (i) have been already dealt with fully in the preceding pages, and the range of possible previous experience is so wide that no general rule can be laid down. But both for them and for the previously unskilled amateur, it is obvious that the chance of obtaining employment must depend on the training given. That training must evidently be very restricted in character, and, before it is entered upon, those responsible for the teaching should have made careful inquiries as to the vacancies likely to be available at its close, and should then direct the teaching strictly to the purpose in view as a piece of "cram" pure and simple.

With regard to (c), the conditions are so complicated and various that the Authors at this stage express no opinion, but it has been suggested to them by foremen and works managers that an over-utilization of semi-skilled workers so trained leads to serious damage to machine-tools, requires the constant attention of many skilled men, and may result in a retardation of output. An expression of the expert opinion and of the results of experience by members of this Institution on this important matter would doubtless be of considerable assistance to the Authorities.

3. OTHER ENGINEERING WAR WORK.

This Paper has already extended to such a length that there is no room to deal adequately with the important work, other than the direct production of munitions and the training of munitions workers, which comes within the purview of the engineering colleges and their equipment, and which has been undertaken by

the colleges. There is, in fact, room for a very full Paper, or even a series of Papers, upon this work alone, but it may be of interest to summarize very briefly the types of work alluded to, which may be tabulated as follows :—

- (i) The testing of war materials, for which the splendidly equipped laboratories of first-class technical colleges and technical departments of the Universities are particularly well adapted.
- (ii) The testing of new constructional details for military and naval purposes, which can also be well carried out in the same laboratories.
- (iii) All kinds of chemical and metallurgical analyses and the analyses of new products for use for warlike purposes.
- (iv) The testing of the numerous optical appliances which form so important a feature in modern warfare; also the working out of new designs to meet new requirements, *e.g.*, optical aids for aircraft and anti-aircraft work.
- (v) General experimental work of various kinds in connexion with the numerous committees which have been, and are being, organized under the Munitions Inventions Department, the Royal Society, and other public bodies.
- (vi) The requisitioning of individual members of the staff to give technical advice on subjects in which these individual members are specialists.
- (vii) The training of drafts from the new armies in intensive short courses of special work. Range-finding, field telephony and map-reading may be mentioned as subjects which, amongst others, can be well taken charge of in technical institutes with proper professional guidance. Other subjects will suggest themselves, but, as showing the possibilities, it may be mentioned that nearly 900 men of the Artillery have been passed through such courses at one institution.

The Paper is accompanied by two Appendixes.

APPENDIX I.

*Abstract of Memorandum relating to the Scheme for Training
Semi-Skilled Munitions-Workers in Technical Schools.*

The Ministry of Munitions, acting in co-operation with the Board of Education, the Scotch Education Department, and the Board of Trade Labour Exchanges, calls attention to the following scheme for training men and women in Technical Schools as semi-skilled workers for munitions factories.

Inquiries by the Ministry of Munitions have convinced it that the scheme for training semi-skilled workers in Technical Schools is fundamentally sound, and that where the training has been conducted on the right lines the reports of the Education Officers and employers alike leave no room for doubt as to the value of the training, the adaptability of the learners, and their usefulness in the factories, and the Ministry has decided to encourage the use of facilities for training in all Technical Schools to the full. As in certain Technical Schools machinery and labour have been, and are being, used for munitions making as well as for training, the Ministry desires that preference should be given to the training of munitions workers, except in special cases where very highly-skilled work, such as the making of gauges, is being undertaken.

The scheme gives special emphasis to the importance of the training being of a thoroughly practical character, and purely educational ideals are to give place to utilitarian methods. It is particularly desirable that benchwork, which absorbs so large a proportion of the learner's time in Technical Schools, should be reduced to a minimum, and the aim of all such courses should be to impart to the learner the "machine sense" and to teach him to use a certain definite machine-tool on which he is likely to be employed in a munitions factory. To this end, it is desired that the Technical School Authorities should get personally into touch with munitions works so as to direct the tuition on suitable lines.

For the purpose of drawing up a Training Scheme where none is in operation, a small local Training Committee should be formed to assist the local Education Authority and the Managers of the school or schools concerned. It will be the duty of this Committee to draw up a complete statement of the scheme, giving all details of machinery available, staff, number of learners, etc. The Ministry does not propose to insist upon absolute uniformity in detail for all Training Classes, but the following points are to be carefully noted* :—

- (1) No male learner must be accepted who is of military age, unless he is for some reason debarred from Military Service.
- (2) As far as possible, learners should be men or women of superior intelligence who are likely to learn quickly—for example, professional men, those who have had a secondary education, men skilled in other trades, such as cabinet-makers, jewellers, etc., who will return to their ordinary occupations after the war.
- (3) Preference should be given in the first instance to those who are willing to leave the town where they live and go where there is demand for labour.
- (4) Each learner entering a class must give a written undertaking that he will work whole-time in a munitions factory on the completion of his course. If he fails to do this without good cause, the cost of the training will be recoverable.
- (5) No fee should be charged for any course in respect of which it is intended to claim a grant from the Ministry of Munitions.
- (6) Each learner satisfying the Head of the School should, on the completion of his course, receive a certificate

* The numbered and lettered paragraphs which follow are verbatim quotations from the Memorandum.

of efficiency specifying the nature and duration of the course. The utmost care should be exercised in this matter. The whole scheme will fail if incompetent persons are placed in factories on the strength of their certificates.

- (7) The Head of the School must have absolute power, on the advice of his Instructors, to eliminate the unfit at any stage of the training. This power must be fully used if waste of time and money is to be avoided.
- (8) Weekly returns must be made in duplicate to the Ministry of Munitions for their use and that of the Board of Education (or the Scotch Education Department) on the lines of form annexed.
- (9) Periodical inspection of Training Classes will be undertaken by the Board of Education Inspectors and representatives of the Ministry of Munitions.
- (10) It will probably be found that the number of applicants will be far in excess of the accommodation available and that a waiting list will be necessary. It is not essential that learners should be taken strictly in the order of their application. Priority should be given to applicants who seem likely to make specially good munitions workers.
- (11) The length of the course must be largely conditioned by consideration of local circumstances. The Ministry is not prepared to sanction any course which provides less than 30 or more than 100 hours' instruction. It is suggested, too, that in all cases where classes are worked in shifts, arrangements should be made that no course should last for more than one month.

The financial arrangements made between the Ministry of Munitions, the Board of Education, the Scotch Education Department and the Treasury allow for the payment by the Minister of :—

- (A) Salaries and fees of teachers or a proportion of these, according to the time devoted to the work.
- (B) Actual cost of fuel, light, cleaning and materials so far as not supplied by the Ministry of Munitions.
- (C) Cost of making good any damage to premises, equipment or apparatus.
- (D) A reasonable allowance for depreciation of apparatus.
- (E) The cost of altering, providing or re-assembling machinery to meet the special requirements of the Ministry of Munitions.

The members of the Training Committee are to leave nothing undone to ensure the placing of students in munitions factories.

Normally the output of the Technical Schools is to be absorbed in local factories, but cases will occur where local openings are not immediately available, and it is suggested that preference should be given to applicants who are ready to work anywhere. In such circumstances, the machinery of the Labour Exchanges should be of assistance.

Where there are Technical Schools in non-industrial centres with adequate equipment for training, it may probably be found that there will be a considerable number of applicants willing to work elsewhere after training, in which case transference of labour can be effected through the Labour Exchange. If an adequate supply of such applicants is not forthcoming, the Ministry of Munitions and the Board of Education would favour the temporary removal of machinery to training centres where there is a demand for labour and facilities.

It is to be understood that all these proposals apply to the training of women as well as of men, but the Ministry is not in a position to decide in what proportion women should be accepted as learners in particular centres; this must be left to the discretion of the local Training Committee. The Ministry emphasizes the necessity of getting assurances of employment for women before undertaking to train them.

The "trained workers" will not be skilled engineers. At most they will be semi-skilled workers, but having had on an average 60 or 70 hours' practice on lathes or the like, they should be more useful recruits in a shell factory than those who have never seen a lathe before. "The Ministry is convinced that the scheme will help in some degree to provide the labour which will be urgently required, and that it needs only a careful attention to local conditions and the cordial co-operation of the various Authorities to make it a success."

APPENDIX II.

Technical Colleges and the War.

SCHEDULES OF INFORMATION REGARDING PRESENT AND POSSIBLE WORK.

1. *Manufacture of Munitions.*

- (i) Date of commencing.
- (ii) Whether the work is done for a Government Department, or through the local Munitions Committee, or in orders received from a company or private firm.
- (iii) Conditions of payment for munitions work with respect to costs of material, direct labour, shop charges (and profit, if any).
- (iv) Kind of work manufactured, and whether finished work or partly finished work.
- (v) Number of hours per week, and number of shifts if more than one, with weekly hours per shift.
- (vi) Whether the work undertaken is under the direction of the engineering staff or under some outside firm or committee.
- (vii) Extent to which the engineering staff is employed in this work and simultaneously (if at all) on educational work.

- (viii) Extent to which engineering students, day or evening, are employed.
- (ix) Extent to which outside or additional workmen are employed.
- (x) The extent to which the additional assistance is
 - (a) unskilled, (b) semi-skilled, or (c) highly skilled.
- (xi) Rates of wages to (a) staff, (b) students, and (c) others.
- (xii) The extent to which staff wages or salaries are charged directly to munitions account (*see also* (iii) *above*).
- (xiii) Holidays and overtime worked on munitions and payment for same.
- (xiv) If not already engaged in the manufacture of munitions, is it proposed to undertake such work?

2. *Non-educational War Work.*

(a) *Testing of Materials for Munitions or for Tools and Ancillary Apparatus used in the Manufacture of Munitions.*

- (i) Actual testing undertaken arranged, if necessary, in different classes.
- (ii) For whom the tests were made.
- (iii) Approximate quantity of material tested.
- (iv) Equipment available for each class of testing undertaken.
- (v) Staff and skilled assistants available.
- (vi) Method of payment (if any) as regards :—
 - (a) Out-of-pocket expenses.
 - (b) Other remuneration, and by whom made.
- (vii) Particulars of other tests which can be undertaken, with data regarding staff and equipment available.

(b) *Testing of New Constructional Details for Military and Naval Purposes.*

Details as under (a) (i)–(vii), but quite general as regards (i), so as not to disclose confidential matters.

(c) *Analyses, Chemical and Metallurgical.*

Details as under (a) (i)-(vii), *mutatis mutandis* with the proviso as under (b).

(d) *Testing of Optical Appliances.*

Details as under (a) (i)-(vii), *mutatis mutandis* with the proviso as under (b).

(e) *Particulars of Research and Experimental Work Generally for the Munitions Inventions Department and Official Committees of all kinds.*

- (i) This can only be stated quite generally, as much of the work is, and must be, confidential, and so diverse that no one schedule can be applicable.
- (ii) Special mention, giving full particulars, should be made of any staff and equipment available for work of this kind likely to be of service to the country and not yet utilized.

(f) *Personnel for Other Work.*

- (i) Particulars of staff and students who have been engaged as workmen or in other capacities with Government Departments or private firms for the manufacture of munitions or other purposes
- (ii) Conditions of transfer.

3. *Educational War Work.*

(a) *Training of Munitions Workers.*

- (i) Date or dates of starting the courses.
- (ii) Duration of courses and number and duration of lessons.
- (iii) Kind of training and brief outline of syllabus.
- (iv) Extent to which training is being given to prospective munitions workers other than in the direct manufacture of munitions.
- (v) Particulars of supplementary training (if any) given to skilled hands,

- (vi) Particulars of training (if any) given to women.
 - (vii) Fees (if any) charged for instruction.
 - (viii) Whether the instruction or supplementary training has been given by the engineering staff
 - and } under any outside firm or committee. .
 - or }
 - (ix) Total number of hands enrolled.
 - (x) Method of selection, especially as to the extent to which previous workshop experience was made a condition of admission, or not insisted upon.
 - (xi) Number of previously unskilled hands who have received instruction.
 - (xii) Number of semi-skilled hands who have received instruction.
 - (xiii) Number of skilled hands, according to Trade Union standards, who have received the supplementary training offered.
 - (xiv) Number of women enrolled.
 - (xv) Number of those enrolled who have taken full advantage of the instruction available.
 - (xvi) Number of those enrolled who have not taken efficient advantage of facilities offered.
 - (xvii) Obligation (if any) to find employment for hands trained in the courses.
 - (xviii) Proportion of hands trained who have been given work in munitions factories.
 - (xix) General remarks on the results of training of youths and men (unskilled, semi-skilled, or skilled according to Trade Union standards).
 - (xx) General remarks on the results of the training of women, or on their ability, or otherwise, to stand the strain of work under factory conditions.
- (b) *Other Educational Work.*
- (1) Particulars of courses and classes for officers, N.C.O.'s and privates, or others serving with the colours.
 - (i) A brief syllabus of the courses and classes.

- (ii) Duration and number of class hours of the courses and classes.
 - (iii) Whether the teaching was given by the regular staff of the institution, or by the staff assisted by special teachers, and the proportion of the work undertaken by such special teachers.
 - (iv) Type of students enrolled.
 - (v) Number of students enrolled.
 - (vi) Fees or other remuneration received and by whom paid.
 - (vii) Board of Education grants (if any) received.
 - (viii) General results obtained
- (2) Similar particulars of other courses or classes (if any) directly bearing on war service.

4. *Suggestions for Additional Work.*

The above schedule is necessarily not exhaustive, especially as regards the type of war work which may be undertaken by Technical Colleges. Suggestions for work not referred to are therefore desirable.

Discussion.

The PRESIDENT said that before the Paper was read he desired to call attention to the following Resolution, which had been received from the Ministry of Munitions, which seemed to him to be of importance: "The Minister of Munitions appeals therefore to those responsible not to make public the position of works other than those already known as munitions factories now engaged in the manufacture of guns, munitions, explosives or other things, or to make statements calculated to show directly or indirectly the scope of the Government work on which they may be engaged, or the quantities which they may be able to produce." The Government was afraid of information in regard to the production of munitions being so used as to help our enemies, and possibly to guide them to seek out those places which it might be most important to destroy.

(The President.)

He appealed, therefore, to the Authors, to the Members, and to the gentlemen of the Press to make a special note of the Resolution. He thought it would be necessary for the Institution to edit the Paper before it went into the Journal, in order that any mention of localities or other things, which contravened that expression of opinion by the Ministry of Munitions, might be erased. Neither localities nor quantities being produced or capable of being produced in particular places ought to be mentioned. With that caution, he had very much pleasure in asking Dr. Walmsley to read the Paper which he and Mr. Larard had prepared.

The Paper having been read in abstract by Dr. Walmsley—

The PRESIDENT said he was very glad indeed to find that the change in the hour at which the Meetings of the Institution were held had not prevented an excellent number assembling to hear the very interesting Paper that had been read. He would not take up the time of the Meeting by any criticism of his own, because he knew there were many present who wished to speak on the subject. There were, however, many points in the Paper on which, as an old teacher, he held some opinions. It was a revelation to him that a great deal of the work which engineers considered to be skilled work could now be undertaken, after a comparatively very small amount of training, by unskilled workers or by women. It was really wonderful to see a line of lathes worked entirely by women in their tidy overalls and mob caps, turning 3-inch and 3½-inch shells with very slight male assistance. He had great pleasure in proposing that a hearty vote of thanks be accorded to the Authors for their interesting Paper.

The Resolution of Thanks was carried with acclamation.

Dr. R. M. WALMSLEY, after thanking the members very cordially indeed on behalf of his colleague and himself for the hearty manner in which the vote of thanks had been adopted, said the Authors knew that the Paper was full of controversial matter,

They had given their own opinions and expected that they would probably be very much attacked. They knew they were not upon scientific physical grounds where measurement finally settled the question.

Mr. J. D. ARMSTRONG (of Leeds) opened the Discussion.

Dr. WILLIAM GARNETT said he was glad to have had the opportunity of listening to the Paper, because it would be difficult to find two Authors more competent to deal with the manufacturing and teaching sides of the munitions problem as presented in educational institutions. Coming face to face, as the country had recently done, with the production of highly specialized work, it had been learned that in some measure the engineering schools required development, and that they must not be content in future with training the fitter and turner of thirty years ago. In the historical perspective which the Authors had drawn, the methods of Boulton and Watt and those of Whitworth were blended in the far distance, and the range-finders of the Authors failed to detect the difference of parallax. He was not prepared to accept so near a vanishing point, for he was brought up to regard the Whitworth system as something like the acme of engineering accuracy. But since those days the milling machine, the universal grinder, and other tools of precision, the capstan, a whole battery of automatic tools and limit gauges, had come, and [come to stay until they were replaced by tools of still greater accuracy and capacity, and students must be trained to work to the degree of accuracy now demanded by standard gauges and interchangeable parts.

The mechanical training of students must be developed in two respects: the first was the use of precision tools, and the second was tool-making and tool-setting. He did not think much could be done with the automatic tool, properly so-called, in the schools. It was too productive and too highly specialized; but the capstan lathe might quite suitably be introduced for the purpose of teaching tool-setting. Automatic tools were frequently so unique that it was necessary to learn separately tool-setting for the tools

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of each maker. Formal training, as the educationalists called it, would not suffice, because there was not enough "transfer" from one tool to the other. When a capstan lathe was employed for training in tool-setting and, incidentally, in tool-making, it was practically outside the productive field, for as soon as the tools were ground and set so as to produce a perfect piece of work, the time had come for taking them out and starting afresh with a new set of tools or a new pupil. There could be no doubt that in normal times tools of that description should find a place in all engineering schools of the first rank, but the question might well be raised whether at the present time it was justifiable to transfer tools of such capacity from production to education. The answer to that question depended on whether workers were wanting tools or tools were wanting workers. In the latter case it might be worth while to bring a capstan lathe out of the works and into the school for a couple of months, if thereby a hundred capstan lathes could be provided with tool-setters, and it might even be worth while to make the transfer merely to give a dozen turners some practice in using the capstan lathe under supervision.

Some time ago he (Dr. Garnett) paid a visit to a private works engaged on munitions where the management was so keen on securing half-skilled workers with some experience of the semi-automatic tool that he was offered the free loan of a new capstan lathe if it could be employed for that work; and he had since seen larger and more specialized tools similarly lent to a school by more than one munitions company in order that men might be trained to use them for the special operation for which they were designed. The action of those companies, which presumably knew their business, indicated that there were circumstances under which it was worth while to appropriate, for a time, highly productive tools for the sole purpose of training, even in the present times of pressure. A time seemed to be rapidly approaching when, for the ordinary work of the shops, there would be a demand for only two types of workers—the highly-skilled tool-maker, tool-setter and precision worker, who was quite at home with $\frac{1}{10,000}$ inch, and the unskilled tool-minder, who could learn his job in an hour or two

in the shops, but was nevertheless all the better for some preliminary training in vice and lathe work. That time had not yet fully come even in munitions work, for in many, though not all, munitions shops there was a demand at the present day for plain turners, and tools could be used profitably in the hands of semi-skilled workers at low wages for work for which very different tools would be employed under normal conditions. Nevertheless, the most striking feature of the present labour market was the large number of men who, a few years ago, would have passed as skilled fitters and turners, who were now unable to obtain employment at ordinary trade wages.

When the war was over, it would be necessary to aim at securing in the schools a higher degree of accuracy than that which had hitherto been attained. At present it was rare to see a universal grinder, while universal milling machines were not plentiful in an engineering school; and where precision tools were to be found, they were vastly outnumbered by the ordinary lathes and shaping machines of thirty years ago, at any rate in London. That distribution of tools had introduced some difficulty into the problem of gauge-making in the colleges and polytechnics. In the majority of cases the roughing-out operations took far less time than the finishing, but the ordinary engineering school would boast a dozen tools suitable for the former against one adapted to the latter class of work. When a large number of gauges had to be made, each requiring a dozen operations, the tools, like the men, engaged in each operation must be proportioned in number to the time required for that operation if tools and men were to be kept fully employed.

The extent to which teaching could be advantageously combined with production in the engineering schools in the present time of stress had not been definitely determined. The distribution had settled itself for better or worse more or less permanently in London, and the institutions possessing well-equipped shops with, say, a couple of dozen machine-tools, had been used almost exclusively for production, and in some cases extra tools had been transferred from smaller institutions to those workshops where

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room existed. On the other hand, the lathes, drills and vices belonging to the manual training centres of the Elementary School system, which formed units too small for economic supervision, had been concentrated for the most part in two institutions which had been used almost exclusively for teaching purposes. In one of those institutions countershafts had been erected for all the treadle lathes brought from the centres. In the others a fast-and-loose pulley had been placed on the crank-shaft at the end remote from the fly-wheel, avoiding the necessity for separate countershafts, with the inconvenience only of introducing more moment of inertia into the system than might, *a priori*, be thought desirable.

The Authors had asked about the results of that teaching work. He was not at liberty to state precisely where and in what work the students had found employment. The great majority on joining the classes had had no experience of engineering work. They included professional men of many sorts, clerks and other commercial men, and skilled tradesmen belonging to the building and other trades. The course extended over six weeks, and included 144 hours of actual work. The jobs were a series of graded exercises of the type well known to manual training instructors, but towards the end of the course the better students might be entrusted with the carrying out of some useful work, such as the turning of test-pieces to gauge. Of 518 workers who had completed the course of instruction in one school, 357 had been placed in Government or in private munitions works. Many were employed on capstan and turret lathes, many more on plain turning, and one at least had gone as a gauge-maker for cylindrical gauges. It would be noted that in the school to which he had referred, the course of instruction extended over 144 hours. The Board of Education suggested a period not under 30 and not over 100 hours. In those provincial institutions in which the course had been reduced to 10 hours, no pretence had been made at a course of training. The 10 hours had served simply to introduce the pupil, if a novice, to the workshop atmosphere, aptly expressed by a former Professor of Engineering as "teaching him how to

pinch a spanner from the next man without being seen," and for the purpose of a test, enabling the school authorities to observe how the pupil shaped, and then to be in a position to recommend him to would-be employers as first, second, or third class. But even where the training extended to 100 hours or more, the most that could be done with the novice was to teach him to perform certain operations, in the hope that if he were young he might, when the war was over, study engineering. When he (Dr. Garnett) was asked some months ago what course he would recommend for these workers, he said that he would throw overboard all the principles he advocated before the war, as the business now must be production and not education.

The Authors had referred to the difficulty of suitably hardening the gauges in the workshops of technical institutions. He took up that subject some months ago, and recommended that all the gauges made in the polytechnics and technical institutes in London should be hardened in, say, two institutions where electric muffles should be maintained at a temperature of 750° C., or a little higher, and reduced to that temperature when the gauges had been sufficiently tested, and all the hardening should be carried out by workers devoting themselves exclusively to it when required. He found, however, that when he made this suggestion he was met with the reply that a gas blowpipe, a cherry red, and a practical operator were all that could be required.

Although repetition work loomed very largely in the manufacture of munitions, the speaker did not intend to imply that the time would ever come when there would be no room for the ordinary "fitter and turner" in many branches of engineering, especially in general engineering and repairs work. He was sufficiently old-fashioned in his ideas to think that a boy could learn very much of the nature of the materials on which he was working, by using hand-tools and a foot lathe for a few months. By these means he made friends with his material in a manner which was impossible when his cutting tool was fixed and his lathe was "power driven." But these were points for consideration in times of peace only.

Mr. H. G. TAYLOR said that the Paper opened out a very considerable range of inquiry, and afforded an ample ground for discussion. It was quite impossible in a Paper of this description to escape from the educational aspect of engineering. He was tempted to devote some time to that portion of the subject, but he quite recognized that at the present moment the members were assembled to discuss what were the best methods by which either the regular students of the colleges or the incoming students of the colleges could be taught to become useful in as short a time as possible. Since the beginning of last July he had been in charge of classes for the training of munitions workers, and during that time he had learned a great deal about human nature, because he had come into contact with people of so many different classes. Every imaginable profession and calling had come under his view, from parsons and gardeners to journalists and omnibus-drivers, and in most cases he had been able to turn them out successfully. So far, he knew as a fact that at least 90 per cent. of the men who had been trained had become satisfactorily established in munitions factories, and many of them were doing remarkably well.

There was one feature of the work, from an educational aspect, on which they particularly prided themselves. At the very outset of the training scheme they were approached on the question of the advisability of training tool-setters, and inquiries were made if it would be possible for them to do so. They possessed no up-to-date automatic machines, but only the ordinary lathes, milling machines, etc. At first it appeared impossible to do much in tool-setting at the College. On further consideration, however, he thought that something might be done in regard to the training of tool-setters. He approached a firm which particularly wanted such men, and requested that the men should be put through the course of exercises, and that the best of them should then be sent to the works in order that they might be practically tested. A recognized course, therefore, was established, consisting of about 140 hours' work. On the average, seven students were allotted to each instructor. The instructors were not merely college teachers, but were skilled men who had done the

work themselves. Every student had to do his share of hardening, tempering, drilling, tapping, machine-planing, slotting, milling, the usual screw-cutting on the lathe, V threads, left-hand square threads, and inside threads, and all that work was taught in four weeks.

Mr. LARARD asked if those men had had any previous works' training.

Mr. TAYLOR said they had not, in the great majority of cases, and in the case of those turned out as tool-setters, not one had served an apprenticeship. After the course, the men were sent down to the works he had mentioned, where they received, at the most, one month's training, and were found so satisfactory that a request was received by the College that more men should be sent. Of the output of the College, quite one-fifth had gone to that particular works, and they were all doing very well, not one having proved unsatisfactory. It was his good fortune on the previous Tuesday to visit those works, and, as the College had not any of the automatic machines on to which the men were put when they went to the works, he thought it would be advantageous if he could get some. The manager informed him that the men who had been sent down from the College were doing remarkably well, and that some of them had already arrived at such an advanced state that they were training the incoming probationary tool-setters. The men, therefore, had not only become skilled tool-setters themselves, but were super-skilled, and were able to teach learners. As examples of the type of men, it might be mentioned that the selection comprised, amongst others, a solicitor, journalist, house agent, art student, day school teacher, wounded (regular) soldier. He had a conversation with the manager with reference to supplying the College with automatic machines, and the manager told him that if it was feasible he would do so, but personally the manager thought the College could not do better than follow its present procedure of putting men through their ordinary course, teaching them their alphabet, so to speak, and when they

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were sent to the works, they would be taught to spell. After carefully thinking the matter over, he had come to the conclusion that that was the best thing to do, and that the College did not require any automatic machines. He did not at all admit the educational value of a capstan lathe, an automatic milling machine, or tools of that kind.

He thought engineers had become rather confused at the present time with reference to the meaning of the term "highly skilled." A man who could set up an Auto-Lincoln was not necessarily highly skilled; he was highly specialized. It was a fact that men, such as turners and fitters, had been taken from other departments and put under training as tool-setters, but in most instances this had proved a failure. The works preferred the men who came from the University, as these had been trained on a machine with one cutting tool. When they approached a machine cutting with six tools at once, they were not embarrassed, but accepted the fact. On the other hand, when men, known as skilled, were shown such a lathe, they looked at it and did not believe it; they simply refused to accept facts.

As regards mechanics who had left the trade a number of years ago, he had not found them of the type he could recommend as tool-setters. The College thought it was doing the best thing by putting the men to whom he had referred through their paces, giving them a strictly limited, but real, education—no specializing—until they had gone through all the preliminaries he had mentioned, and then putting them on to manufacture. He thought it would be of interest if he gave a rough sketch of the Course that was given, because it might be helpful to other people who had charge of munitions classes.

The following illustrates the Course:—

FIG. 1.—Flat gauge in wrought-iron, made correct to $\frac{1}{1000}$ inch.

FIG. 2.—Tool-steel gauges, introducing the idea of limit gauges. Hardened and tempered and afterwards finished to size.

FIG. 3.—Cast-iron girder embracing the following exercises:—

Slotting.—Three key-slots A B C; afterwards plain slotting the intervening portion to the line XY.

Shaping.—Portions D and E removed to the level of the line XY.

Vertical face F cleaned up.

Drilling and Tapping.—Six holes drilled in web in three sizes, clear and tapping. Three holes tapped out.

Hand-Screwing.—Three simple plugs chased with dies to fit the three tapped holes.

Planing.—The four edges G planed and made to size.

Milling.—The underface faced to the line H and afterwards slotted the whole length as K.

FIG. 2. LIMIT GAUGES

FIG. 3. SLOTTING, SHAPING, DRILLING, TAPPING.
PLANING AND MILLING

FIG. 4. V-THREADS.

FIG. 5. SQ. THREADS π AND λ .

FIG. 4.—Plain cylinder turned and screwed as shown. Whitworth V-threads.

FIG. 5.—Plain cylinder turned and screwed right and left hand square threads, 5 per inch. Students work out and set up the change-wheels in all cases.

In Fig. 3 a central hole L is bored in the lathe and afterwards screwed to fit the square thread of Fig. 5.

On the hand-shaping machine a simple cube is made. All the students are encouraged to forge and harden their own tools, and each receives special instruction on the use of the micrometer and vernier.

MR. A. WIGGLESWORTH said he had listened to the Paper with the greatest pleasure, because, as Dr. Walmsley had said, it opened a vast field for discussion, and he thought the discussion which had so far ensued was quite worthy of the high class of the Paper itself. As the most intimate subject in connexion with the war was the output of shells, he desired to confine his remarks to the training of men for that purpose. The criticism which had been brought before him in many of the factories, where trained students

(Mr. A. Wigglesworth.)

had been sent, was that the general knowledge which they had acquired in six weeks was of necessity somewhat superficial, and did not enable them to start in the factory with that knowledge of the work which they really ought to have, if they were to assist the management in obtaining a quicker and better output from those particular men. That being the case, he thought it remained to be considered how best to train the men for that particular work, because he thought every engineer present would admit that a general training in six weeks was entirely out of the question, and that the men could only do the simplest operations. If, then, the technical schools were to train those men to a single operation which was to correspond with the operation they would carry out in the factory, he believed the purpose of the Ministry of Munitions in issuing the circular which was referred to in the Paper would have been carried out. But if that were not done, the purpose would not have been carried out, because the men who had received training in all the various things which had been mentioned in the course of the discussion would be of very little more use in the factories than men who were taken right out of the labour market without any previous experience.

It had been brought to his notice also that the students, when they went to the factories, had the notion that they had acquired a considerable degree of skill. That was a very dangerous idea, because they were more difficult to teach than men who went openly with a blank mind saying that they knew nothing, and who started unprejudiced. As each manager and often each foreman had his own particular methods, those men were soon able to acquire the necessary knowledge and did not have to unlearn what they had previously learned. If the output of shells was to be the chief consideration in the training at the colleges, he strongly urged that the training should be confined as far as possible to a single operation. He was sorry to disagree with the last speaker in that respect. He suggested that the capstan-lathe should be introduced as much as possible, and that all idea of training by means of an engineering course should be abandoned for the time. It was a well-known fact that thousands of workers were required

for the factories, and if that particular class of training would fit the men to go into the factories and, with a minimum amount of scrap, turn out really good work which could be passed by the authorities at Woolwich, he thought the training would be successful. It was only four months and a half since the movement was started, and already quite a substantial number of students—about a thousand—had been trained, which gave an idea that the work had been satisfactory.

The only other point to which he wished to allude was that of the management. He thought he had never investigated any subject in connexion with which he had heard such a vast difference of opinion as to the capabilities of the students. He had heard them described, so far as the results they had turned out were concerned, as wonderful; on the other hand, he had heard them described as total failures. He thought it all depended upon the point of view of the management, and their ability to apply the particular training the men had received to the best advantage. It would, of course, be of great advantage if there was a closer correspondence between the managers of the different factories and the technical colleges. For instance, if a factory in a certain district knew it was going to receive men from a college, it would be of great value if the management were to meet occasionally to ascertain what class of workers was required, and, if possible, to train the men in that particular work. As an instance, he mentioned the case of an important provincial town which he thought was perhaps the best example of successful training for a specific purpose. A great deal of the credit for that good result was due to the manager of the Labour Exchange, who had a good practical knowledge of his business, and, being well in with the different factories, had called on the managers and found out what they really wanted. He did not think there was a single training centre where students had been drafted into the factories with less trouble. There had been no loafing about or waiting to get a place. The moment they were trained, and the manager knew they were suitable for the work, the men were sent straight to the different factories and started work the next day after they left the college.

Professor G. J. WELLS said there was one general remark he was tempted to make on the subject dealt with in the Paper, namely, the criticism of the conflict or the supposed conflict between "Professors" and the "Shop." The statement was made in the Paper: "Many practical engineers and some engineering professors have in the past looked with disfavour, almost with contempt, on the college workshop, and have doubted whether any serious work or instruction of real value can be given in it from a practical engineering point of view." He thought a large part of that difficulty was due to the various Committees, because, if the authorities required their teachers to have high academical qualifications, it was unreasonable to suppose such men also could have adequate workshop training. It seemed to him that if the authorities had in the first instance recognized the need of teaching actual engineering, the possibility of conflict between the two would have been avoided. An engineer only could teach engineering of real value. The remark was made in the Paper that the Authors thought the educational authorities should take charge of the proposed centralization. Personally, as the result of his experience during the present crisis, he thought that much time and money would have been saved, and an increased output obtained, if all such work in the future were taken sole charge of by engineers. There was no body of men better qualified for that purpose by their training than engineers, and he was sure that would be admitted by every member of the Institution who had had to do actual manufacturing work.

The work being carried on at the College with which he was connected had come before him in the following way. Early in the war the question was raised as to what that College could do. There were two possible courses open, first, to train munitions workers, and, secondly, to send the skilled workers they possessed to a suitable place where their special skill could be utilized. The Government decided that the latter course should be adopted, and as a result the College lost at an early stage the whole of its trained skilled workers. The next step in the process arose because it was thought that the College could do something more,

and, as the Paper suggested, they took up testing. As a result, a large number not only of physical but commercial tests were being carried out, and the electrical engineering, physical, and mathematical departments had been exceedingly busy in that direction. That part of the field was now fairly well covered.

Then the next question that arose was that, as the College possessed some of the antiquated tools to which reference had been made, which ought to be capable of being used, it was necessary to decide the sort of course which would be best fitted to utilize them advantageously. He was able to say that the line of work, first suggested some three or four months ago, had been proved to be quite correct, and it was gratifying to find that those who had taken part in the discussion were entirely in agreement with what was now being done. A course was started which consisted of a good many exercises and similar work, but it was at once obvious that what was required was not men that were "neither fish, flesh nor fowl, nor good red herring," but men who could do munitions work in the local shops. The College had got into contact with the local Committee of Munitions and ascertained from them the exact quality and kind of work that was going on in the district around them. Having discovered that, they tried to find the right material in the shape of men to carry out that work, and to a very large extent they had been successful, not only in placing the men they trained, but in having further demands made upon them for supplying additional men. Scarcely a day passed but an application was received for a turner or a man capable of doing some other kind of work, the request being accompanied by the statement that a man should be sent like one who had been supplied before. All that was exceedingly satisfactory, but it had only been achieved by throwing overboard all the educational routine of graduated exercises and the like, and trying to make the men fit to do the work on which they would be actually engaged.

One of the latest developments was in regard to shell-turning. The College discovered that a good many shells were being turned in the neighbourhood, and, owing to that fact, they were able to

(Professor G. J. Wells.)

obtain a supply of the ends of the bars of steel that were actually used in the shops. As everyone knew, in shell-making there was always some material over, too short to work up, and that spare material was now utilized in the College. It was first centred, then put into the lathe, and a $4\frac{1}{2}$ -inch shell prepared. The groove was turned and the base prepared for the end plates. An attempt was being made to do the "waving" in the grooving by means of a special tool. Then it was turned round and the nosing done; next, the inside was bored out, but they always made a point of boring the inside too small, because that allowed them to utilize the stuff that was over for two shells, and so enabled the men to repeat the process of turning and cutting the driving groove, etc., without waste of good material. He had also been able successfully to place several men for turning shell-punches.

He was originally of opinion that the jobs to which he had referred could not be done by the class of men turned out, with the short training they received, with a sufficient degree of accuracy, but he was bound to say that the proof of this had shown that he was wrong in his estimation of the amount of skill that could be imparted in so short a space of time. Lastly, they had trained men as far as they could in the limited time available for accurate work, and, to discover their amount of success, they make a definite test, which the Authors called a "precision test"—that is, to find the ability of the men to "feel," because, after all, that was what was really wanted. First, the man had to be trained to feel whether, when he was callipering, the article was $\frac{1}{1,000}$, or $\frac{2}{1,000}$, or $\frac{1}{10,000}$ tight. Secondly, he had to learn to feel the depth of cut of the tool, in order to give him some idea of whether the chip he was cutting off was the proper size. Most of the limit gauges that had been produced were very close; they were very nearly accurate, the usual fault being slight tapering. He would like to know from the Authors whether they knew the proportion of wasters in some of the other centres.

It was not easy to speak at present of the exact value of these trained men; several instances of real success had come to the knowledge of the speaker, but there were several cases where fair

treatment had not been given to the munitions trained man. One instance would illustrate this point. A man had been recommended as one who would, if some opportunity were given, do good work as a turner on straightforward work. At first when in the shop he experienced difficulty in getting work; eventually he had to make his own tools before starting at a lathe. He had also to make some dies for screw-cutting, and seemed generally set to do work such as demanded the skill of a tool-maker, instead of being set some job that such a man might reasonably be expected to do. Nearly all the disappointments met with would be, he believed, eventually traced to the "duty" that led the skilled worker to see that these raw hands were rejected as incompetent sooner or later. From the start the closest touch had been maintained between the College, the local Munitions Committee, and the Board of Trade Labour Exchange.

As regards organization, etc., every effort was made to show the men being trained what would be required of them when at work under commercial conditions, but as the Authors said, educational and commercial conditions could not be easily reconciled under the same roof, and so far, in the matter of "training" the men at the speaker's College, no pretence was made to do so under the commercial conditions that existed in a shop. In this matter no pretence was made as regards booking the time spent upon any piece of work, whilst the College staff had been so much reduced that no use could be made of the data until after the War, when its value would be very questionable, except for statistics. The Authors were to be congratulated upon having been able to find the time required to put this Paper together, whilst it appeared to be marvellous that they should also have been able to carry out a complete prime cost system.

Mr. C. E. LARARD, in reply, said he could add very little in the short time remaining for the discussion, but he would supplement his remarks in the joint Communication which the Authors would send in for publication in the Proceedings. The chief objects of the Authors in writing and presenting the Paper to the Institution were to enable a discussion to take place on matters of very vital importance,

(Mr. C. E. Larard.)

and at the same time to show what was being done and what could be done in the technical colleges to assist the country during the present national crisis. Those objects had been achieved, and if they were to spend a good deal of time in adding to the facts which were embodied in the Paper, he did not know that they could say very much more. The President had made one remark which must have struck all practical engineers as being exceedingly apt, when he called attention to the remarkable revelation which had been brought about by the utilization of unskilled and partly skilled labour in munitions factories, particularly in relation to women. He thought that must have been a revelation to all the members, particularly to old engineers who had gone through the usual process of serving an apprenticeship and picking up their skill and knowledge in the ordinary way.

He considered that the remarks made by Dr. Garnett, Mr. Armstrong, and Mr. Wigglesworth were exceedingly valuable, and the points they had brought out clearly deserved very special emphasis. Mr. Wigglesworth, for instance, made a remark to the effect that general training at the present time was entirely out of the question. He quite agreed with that statement. What was wanted in connexion with unskilled labour was, as Mr. Wigglesworth said, to train the worker to one simple operation, but in the technical colleges the students and other workers were able to do, and would be able to do in the future, more than one operation. Mr. Taylor had outlined a course of simple instructional work, but personally he very much doubted whether that instructional work could be of any real value in a munitions factory. No man with the short training referred to could possibly apply that sort of exercise work to munitions work of practical importance.

Mr. Armstrong had called attention to articles which could be manufactured by labour which initially was entirely unskilled, but which had been taught to be skilled in the particular operation in a very short time. That was common knowledge to the engineer. A boy fresh from school could be taken and put on a capstan-lathe, and in a fortnight to a month he could be earning 15s. a week at piece-work. He would probably be rated at 4s. to 5s. a week.

Reference had been made in the Paper to combined teaching and manufacturing, and he understood Dr. Garnett to remark that that could be done effectively; but personally he held a totally different opinion, having had experience in connexion with both. It had been shown that if a shop were organized for munitions work for one part of the day and then a body of unskilled men were, later in the day, allowed to use the same tools for instructional purposes, a good deal of upsetting of work was caused; lathe centres and tools were damaged, and it was necessary to spend hours the next day in putting the tools right and resetting the work before the munitions work could be gone on with. If the tools could be kept separate and distinct, one set being kept for the munitions workers and another for training the munitions workers, the scheme was more feasible, if the other difficulties could be overcome.

Dr. GARNETT said that he did not say in his remarks that teaching and manufacturing could be combined effectively.

Mr. LARARD regretted that he had misunderstood Dr. Garnett's remarks. Mr. Wigglesworth had referred to the various opinions which had been given by different individuals on the ability of engineering students or students in the works; some had thought they were wonderful, and others had thought they were total failures. Mr. Wigglesworth had further stated that the value of the training must be in its application and in the ability to know exactly how to utilize it. He fully agreed with Mr. Wigglesworth in that respect. In his own experience, engineering students with no previous works' training had in two or three months been able to finish gauges accurately to $\frac{1}{10,000}$ inch, but those students, as pointed out by the Authors, were comparatively few in number. They had to be selected students, but such students could be very quickly trained to gauge-making.

He thought Professor Wells had misunderstood one remark in the Paper. Professor Wells presumed that the Authors recommended that centralization schemes should be carried out and the engineering

(Mr. C. E. Larard.)

work conducted by the Educational Authorities. That was not exactly what the Authors meant. The Educational Authorities were the executive body with power to move tools, but the work would naturally be grouped and carried out by the trained engineers whom they might have available in their numerous technical schools. Reference was also made by Professor Wells to gauge-making, and the proportion of wasters likely to be obtained at the technical schools. Without going into detail, he would simply say that thousands of gauges had been turned out true to specification, and in one prominent institution the first rejections were not 5 in 100. The rejected gauges had been put right and finally approved, so that the final rejections were not nearly 1 per cent. He was informed that as late as the middle of last summer a very large proportion of gauges was being rejected even from engineering firms.

Communications.

Professor FREDERIC BACON wrote that the arrival of this thoughtful and suggestive Paper was most timely, and, taken in conjunction with the discussion it was intended to promote, would doubtless prove most fruitful and far-reaching in its results regarding the immediate and future relationship between technical colleges and the supply of munitions. When peace returned, the vexed question of the proper sphere of the college workshop would have to be looked into again, and from a new and little suspected standpoint, namely, from a point of view in which the War Office would be, or at least ought to be, just as immediately interested as the Board of Education or the Engineering Institution. He hoped that in due course all the engineering colleges of the country would be linked up in a national scheme, which would enable them to train and otherwise provide for a national industrial reserve, ready for immediate and automatic mobilization on the outbreak of another war.

Six months ago, when he had had to choose between undertaking munitions work or the training of munitions workers, he had selected the former, and although it was exceedingly doubtful whether the Authors would have placed his equipment in their "higher category," he had never regretted his decision. Naturally, many technical difficulties had had to be overcome; but these difficulties vanished in comparison with the difficulties which had arisen from local ignorance of the requirements of accurate machining processes, disbelief in scientific methods, and distrust—even amounting to bombastic contempt—for the idea that a teaching institution could possibly handle with success a practical problem beyond the limited range of experience typical of the district. In fact, had it not been for the existence of the National Physical Laboratory to vindicate his claims of accuracy, and another Central Authority ready to receive and act on suitable representations, all his endeavours would have proved unavailing. He was prepared, on the strength of his recent experience, to corroborate and even strengthen the Authors' assertion that many engineering students could very quickly pick up the special grinding and lapping operations necessary in the final stages of gauge-making.

When it was recalled that the chief engineering activities in his present district were in connexion with coal-mining and ship repair, it would be easily understood that trade mechanics possessing "the necessary temperamental faculty of perceiving by touch and gauge very small differences of dimensions" had been simply impossible to secure, and after failing dismally in a few attempts to convert the ordinary "foot-rule man" into the highly specialized tool or gauge maker, he had ended by relying entirely on a judicious selection of his own students to supplement the efforts of the permanent staff. It was really surprising to find, in this high precision work, how superior intelligence and a little scientific training overpowered years of shop experience of a not quite suitable kind; a middle-aged professional instrument-maker proved a complete failure in working close to absolute dimensions, whereas a scholarship lad who had won his way to college from the smithy and the forge was shaping well on precision work. If required,

(Professor Frederic Bacon.)

this young man, after only two or three weeks at his new job, could knock out a horse-shoe gauge blank on the anvil and then proceed to rough file, harden, grind and finally lap the jaws until the final result was correct to size within one or two ten-thousandths.

At the outset of Section 1 (v) (page 728) the Authors insisted upon the fact that only full-time work was of value. While in entire agreement with their statement of the case, he would like to point out that a short course of voluntary part-time munitions work supplied an excellent means of selecting suitable men for subsequent engagement as full-time workers. Before his senior classes had been entirely suspended, a voluntary part-time scheme had been in operation for a short while. Naturally, nothing of material value had been directly accomplished thereby; but indirectly the scheme had proved a great boon in indicating which were the right students to convert into full-time munitions workers.

An important matter touched on by the Authors was the conditions on which machine-tools, etc., had been lent or exchanged between technical colleges and Munitions Committees, etc. In certain cases machine-tools had been rashly handed over without any very definite stipulation, and it was to be hoped that regulations, or at least guiding principles, would be framed such as would secure fair and uniform treatment all over the country before the final day of settlement arrived.

In regard to the training of munitions workers for the actual machining of shell bodies, it was important to remember that there were other places where such training could be given even better than in the average college workshop and without disturbing the regular shell factories. He referred to repair shops attached to electric power stations, pumping stations, gasworks and the like. Such repair shops were often well equipped with suitably heavy lathes, drilling machines, etc., under the supervision of an engineer of high standing in his profession, and ready manned with a nucleus crew of expert hands thoroughly acquainted with the capabilities of the shop in question. Mr. Arthur Ellis (page 780) had shown him what wonderfully successful results could be achieved in this direction, and had also opened his eyes regarding the immense

possibilities of profitably employing the voluntary part time services of professional, non-technical men when properly organized and directed. He, the present writer, thought the Authors of the Paper had spoken too disparagingly of the work of amateurs. He could think of several—and there must be a considerable number like them—whose skill in fine metal work, such as model making, was of the very highest order, and skill of this kind could be much more readily utilized for munitions work than that of the average non-specialized engineer, say, such an engineer as was suited for taking charge of a small power-plant. There were many long-established engineering works of the rough-and-ready variety which had experienced the utmost difficulty in working up to the requisite accuracy, while small and obscure shops owned and controlled by a man of the right type had attained immediate success in meeting the most stringent requirements.

In conclusion, he would like to acknowledge his debt of gratitude to many members of the Institution, including one of the Authors, for giving him the free run of their works and the benefit of their expert knowledge. Had it not been for their unstinted help and encouragement, it would never have been possible for him to achieve his present measure of success in converting his laboratory repair shop into a shop dealing in considerable volume with munitions work, demanding almost the highest degree of accuracy possible to secure.

Sir ROBERT BLAIR (Education Officer, London County Council) wrote that there were many things of importance and interest in the making of munitions which could not at the present time be discussed in public. The Authors, in exercising a natural restraint on themselves, had therefore deprived their Paper of much that would have been very interesting. Further, the Authors had had experience of the manufacture of munitions in certain directions, but not of the training of munitions workers, and on both these heads it might be said that, so far, engineering colleges were yet on probation, though they were gradually asserting their position. The full story could not be told now, and more experience was necessary before any definite conclusions could be generally enunciated.

(Sir Robert Blair.)

The important matter which had been before the Metropolitan Munitions Committee and the London County Council had been the effective utilization of the resources in staff and machinery of the various technical institutions. To effect this, a specialization of functions had been imperative, and the predominant factor in the success of the work, so far as it had gone, had not been so much machinery and equipment as staff. Over 1,800 workers had been enrolled in munitions training classes, and about 1,100 had received certificates for proficiency for their work during a six weeks' course comprising 144 hours' instruction. Persons so trained were now distributed over about 120 different factories, in some of which only a few were employed, but in others as many as 50 and 100. The reports which have been received from individual firms showed, on the whole, that these semi-skilled workers had been found of very great service.

Sir A. TREVOR DAWSON (Member of Council) wrote, in response to the President, that the Authors, it would seem, generally based their observations on the conditions prevailing in the Metropolis, which, it would be recognized, differed materially from those obtaining in centres where engineering was the dominant or most important industry. From the metropolitan point of view their observations were interesting. The extent and character of the work that a technical college or workshop could do towards augmenting the output of munitions was dependent on the equipment as well as the staff. As this equipment was of a very varied character, necessarily for educational purposes, "repeat" work would be done under conditions not conducive to efficiency either as regards the time taken or the cost. No doubt in the making of gauges and other articles, where great numbers were not required, and where highly skilled and precision work was essential, the instructors, and perhaps advanced students, with their fine appliances, could perform useful service.

The great need for the moment, however, was the maximum output per man per hour, and per machine per hour. Each had to be utilized on the work he or it was best fitted to accomplish, and

had to be operated to the fullest extent possible. It was his experience that, to achieve these ends, munitions work should be done in large factories. The highly skilled men who were now instructors in technical colleges could influence, to a far greater extent, munitions productions in factories where larger bodies of workers were under their control than in colleges now with limited equipment, particularly if they were utilized there for the training of non-skilled workers at particular machines assigned by the foreman to each new-comer. The students could do more work alongside commercial workers than at college; the atmosphere was more encouraging. The lathes could be better disposed if set among their respective classes in factories, and more fully utilized as units of a complete sequence. In colleges the amount of work done would not be commensurate with the extent and value of the supervision given, or the cost involved in the equipment. He (Sir Trevor) suggested this absorption rather than isolated action, the more readily as the Authors stated (page 729) "it is one of the sacrifices demanded by the stringency of the present crisis that at least some of the educational work, and from the conditions that of the higher type, has to be set aside for the present so that the personnel, both students and instructors, as well as the material equipment, may be freed for national service." Where he differed from the Authors was that he thought personnel and equipment should be merged into the great factories making tens of thousands of shells per week, rather than be retained in college workshops producing hundreds.

Again, as to training men and women for factory work, his opinion was that this was much better done in the workshop, and at the very machine whereat the man or woman was ultimately to carry out his or her part in the making of a shell than in the college workshop. College machines, installed for purely instructional purposes, were necessarily so varied that the man or woman trained to work one or more of them might ultimately be called upon to operate a different one in the factory. Furthermore, the example of the expert alongside, and the obvious stimulus of the wage earned by others in a factory, increased the eagerness of the learner

(Sir A. Trevor Dawson.)

to become expert. But, as he had already said, the college instructors, and perhaps also the advanced pupils, would be most serviceable in training the unskilled workers in the shops—a work for which their qualifications rendered them specially suitable.

Mr. ARTHUR ELLIS wrote that he considered the Paper was one of a most interesting character, and he could speak from experience in this respect in consequence of having had such valuable assistance from the local University College, and in particular the head of the engineering department, who had for some time past taken a keen interest in the manufacture of gauges necessary for shell-making by utilizing their equipment, aided by his permanent staff and a number of trained students. Had it not been for these gauges, the work of shell-making which was being carried on at the writer's works would not have reached the present advanced stage of development.

The members might be interested to have a few details relating to the work of shell-making that had been undertaken in the little workshop attached to the Power Station. Some time ago the writer and a number of personal friends, comprising professional gentlemen, volunteered their services during the week-ends, free of cost, in any factory within 100 miles of the city, to assist in the manufacture of munitions, and to relieve the regular workers during the week-ends. Whilst this offer brought forth an expression of appreciation, it was not taken advantage of. Subsequently the writer made a proposal to the local Munitions Committee, to assist them to some extent by manufacturing shells in his own workshops, and so help forward the output in the particular district. This offer was accepted and much appreciated, and was working remarkably well, but the writer felt it was due to the professional gentlemen who had given, and were still giving, so many hours of their spare time, that such services as those rendered by them should receive the recognition that was due to them.

Shell-making was only carried on during the spare hours and week-ends, as during the ordinary hours of the day, namely, from 6 a.m. to 5 p.m., and until 1 p.m. on Saturdays, the usual work

connected with the operation of the Power Station had to be carried on, and in consequence of which the machine-tools were fully occupied; but upon completion of the day's work, and after a short interval to clean the tools, etc., shell-making started, the volunteers commencing duty at 6 p.m., working in two shifts of six hours each until six the following morning, throughout the week, with three shifts on the Saturdays and Sundays, so keeping the machine-tools occupied during the whole of the spare hours of the week. The volunteers were drawn from professional gentlemen, none of whom had previously had any mechanical training, and comprised solicitors, architects, accountants, shipowners, coalowners, etc. The experience that the writer had so far obtained had convinced him that the unskilled individual was more useful and more accurate in shell-making than the skilled operator usually found in workshops, except in those shops where very special work was carried on; and even in those cases, with modern automatic machines, and particularly so, the individual who worked during his spare hours (for the love of it only) realized the important character of the work upon which he was engaged, the importance of avoiding mistakes, and he always had present in his mind the fact that in some instances he was working to a thousandth part of an inch, or less, with the result that he exercised extreme care, in addition to which such people were able to appreciate the importance of this fine work.

It naturally took some little time to train the volunteers, but it was remarkable the speed with which they seemed to grasp the handling of the tools, etc., and to-day they had seventeen different shifts working throughout the week. He thought that there was not an individual on any shift who was not able to go straight to his machine and carry on his work in a satisfactory manner under the supervision that was provided from members of the writer's staff, who were likewise keenly interested in the work, and devoting a great deal of very valuable time to the same. The number of tools available was of course limited, but they were hoping to receive other necessary additional tools, which would enable the existing output to be doubled or even trebled. The

(Mr. Arthur Ellis.)

regularity with which the volunteers turned up for their work was remarkable, and not one of the machines was idle for a single hour. Each volunteer worked two duties per week, of six hours each. He gave his time absolutely gratuitously, whilst the writer's department furnished the use of its machines, tools, equipment, light, heating, and everything else free of cost, the only cost borne by the local Munitions Committee being that of the steel bars. The work was carried on in a regular manner; each volunteer had a time sheet, upon which he booked up the output during any one duty. The time sheets were signed by the volunteer who was looked upon as the leading man in charge of the turn, under, of course, the supervisors, who were provided from the writer's assistants; and a careful record was made, not only of the number of hours worked by each volunteer, but of the actual work that he had performed. This was done for the purpose of supplying to each of these gentlemen at the end of the War a complete return of his contribution—in time and output—towards the manufacture of munitions.

MR. THOMAS T. HEATON wrote that he understood the Authors recommended the employment of the staffs of the Technical Colleges for the training of persons who might proceed therefrom into factories engaged in munitions work. The persons whom it was proposed to train were those with no knowledge of the kind necessary, seeing that trained or semi-trained people were not available.

The discussion dealt with the method of the training in question; some speakers approved of a sort of general training and others thought differently. Having had to deal with this kind of thing in the organization of the works where he was engaged, he (Mr. Heaton) thought that his own experience might perhaps be useful to other members. He was under the impression that the work under discussion was "repetition work"—that is to say, work consisting of large numbers of similar articles. This was the only kind of work to which rapid training could apply, as adequate general training took too long under existing circumstances. He had dealt with this kind of work by employing persons without any

previous experience at all connected with the work to be done, and therefore with no preconceived ideas. Each person was set to one class of work only and kept at it, with one end in view, namely, to do his one job over and over again and produce an accurate result. This ensured the proper beginning of the next operation in the sequence and the starting of the next man's job on an economic basis. With proper instruction and supervision, he had found this plan to work admirably.

It would follow that if a college were to undertake the training of persons as suggested, the principle adopted should, in the writer's opinion, be to specialize in the operation the said person respectively would be required to perform. The advantages of this system were obvious, as all sorts of persons could be made into skilled workers, each in his or her own sphere. To make the system practicable, agreement was necessary between works managers in need of men and the college staffs, so that the need might be first specified and then supplied. The colleges would need the apparatus for training.

He could not understand why the fact of women having proved such good munitions workers should cause wonder. If the work were not too heavy, women were quite as capable as men and often much more so than the hybrid workman of to-day, whose mind was often divided between football and his rights, but never occupied itself with his duties.

Professor H. H. JEFFCOTT wrote that for some time past they had been working day and night at his College on the manufacture of fuze parts and they were making arrangements for considerable developments. In the first place, capstans and special chucks were made for several ordinary lathes, thus converting them into semi-automatics. They had also made practically all their jigs and tools: taps, dies, hobs, cutters, box tools and form tools of many kinds. In addition to the manufacture of munitions, they were also engaged in the training of munitions workers.

Engineer Rear-Admiral EDWIN LITTLE wrote that inspection, on behalf of the Ministry of Munitions, of the work in progress in

(Eng. Rear-Admiral E. Little.)

engineering workshops of the Technical Institutions, which were co-ordinated under the London County Council, had formed, till quite recently, a part of the service he had been endeavouring to contribute to the National cause. The special acquaintance with the work of these institutions thus afforded him might warrant a few observations, if only by way of testimony to the excellent results obtained.

The workshops were mostly small and the plants of machine-tools were arranged rather for instruction than for output or reproduction. The tools were mostly light machines and served to illustrate the principal operations involved in ordinary manufacture. In very few cases were there any automatic or semi-automatic tools available. Except at the Imperial College, none of the shops could be regarded as adequately equipped even for good technical instruction in modern workshop practice. Generally speaking, the machines suffered from the repeated first attempts by the beginners during successive courses of instruction, and, without considerable refitting, could not be relied upon for any really accurate work. The instructional staffs included several highly skilled men of the type usually selected to be employed as tool-setters, first-class gauge and jig makers, charge men, and shop foremen or managers in large and important works. The principals of the institutions were actuated, as would be expected, by a high standard of technical achievement, and a well-trained conception of the underlying principles and methods by which alone close accuracy of form and dimensions could be realized in practice. With a very uncertain and doubtful supply of labour, and notwithstanding inadequate appliances, the resourcefulness and good organization in the division of the work, and in adapting the appliances available, they have accomplished much really good work, and have maintained the standard of accuracy and the fine limits mentioned in the Paper. The gauges made included ring, plug, and screw gauges, some position gauges of a difficult and intricate kind, and a large number of plate gauges needed for the examination of fuzes and shells. The ten or eleven institutions employed have produced over 4,000 of such gauges, which have been subjected to very

unsparing and rigid examination by the National Physical Laboratory.

Side by side with this work, the usual engineering courses of instruction have had to be maintained. In one institution the writer was desirous of discussing the design of a special jig for simplifying the manufacture of an intricate fuze, and found the designer fully occupied in lecturing at a blackboard to a class of students in applied mechanics involving a long calculation. In some of the shops, in order to keep the younger students occupied, it has been found necessary to take sub-contracts for details of gun mountings, transport lorries, air-craft parts, and other details of a simple kind, and this interchangeable work has been very successfully organized and carried out.

It was in the training of partly skilled workers that the institutions have done most excellent service. Having taken in past years a considerable part in the workshop-training of partly skilled mechanical ratings in the Navy, he (Admiral Little) was well able to appreciate the really amazing results achieved by a most cleverly graduated step-by-step course of some six weeks' duration at one of the colleges, and he was glad to have an opportunity of congratulating the London County Council upon possessing such able and discerning instructors upon their staffs. To the large amount of technical training for war work, other than for engineering, done by the institutions, it was not necessary here to refer. About 1,500 willing munitions workers have passed through three of the institutions, and nearly 1,200 have been granted certificates of usefulness. About 80 per cent. of these were, he understood, actually employed in munitions works, not as fully-trained mechanics, but with clear notions of accurate measurement, a workshop sense of touch—a sufficient knowledge of tools and material to be safely and satisfactorily employed, after a few days' practice, upon some one or more of the operations involved in shell manufacture.

However, he did not consider this was a function that, after the war ended, these institutions should be again engaged upon. He hoped such hastily-devised means of production might never again be relied upon, should the Country be again engaged in so stupendous

(Eng. Rear-Admiral E. Little.)

a struggle. The need of preparation and timely organization of all the engineering trades for national defence would surely have been too deeply impressed upon them, nor did it appear desirable that these small workshops should be equipped for manufacture or production, and that much more valuable service could be given by the very fine staff of practical and highly intelligent instructors, by taking part in the management and direction of national workshops fully equipped with up-to-date tools, and where the output of components was counted in several thousands rather than a few hundred per week.

Mr. DAVID A. SHERET wrote that, in his opinion, to fulfil the object of their purposes colleges should be educational, and not in the rearguard to the extent of sixteen months. Had technical colleges proved their capacity, no one would deny that prominent engineering firms would have appreciated their work in practical training, but this had not been so, and one must appreciate the management's decision in this matter when they said that the advantages of such training were negligible. To suggest that they could train men to be gauge-makers to any degree of exactness, when engineering firms with large numbers of employees found the class fitted for such work extremely scarce, failed to meet with the commercial engineers' approval; and that if they sought to have efficient teachers in this line it would deplete important works of the best men, due to the general terms given when public moneys were to be used.

Centralization, to be worthy of recognition, would only be useful in such an abnormal condition as the present, and would entail expenditure out of proportion to the benefits resulting therefrom. To establish costing arrangements, etc., was too Arcadian to be practical, and would also prove financially wasteful. It would be more effective if the colleges carried out more laboratory investigation work, for instance, on crude-oil internal-combustion engines. Mechanics could produce such machines economically and commercially, allowing that they had the necessary plant. To train an engineer, he should not learn to use automatic machinery; in fact, a hand-lathe would be preferable to a capstan—there he was required to use his head equally with his hands.

No one would be foolish enough to suggest that munitions were being produced economically at present; the costs went up by leaps and bounds, and it would be well if the Government looked to the stock of munitions in times of peace rather than rushed to projects which the highest and best authorities feared for an instant to deal with. When controllers of shipping, finance, and coal production were first installed, and only when the common voice of those who knew prevailed, did the engineer find his services sought.

Professor W. H. WATKINSON wrote that the object of this Paper was, in the main, admirable, and it would have been much more useful if it had been written and discussed six months ago. Rapidity of output of munitions of war and of all things necessary for their production was, at the present time, of the most vital importance. The maximum rate of progress could not be attained if machine-tools were not employed continuously day and night. Another condition for maximum rate of production was that the machine-tools and men should be concentrated in factories of considerable size, as, otherwise, too much time was expended in distributing the raw material, in inspecting and testing the products, and in collecting the finished products. These conditions could not, in general, be attained in a school or college workshop, and he thought that the Ministry of Munitions ought, without delay, to take over and concentrate in factories, all suitable machine-tools and all skilled men, whether teachers or students. Even in the manufacture of gauges there was great dissipation of energy when these were manufactured either in college workshops or in small private factories. The best results would be attained if all the gauges required in the country were manufactured in two or three factories at the most.

In June of this year it was decided that the best way in which the machine-tools in the University with which the writer was connected could be utilized was in the manufacture of shells in a local factory, and the tools were immediately lent for this purpose. Shortly afterwards they were asked to undertake the manufacture of gauges, also to start classes in the elements of turning for persons

(Professor W. H. Watkinson.)

desirous of working in shell, fuze, and other munitions factories. To enable them to do both of these things, they appealed to amateurs and others for the loan of lathes, and they soon succeeded in obtaining a sufficient number of machine-tools quite suitable for the above purposes, although they were not sufficiently powerful for use in a shell factory. They were also fortunate in being able to enlist the services of a considerable number of skilled men, including about a dozen instructors from manual training schools in the city. Nearly every one on the writer's staff, and many of the above men, sacrificed their summer holidays, and during the long vacation they succeeded in constructing over 1,500 gauges for shells and in giving instruction in lathe work to nearly three hundred men and women. These were absorbed into munitions factories as rapidly as they were trained. A considerable number had, of course, to be rejected during their training owing to their lack of adaptability.

The AUTHORS, in replying to the written Communications and in further reply to the Discussion, would deal as far as possible seriatim with some of the more salient points raised, realizing that space would not allow them to refer in detail to all the valuable suggestions and criticisms advanced by speakers and correspondents.

Mr. Armstrong's samples of work, executed in the factory with very little training by previously unskilled workmen and lads, were good examples of what could be accomplished by intensive training on single operations with or without the aid of jigs, and his suggestion that it was less necessary for the technical institutions to lay themselves out for such training was aptly enforced by the statement that "about 100 workers had been trained in the L.C.C. schools, but unfortunately they had to be specially trained for the modern machines."

In this connexion Mr. Wigglesworth's remarks on page 766 were valuable as coming from one who had had good opportunities of collecting expert opinion of the value of the workers produced by courses of so-called general training, and who also had a good

knowledge of the "purposes of the Ministry of Munitions in issuing the circular which was referred to in the Paper." As Dr. Garnett remarked, the "business now must be production and not education."

With reference to the same point, Sir Trevor Dawson in his written communication (page 779) stated that the training of munitions workers "was much better done in the workshop, and at the very machine whereat the man or woman was ultimately to carry out his or her part," and Mr. T. Heaton emphasized the point (page 783) that each person should be "set to one class of work only and kept at it, with one end in view," namely, to specialize in one operation.

These and the other statements made showed, and the Authors concurred, that training to be of immediate value in the munitions factory should be confined to the single operation on the type of work and tool upon which the worker would be employed. It might also be stated, and with a good deal of truth, that for this purpose general instruction courses at technical colleges had another value. They enabled the authorities to select workers likely to be useful as munitions workers in the factories; but in this respect there was a danger that the cost of general instruction courses which were being given to would-be workers would throw a very severe charge on the already heavy cost of munitions. When it was kept in view that a schoolboy fresh from school, or any intelligent person, could be placed directly in a munitions factory, and could acquire in a few hours the necessary ability to carry out a simple operation controlled by jig work or through the mechanism of a capstan lathe, it would be realized that a good deal of waste in material, skilled staff, tool facilities, etc., was involved in carrying out elaborate and graduated courses of instruction which could not possibly be utilized, and which could not possibly give to the worker the degree of accuracy required in the processes dealt with.

The remarks of Mr. H. G. Taylor (page 762) had been so completely answered by the speakers whose comments have been alluded to above, that the Authors felt it was not incumbent upon

(The Authors.)

them to analyse his contribution further, and they were therefore content to place on record a general dissent from most of his arguments and conclusions, and their disapproval of his course for training munitions workers.

With reference to Dr. Garnett's remarks (page 757) on the workman of the future, the Authors agreed that although the tendency was distinctly towards specialization, there would in ordinary times always be room for the type of worker trained concurrently in non-specialized works and works not capable of being specialized, and their observations on page 741 should be noted in this connexion.

The Authors were entirely in agreement with Dr. Garnett in his views (page 757) as to the desirability of installing modern capstan lathes in first-class college workshops, and while they thought it could be shown that there was a proper place in the college workshop for some of the highest specialized tools, yet they further agreed that the older tools and workshop methods should receive a first and very prominent place. In this connexion it might be remarked that the question of the relation of college workshop equipment and training to certain aspects of the training of mechanical engineers had not yet been properly understood by the Education Authorities or even by many engineering teachers.

Dr. Garnett's recommendation on the hardening of gauges (page 761) was a practical one which would have saved much trouble and much material had it been adopted, and the Authors had found the notes which he sent to them in the early days of munitions manufacture to be of practical value.

Dr. Garnett's statement, that in the majority of cases roughing-out operations took far less time than the finishing, needed a little qualification, for the relative time taken depended upon the nature of the work to be done. For example, in gauge work the grinding-out operations on a universal machine could often be done very much more quickly than the roughing out of the gauges preparatory to grinding; but as stated by Dr. Garnett, the ordinary engineering schools could boast of a dozen tools suitable for roughing as against one for the more accurate work, and it was in this respect that the

roughed-out gauges accumulated more rapidly than finished ones. The remedy in such cases was to secure a higher proportion of work which could be finished by the ordinary machine operations, including work which could be carried out on capstan lathes or repetition machines, so as to keep the less-skilled workers fully employed whilst the relatively few highly-skilled men were finishing the gauges.

Professor Wells's remarks (page 768) expressed a caution of which very careful note should be made. Education Authorities undertaking the manufacture of munitions should throw the whole responsibility and direction on their skilled engineering staff, as unless this were done serious mistakes would be made, and the cost of the munitions work would be altogether out of proportion to the value of the work done.

Dealing next with the written Communications, the Authors were in agreement with Professor Bacon's statement, but they regarded the matter from another point of view than the one he mentioned (page 774), that "when peace returned the vexed question of the proper sphere of the college workshop would have to be looked into again." They desired to add that the old ideas which had hitherto largely prevailed as to the proper function of the college workshop could no longer suffice. The Authors were in agreement with those ideas so far as they went, but they did not go far enough, and excluded special considerations of vital importance in connexion with mechanical engineering. The Authors were interested to learn that Professor Bacon had achieved so much in the face of considerable difficulties and prejudices.

The few statistics given by Sir Robert Blair (page 778) and Admiral Little (page 785), as well as those given by Dr. Garnett, on the training of munitions workers by the London County Council, were interesting. The Authors stated on page 720 that "on the outbreak of war it was inevitable that the work of the technical colleges in relation to it should be put on its trial," and they noted that Sir Robert Blair was in agreement with them when he stated in relation to manufacture and the training of munitions workers "that, so far, engineering colleges were yet

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on probation, though they were gradually asserting their position."

Sir Robert Blair also stated that the Authors "had had experience of the manufacture of munitions in certain directions but not of the training of munitions workers." The Authors regretted that, for military reasons, it was impossible to give details of manufacturing work or other expert work done by them or carried out under their direction. Had they been able to do so, much support would have been given to certain statements made by them in the Paper. The last part of Sir Robert Blair's statement, that the Authors had had no experience in the training of munitions workers, was incorrect, as was shown in many parts of the Paper, and also inasmuch as workers had been trained by them in the direct manufacture of munitions. The Authors were of opinion that short graduated instruction courses were not the kind of work which would be of value in the munitions factories, and their views on this point had received ample confirmation by the various speakers and correspondents.

The Authors were pleased to note that Sir A. Trevor Dawson was in agreement with them when he stated that, "in the making of gauges and other articles where great numbers were not required," instructors and students could perform useful service. It was just in this respect that the best of the college workshops were doing such good work, and the Authors strongly held the opinion that work more effective and more valuable to the country could be done in such college workshops by keeping their plant, staff, and students together as a manufacturing concern than by distributing the personnel and equipment amongst a number of factories. These remarks applied, however, only to a few of the college workshops, as mentioned in the Paper. On page 723 the Authors, as an example of what might be done by the Education Authorities in a large area, said "it would be quite possible to obtain an output of 200 to 600 shell-bodies per week." Sir A. Trevor Dawson (page 779) stated his opinion that "he thought personnel and equipment should be merged into the great factories making tens of thousands of shells per week, rather than be retained in college workshops

producing hundreds." To this the Authors replied that it was not quite fair to compare the output of a single unit with that of a number of factories taken together. Moreover, many munitions firms making shell-bodies did not exceed the small output stated. Since, however, the above was written they were of opinion that still more suitable manufacturing work, as outlined in the Paper could be undertaken by the college workshops.

Mr. Arthur Ellis's contribution was of much interest as showing what could be done under difficult conditions, but under expert direction, by professional men without previous training, working from purely patriotic motives. Mr. Ellis's system, whereby each worker would have supplied to him at the end of the war a statement of the value of "his contribution—in time and output—towards the manufacture of munitions," was a stimulating one, and was perhaps about the only suitable return which could be made to these men working with such high motives.

The communication of Engineer Rear-Admiral Little bore testimony to the valuable work which the college workshops had done and to his appreciation of that work. The Authors were not fully in agreement with the Admiral's statement (page 784) that "Except at the Imperial College, none of the shops could be regarded as adequately equipped even for good technical instruction in modern workshop practice." They agreed that, without a single exception, the equipment was in certain directions inadequate, but they could prove from actual results that in these workshops good technical instruction could be and had been given in modern workshop practice, and that, moreover, certain intensive training over short periods of time, given to apprentices, learners, improvers, and to engineering students generally, was far wider and even more thorough than could be obtained in anything like the same time spent in the works of most engineering firms.

The Authors agreed with the opinion of Mr. D. A. Sheret (page 786) that "colleges should be educational," as he was evidently referring to college work under ordinary peace conditions. They could not, however, accept, as he implied, that the colleges were "in the rearguard to the extent of sixteen months." They did not

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know of any prominent college to which this could apply. Nor did the Authors agree with the unqualified and sweeping statement made by him that in any large or preponderating number of cases the management of prominent engineering firms had arrived at the decision that the advantages of college workshop training were negligible, nor with the further remark "that to suggest that they could train men to be gauge-makers to any degree of exactness . . . failed to meet with the commercial engineers' approval." The facts given in the Paper, the Discussion and the written Communications showed these statements to be fallacious. It might further be pointed out that the manufacture of some 5,000 gauges by the London college workshops, setting free something like sixty commercial engineering factories for the manufacture of the munitions for which these gauges were required, must and did meet with the manufacturers' approval at the present time of national crisis. The college workshops had been successful in gauge work where many commercial engineering firms had failed. The best colleges did not, as implied by Mr. D. A. Sheret, seek to obtain efficient teachers in gauge-making from important works; they already had teachers possessing these and other qualifications on their permanent teaching staff, and these men, who were capable teachers in other directions, were now working as gauge-makers and also giving instruction to less-skilled men and boys in the college shops.

Mr. D. A. Sheret stated that "to establish costing arrangements, etc., was too Arcadian to be practical and would prove financially wasteful." He would be interested to learn that "Arcadia" had been realized, and that not only was the scheme outlined by the Authors in use in at least one institution, but that all colleges had some system of arriving at the cost of the work done. Mr. Sheret referred to laboratory investigations, and here the Authors were in full sympathy with his remarks. That more investigation in the laboratories was not done was due to the neglect of successive Governments, and, it must be added, of Education Authorities, in not appreciating the importance of scientific research and scientific technological training, and providing the necessary funds to be administered under real expert advice.

Professor W. H. Watkinson's remark, that the Paper "would have been much more useful if it had been written and discussed six months ago," overlooked the fact that, at the period referred to, the experience and facts utilized in the Paper had not accumulated. At that time much which has now been ascertained would have been matter of conjecture only. Professor Watkinson's own experience appeared to have been unfortunate and due to a lack of prevision at about the period named as to what would be required in the immediate future, and the Authors sympathized with him in the difficulties subsequently encountered in consequence, and congratulated him on the methods adopted to meet these difficulties. His staff, of course, was not the only one which sacrificed its summer holidays to the pressing necessities of national service.

In consequence of certain criticisms which had reached them, the Authors thought it necessary to guard against a misunderstanding which had arisen, as to their views of the relationship of the college workshop to a properly co-ordinated course of study in Engineering. The Paper was on "Engineering Colleges and the War," and in it they had therefore dealt primarily with the college workshops in relation to the War—an emergency relationship which had never previously occurred in the history of any country, and which, it was to be hoped, might never occur again. To avoid any such misunderstanding, they stated here that it was not the proper function of any engineering college to attempt to teach a trade or to attempt to give what might be called full instruction in modern workshop practice to students attending full-time engineering day courses. The college workshop in relation to day students had different functions altogether, and played a smaller though important part in connexion with their general educational work.

For evening students, however, the case was quite different, and much had been done in giving sound workshop instruction to men desiring to supplement a narrow, inefficient, and specialized practical training so as to make them better workmen. There were other important functions of the technical college workshop for both day and evening students, which could not be dealt with here without a digression quite outside the limits of the Paper.

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In conclusion, the Authors desired to express their cordial thanks to the speakers and writers who had stated their opinions and given the results of much practical experience in dealing with workmen of different types in relation to the manufacture of munitions, either in commercial works or in the college workshops, and also of the value of the work done by the Engineering Colleges in relation to the War. The Paper, discussion, and correspondence, would undoubtedly be of much value to Government Departments and to the Education Authorities in helping towards the end that all had in view. The Authors ventured to hope, therefore, that their main object in writing the Paper had to some extent been attained.