War Time Problems, Planning, and Performance

(Discussion introduced by A. G. Ramsey, O.B.E., B.Sc. (Eng.), M.I.Mech.E., at the Informal Meeting in London on 10th July 1942)

An Informal Meeting was held at the Institution, London, on Friday, 10th July 1942, at 5.30 p.m.; ASA BINNS, Wh.Ex., M.I.Mech.E. (*Past-President*) in the Chair. The subject of "War-Time Problems, Planning, and Performance" was introduced by A. G. Ramsey, O.B.E., B.Sc. (Eng.), M.I.Mech.E., and thirteen speakers took part in the discussion. The attendance was 167 members and 16 visitors. The meeting ended at 8 p.m. A summarized account of the discussion is given below.

Introduction. In opening the discussion, an endeavour was made to review the subject from the viewpoints of the purchaser, the designer, and the manufacturer. From the outset, it was emphasized that, generally, the achievement of maximum efficiency and speed in war-time eclipsed all other demands; but those aims should nevertheless be considered along with the proper utilization of man-power in the widest sense. Man-power was not confined to skilled and unskilled labour, but included everyone associated with the work

from its inception to its satisfactory completion in accordance with a well thought-out programme in which all had definite functions in the solution of war time problems. There must be clearer direction generally, and a greater sense of urgency and responsibility on the part of all concerned; mere acknowledgement of inter-relationship when difficulties arose was totally inadequate, and intensive co-operation—or even coalition —throughout was essential.

There would be cases (e.g. installations and operations subject to explosive regulations) where grave risks to personnel must not be taken, but where speed and perhaps maximum efficiency must to a certain extent, give way to safety; and in these a sense of balance must be developed and applied.

The Problems. In addition to the consideration of new implements of war, engineers were not only confronted with problems arising from the short supply of materials and the reduction in man-power, but also with the necessity to utilize labour to the best advantage, to simplify products, to achieve the maximum speed in production, and to ensure easy maintenance.

Substitution of materials in short supply presented real difficulties, as substitutes might themselves become unobtainable at a later date. In selecting substitute materials special processes might be involved. Less satisfactory products might result, but in war time they might have to be accepted, even if the useful life of such products might be limited. The substitution of new alloy steels for those having certain constitutents now unobtainable had been very vigorously tackled. To get these alternative steels adopted had presented some difficulty, but the problem was now well in hand and the so-called "EN" steels, for instance, would much reduce the number of specifications which had been worked to hitherto. Before that campaign started, one works alone was working to well over 2,000 specifications of steels, which had now been reduced to 85 categories.

Simplification of products meant much more than the omission of special finishes and refinements. It involved the lowering of the grades of materials, the use of the minimum amount of these materials, the minimum number and simplification of operations in manufacture, the minimum use of expensive jigs and special tools, the maximum use of semi-skilled and unskilled labour, and minimum manufacturing and selling costs. In many cases it might mean the fewest possible number of sub-contractors for components which involved transport to manufacturers' works. On the other hand, cheap and quickly made designs might be more easily obtained from a larger number of sub-contractors, especially if the components were of a standardized character adapted for rapid assembly at a central works.

Nearly all production could be much simplified in the drawing office. That was particularly so in the case of such complicated things as gun mountings and mechanisms. During the lean years, designs were produced which, while excellent in themselves, were, in many cases, quite unsuitable for mass-production. Here again, good progress was being made; but the opinion was expressed that still more could be done.

To meet prevailing shortages, designs should be developed on a wartime basis as opposed to mere modification of pre-war designs; improvization should only be resorted to in cases of extreme urgency. What was required was the establishment of a technique controlled by clear thinking in terms of war economy, in contrast to improvization which was usually traceable either to frustration or to lack of thought at the outset. Orthodox engineering should yield to a more original outlook.

It was suggested that a liaison office, run in close accord with the drawing office, and supplying up-to-date information would be particularly helpful in assisting the designer to produce ideal and economical designs. Too often it happened that testing departments and drawing offices worked in watertight compartments, which resulted in the loss of valuable information and the repetition of old mistakes. The reaction of maintenance problems on design must also be carefully studied.

Mention was made of an interesting kind of liaison office existing in Germany before the war. The duties of that office were the combing of all periodicals and scientific papers issued in all countries, for ideas and improvements; the examination of the patent specifications of all countries for new methods and forms of construction; the collection of test and operational reports, and the submission of all constructive results acquired from the investigation to the designing department. In these times all companies could with advantage establish a similar form of liaison office.

Purchasers and consultants should fully appreciate their responsibilities in directing the activities of manufacturers, so that the best use of available material and labour can be made. They must ask themselves the questions:—

- Must I have all the essentials demanded in pre-war days?
- What can I eliminate?
- Can I cut down the number of types of products?
- Can I accept products with a limited life?
- Am I using material in short supply or products difficult of manufacture in war time?
- What is the least I can accept in every one of my demands?
- Have I given sufficient thought to my problem from the points of view of manufacture, installation and operation, and easy maintenance?

Determined endeavours should be made by purchasers and consultants to give the maximum of initial thought and consideration to their problems and to avoid alterations during the execution of the work, as even minor amendments might seriously disorganize performance.

The mechanical designer must also deliberate upon the following questions:—

- What materials are, or are likely to be, in short supply?
- What can I substitute for those materials?
- What materials are controlled?
- Can I reduce the number of components?

What unessential features and refinements can I eliminate?

Need I have such high factors of safety, and is the minimum factor of safety used consistently everywhere in the components of a product?

Have I eliminated to the fullest extent the use of special jigs and tools?

Does my simpler design necessitate a higher grade of skilled worker?

Can my simpler design still further be modified to reduce time in manufacture and give further speed in production?

Honest and careful consideration of these queries would almost invariably lead to drastic modifications in design, resulting in real contributions to the war effort.

With regard to the simplification of design, it was suggested that much might be learned from a study of German methods. The German piston, for instance, was much simpler to construct than the British piston, and the number of man-hours involved was ridiculously low, compared with those spent on piston machining in this country. From time to time certain firms encountered difficulties for want of additional labour, but in many cases it was found that if they made more use of pressings and forgings the work could be done much more simply. It was a mystery why even large firms sometimes machined certain parts entirely out of the solid.

Another speaker suggested that the Germans had not only standardized pistons, but even the cylinder sizes for internal combustion engines. Standard dimensions were fixed, to apply throughout a complete range of engine sizes, extra cylinders being added when the power output was required to be greater. That practice simplified the problem of spare parts enormously. Moreover, when a modification was introduced, it operated throughout the complete range of engines. Against this it was stated, however, that at least one firm of engine builders in this country was making a range of Diesel engines with from one to eight cylinders of standard pattern.

It should, however, be borne in mind that the divine spark of genius was not a German monopoly. The Germans did, nevertheless, secure by virtue of their painstaking plodding work on ideas and inventions, many processes and devices which in this country would have been dismissed as unworkable by some high non-technical civil servant, but which the Germans themselves would bring to fruition after patient research and investigations. Some of this country's temporary setbacks might indeed be traced directly to lack of scientific guidance and co-operation in the highest quarters, and to the failure to make use of scientific consultants who could enforce their decisions by virtue of their professional authority in the face of the well-meaning but entirely unscientific opposition of various civil servants. It was pointed out that industries were in general controlled by officials; scientists and engineers-in-charge were subordinate to civil servants, and there was no supreme scientific and technical authority to advise the Government and chiefs of staff on questions relating to planning and co-ordination of the country's production. It was said that often, when questions of planning were discussed, engineers were not even consulted. Few Government Departments would be so bold as to overrule directly any decision of, say, the Army Medical Council, yet it often happened that various official bodies headed by people with no scientific training whatever were able to overrule the decisions of technical experts.

It was pointed out that the drawing office staff should constantly bear in mind that important saving in time was often to be secured by careful arrangement of the order in which the various components were assembled. Similarly, the drilling and assembly of bolts and studs should be so arranged as to necessitate the minimum number of changes of drills and taps. Time could also be saved by providing a liberal clearance in the bolt holes. Wherever possible black bolts should be used instead of bright bolts, but it had to be remembered that they needed extra clearance, especially in constructional work. Regarding the erection programme, whilst the machine time could be fairly accurately estimated, any estimation of the time needed for erection was pure guesswork. Moreover, erection occupied valuable floor space. It was therefore imperative to reduce hand work of all kinds by stipulating suitable machining limits. The lazy expression on drawings "to be marked off in position" was to be avoided. Accessibility should especially be aimed at. Remembering that any particular assembly might some day need to be dismantled away from the erecting shops, the designer should carry out that process in his imagination. Tolerances should also be the coarsest permissible. This matter was the subject of a great lack of discretion and knowledge. It was not generally appreciated how much more time was needed where limits of 0·001 inch were demanded, instead of 0·002 inch; and how very much more work was entailed if the limits were as fine as 0·0005 inch.

The real remedy for all the production difficulties covered in the preceding paragraph lay, it was suggested, in the appointment (in every drawing office large enough to justify it) of a separate section dealing only with detailed drawings, and in charge of an experienced manufacturing engineer who would, of course, work in close consultation with the designing draughtsman. Such a man would have an eye on possibilities of machine moulding, diecasting, and even the specifications of correct material, e.g. the suggestion that manganese steel might be just as suitable as nickel steel and more easily obtained. In many ways such a man could wield a potent influence on the ultimate cost of his firm's products.

Final designs must reflect a prejudgement of the types and quantity of labour needed for installation, final operation, and easy maintenance. Automatic and foolproof devices were often complicated but *might* be justified by the control they effected over haphazard handling by semi-skilled workers; they might be the means of employing a lower grade of labour, thus releasing skilled and semi-skilled workers for a higher class of work.

Members were reminded that the design of a standard article, whether an oil engine, electric motor, refrig-

erating machine, or any other equipment, was probably the result of many years' experience, during which time, for ordinary commercial reasons, the designer had continually striven towards simplification, with a view to reduction in cost of manufacture and hence an extension of his market, whether in this country or abroad. If an attempt was made to simplify the design of standard plant of that kind in order to meet war-time conditions, it might tend to hamper rather than to accelerate production, apart from introducing elements of improvization with its uncertainties. That, of course, did not apply to new or special war-time products, amongst which there had recently been some striking examples, where necessity had resulted in drastic economies in the use of materials and the cost of manufacture.

The comment was made that the discussion dealt mainly with projects rather than with the manufacturing processes involved in producing specific articles. An immense range of articles was required for the war effort, mostly in vast quantities, and the design of any article might at any time be subjected to urgent modifications, due to weaknesses discovered in use, or to altered technical requirements. It was more important for a manufacturing plant to be able to respond quickly to alterations in design rather than to make maximum output the overriding consideration. Few firms engaged on mass-production were so organized as to cope with inevitable changes as a matter of routine. Such changes involved skill and experience, not only in the drawing office but also in the planning and progress departments. Ingenuity in altering tools instead of making new ones could play a considerable part in the success of such modifications.

As examples of extremes in the range of manufacturing problems the production of small arms cartridges was contrasted with that of aero-engines. The former followed a fixed design and were required in millions per week; in such manufactures, it was an advantage to have well-standardized plant and to give consideration to the best layout of the building to enable the route of the cartridges from the disk to the finished case to be a minimum. The aero-engine, however, once approved for manufacture, was liable to a succession of modifications, usually in an attempt to obtain increased output without affecting its reliability. Alterations, some of a major nature, might therefore be required at any time. With this in mind, it was important in aero-engine works to avoid as far as possible the use of highly specialized single-purpose tools, which, though they would give a maximum output for a certain design (if that design were stabilized) might be quite incapable of functioning if alterations were introduced.

The creation of new standard designs in war time was not to be encouraged. War time standardization should be confined to the reduction of the number of types. In a certain industry at the moment one firm made 186 types of one particular article. As another example, the numerous designs of filters for A.R.P. plants, especially the large variety requested by the Office of Works and by the Ministry of Home Security would seem to call urgently for simplification. It was, however, pointed out that certain difficulties in design had arisen, which were beyond the control of those Departments. There were also real difficulties in regard to patent designs, but they must be overcome in the interests of winning the war.

Manufacturers, although confronted with a variety of extremely difficult problems, must be prepared to make many sacrifices to which they would not agree in peace time; and very many of them had already given a lead in that direction. They must be prepared to co-operate with other manufacturers having activities in the same field, to pool ideas without restriction, and to forget the strong trade rivalry of pre-war times. If the war was to be won quickly, preconceived ideas and consideration of future markets for post-war trade must both be relegated further to the background.

Regarding proprietary articles, etc., manufacturers should realize that the loss of trade secrets would prove less disturbing than the loss of the war. It was obviously right to attach a high degree of importance to the interchangeability of components, but apparently no organized attempt had been made to secure interchangeability of ideas. Segregation of disease was a necessity, but the segregation of ideas was a disease requiring an heroic cure. Monopolies stemmed the flow of war production, and a regulated leakage of information through well-designed channels was needed. Some method was urgently required by which the introduction of a measure making for increased efficiency in one works could be followed by all makers of similar components.

Manufacturers should also restrain the unjustifiable confidence and optimism of their sales representatives in accepting orders, and should replace such peculiarities by honest acknowledgement of ability to undertake work within a specified period after full consideration of all the difficulties.

Thus it would be seen that the *simplest* products must be accepted by purchasers, consultants, and designers of installations; and manufacturers must be asked to confine themselves to those types which can most easily, quickly, and cheaply be produced. The most intensive initial co-operation of all concerned with any problem was imperative, and should be coupled with advice from manufacturers and mechanical designers; the result of this co-ordination should be a reduction in the demand for wide ranges of high-grade and costly products involving lengthy manufacturing processes. The drive for maximum efficiency and speed should aim at the reduction of handling processes and manual labour, and at utilizing all available plant to capacity.

For mechanical installations the adoption of war emergency specifications and codes of practice would provide users, consultants, and designers of installations with a guide to the class of work which would ensure the minimum use of material and labour consistent with a standard of workmanship sufficient for war purposes.

Lack of standardization had led to deplorable setbacks. There were large stocks of non-standard materials and equipment in the country which had been compiled to the requirements of each separate Ministry of the War Department, who insisted on having even the most trivial items made to their exact requirements. It was ludicrous, but unfortunately true, that such details as door handles, width of door openings, size of windows,

types of valves, and gauges of piping had to be specially adhered to for each separate Ministry. One trouble arising from such a state of affairs was the fact that many of the War Departments and Ministries did not employ skilled technical advice. Work was given to firms with little or no previous experience of the problems involved. This was perhaps more apparent in the placing of contracts, where pre-war out-of-date restrictions were imposed on manufacturers and contractors by the Treasury.

To remedy that state of affairs, it was suggested that brief but clear specifications should be compiled, with standard conditions. Government Departments should discuss their requirements with a comprehensive engineering body and then leave it to centralized technical staffs to deal with the whole of the business of getting the work done. Provided that such a course would give the results required by the Government Departments, an enormous amount of labour and time would be saved.

The standardization of valves for various purposes, e.g. water installations, was an example of a case in which such economies could be made. The view was expressed that the root of the trouble in water installations lay in the fact that each of the various water supply authorities wanted a special design to be used only by their own undertaking.

In connexion with general problems, however, it was suggested that the Council of the Institution might consider setting up a strong Committee to study the deficiencies of the national engineering effort. That committee might usefully deal with the unification of the organizations required in manufacture from raw material to finished product, the relation of the inspectorate to the design department, substitutes for materials in short supply, and war emergency codes of practice and specifications. Moreover, such a committee would be of the greatest help in studying problems of peace time enterprize after the war, as well as the present war time problems.

The Planning. Maximum efficiency and speed could only be obtained by a programme in which the work was distributed so that both man-power and plant were used to the fullest extent, in order that a proper sequence and timing of all operations could be secured. Whilst it might be comparatively easy to forecast the requirements on a theoretical basis, quite a different task arose in formulating a programme flexible enough to meet the unexpected and changing conditions encountered in practice.

Success in the production by mechanical engineers of various articles for the war effort was in many cases inextricably bound up with the building industry. Certain criticisms were therefore put forward with regard to the present state of industry, and suggestions were made for its rationalization. It was contended that there were far too many separate units in the building industry, and the average number of employees in each unit was extremely low. Reorganization, therefore, might well be carried out both on a local and a regional basis. In addition, greater attention should be given to the influence of representative bodies of management in this industry. Associated with that problem was the means for recruitment to the industry, the training and education of new apprentices, and the institution of educational schemes for up-grading men who might ultimately fill the managerial positions in the industry. Personnel management, which was rapidly becoming one of the most important factors in the industry, was virtually unknown before the present war. The Ministry of Labour and National Service had managed to secure a considerable degree of progress in imparting a new outlook to those responsible for the management of the building industry. It was suggested that a "Building Management Association" dedicated to the improvement in management technique could serve an important purpose both now and in the future.

The position of the architect in the industry was also discussed. It was stressed that the training of the architect should in future cover a much wider range. In a modern factory, for example, a knowledge of the various services—electricity, steam, compressed air, gas, ventilation, lighting, cranes, transport, canteen, and ambulance room—called for expert treatment by specialized groups of designers. Whilst the architect would not have expert knowledge in all these branches, he should be able to understand the principles of group co-operation, and should function as the leader of a team of designers whose planning must begin right at the start of a project, and indeed, before the detailed design of the building was prepared.

The first stages of planning production for a given rate of output, or of planning a service embracing manufacture and installation to be completed in a specific period, demanded consideration jointly by executives representing the purchaser, the management, the installation contractor, and any associated industrial concern. They should decide the work to be executed in the main manufacturer's works, the work to be sub-contracted, the subdivision of erection or installation (if involved), etc., leaving detailed breakdown into specific operations to specialists. It frequently happened that too much was attempted at high level without the specialized knowledge necessary to make correct decisions.

A suggestion was made that before manufacture began a "Planning Committee" should be formed, consisting of the leaders of the various sectional groups—engineering, buying, planning, manufacturing—who would as a team be responsible for implementing the master plan, and for ensuring that the products were turned out according to schedule. Time charts should therefore be prepared and issued to every section of the organization right at the beginning of the work.

The detailed or second stage of planning by the specialists should record in graphical form all the required operations by the manufacturer, sub-contractors, installation contractors, transport, different categories and numbers of workers, etc., in relationship to each other and to time. The resulting picture should disclose at a glance most of the difficulties and bottlenecks. These might be: time taken to obtain materials, insufficient capacity of certain sub-contractors to produce components to time, lack of certain classes of skilled and semi-skilled labour, lack of programme indicating

"batch" instead of uniform utilization of labour, only intermittent use of expensive and important machines and tools, too much time spent in handling materials and components, insufficient handling tackle, or insufficient transport. The picture might also indicate the need for arranging for the overlapping of processes in order to reduce total manufacturing times. The solution of those difficulties demanded skill and patience, with close co-operation and a sense of urgency and responsability on the part of all concerned; but a satisfactory programme could nevertheless be planned even if a large number of revisions were needed.

The final picture must indicate, even to a non-technical man, the scheme for the execution of the work, and particulars of the labour involved, on a time basis; it should also provide means for making quick decisions at various levels, for making adaptations to meet interruptions or changes in manufacturing conditions, for ensuring a distribution of work in accurate adjustment to capacity, and for dealing with the effects of necessary changes in design after manufacture had been commenced.

It had to be remembered that before the war each works represented a balanced community with a specialized equipment. Each of the various trades involved contributed smoothly to the production of the finished article. Then all those works were suddenly called upon to apply their special equipment to the production of war commodities. They lost experienced workers and had to train relatively large numbers of men and women brought up to quite different activities. The orders often covered raw material in the course of its development, with modifications as manufacturing difficulties arose and operating experience in the war theatres was gained. The old balance of production was upset and there was no longer a smooth flow of work in the various departments, some sections of the works being overloaded and others under-employed. Nevertheless, taking all those facts into account, it was submitted that the production from general engineering establishments under war conditions was highly satisfactory.

Apart from increased output due to improvements in design, the only way to increase further the production from such establishments was to find additional work for those sections not fully occupied. It would appear to be desirable to establish national clearing centres, operating under Regional Boards, to which Government Departments and contractors could make known their wants and which would supply manufacturers with work suitable for bringing all sections of their works up to maximum output.

The importance of specialization should be realized and the placing of contracts should aim at giving each manufacturer or contractor those types of product or operations best suited to him. Such a policy should result in the most efficient use of available machines and should ensure the lowest man-hours for any job.

One speaker made out a strong case for the decentralization of stores as far as possible, not only from the point of view of safety, but because in the dispersal units of the firms, there would be a greater keenness to do the work, arising from a healthy competition between the various dispersal units. A greater efficiency could thus be secured than was obtainable in one factory. The method also enabled the assistance of many of the smaller firms to be enlisted. An attempt had even been made to take the work right back to the people's homes. In Germany, it was believed, the manufacture of many aircraft components was so far decentralized that the work was done in the homes of the workers themselves. Against this it was, however, argued that a certain degree of centralization was essential for the manufacture of a particular product. One man should be in charge of the manufacture of, say, a particular type of gun, and he should be responsible for everything—the design, the production of spares, and modifications. He should also be in a position to review the capacity of his staff. Very unfortunate results had arisen from too much departmentalization, one man being responsible for one component and another man for another.

On services of major importance a co-ordinator might be needed; he need not necessarily be an engineer, but should be primarily an organizer. He should also act as the liaison between the purchaser and the management of the firm concerned. In addition, each sub-contractor should appoint someone to perform similar functions within his organization.

It was alleged that there was an extreme lack of collaboration between the various war services and the Ministries; and again, that the various Ministries were undoubtedly at variance, in spite of statements made by Ministers to the contrary. Moreover, there was said to be a further lack of co-operation between the various Departments in the Ministries themselves, as well as serious overlapping of Departments which constituted a grave waste of time giving rise to lengthy delays.

As against this, however, it was contended that Government Departments did endeavour to work together, for very soon after the present war was declared, an Inter-Departmental Co-ordinating Committee consisting of engineers from each of the Government services was established, with a view to simplifying the materials and the units and apparatus required. That Committee had done very good work. If engineers working on a particular apparatus would co-operate a little more amongst themselves, it would be very helpful to the Government Departments.

The War Office had received many setbacks due to questions of priority. Such difficulties were sometimes due to lack of co-ordination on the part of the various trades involved. There were many ways in which help could be given to Government Departments if the different trades would get together. Certain industries had, however, already set a good example in that direction. On the mechanical side, for example, trade organization analogous to the B.E.A.M.A. were in a position to do very good work.

There were undoubtedly large stocks of materials in the country which had never been carefully checked by any representative body, consequently the materials from such stocks were very frequently misused, as there was no co-ordination between the requirements of the Army, the Navy, and the Royal Air Force and the various ministries. In many instances stocks held on behalf of

these various departments were locked up, whereas they should be centralized, and schedules submitted to all interested parties. If that were done, it would obviate the pernicious results of "requisition by priority". Where general stocks were available to be drawn from all authorized Departments, the decision for the allocation of the materials was usually left to comparatively minor officials in the Ministries who had little or no technical knowledge, instead of being dealt with by a properly qualified staff. Chaotic conditions had often resulted from conflicting instructions with regard to the restriction of the use of various metals. An instance was cited in which a firm was forbidden to use steel in a building; only copper was allowed. On completion of the whole of the copper work, another Government Department arranged for a steel water pipe to run through the building!

Performance. Efficient performance involved the proper supply of materials, the distribution of labour, the flow of processes and the clearing of the channels for the progress of production. Every stage from the procuring of the materials to the delivery of each of the many components or products at the precise times when they were required in the programme, must be anticipated.

The co-ordinator must not rely on spasmodic or even periodical reports from the various sub-contractors on the progress of their work; a much closer control and day-to-day knowledge were required. His staff should watch the progress of materials to ensure their arrival at the right time at the manufacturer's and the individual sub-contractor's works, and on site if installation work was involved.

The progressing of materials involved the breaking-down of components into items from the final manufacturing stage, through the principal sub-contractors, the second and third lines of sub-contractors, to the firms who supplied materials. Orders should be placed as early as possible, and any difficulties which might be anticipated in the provision of materials and labour should be settled with the appropriate Government Departments. It was essential that the manufacture of components should be watched to ensure that the programme was being followed to avoid delays and the formation of bottle-necks. Such progress should be recorded periodically so that the position could be seen at a glance. It was convenient to use one of the visible card index systems having a set of linked cards for each component, indicating the state of progress at the manufacturer's and sub-contractor's works concerned. The progress of erection and site work required, in addition, close supervision to ensure adherence to the programme.

The *general* results of those observations should be indicated on the original programme chart, to provide a comparison between actual and planned progress, and to enable action to be taken to smooth out difficulties. Similarly, the numbers and classes of workers could be related to the figures originally forecast.

The co-ordinator should be able to foresee difficulties likely to arise in the supply of specialist labour, transport, handling of materials and components, storage, plant for erection, etc., and should not wait until the necessity for taking action arose. If the co-ordinator had performed his work satisfactorily, unforeseen events could readily be valued in relation to their immediate and future reactions on the programme which, in consequence, might require modification.

Regarding transport, the suggestion was made that rail transport should be arranged for all war services, whilst road transport should be reserved wherever possible for distribution of equipment from manufacturers' works to the site of the works to be built. Another point closely affecting transport was the method of packing. All bulky material which was not very fragile could be loaded in trucks or lorries; but where a considerable quantity of small and delicate material was required, large quantities of timber for packing could be saved by using railway containers and pantechnicons. That method also ensured the arrival of the whole bulk of small items on the site together. By means of pantechnicons also, various small consignments could be cleared from the various works in the course of the one journey and delivered as a whole to the site.

A suggestion was made that there should be an expansion of the system of Works Production Committees, that they should be made compulsory, and that their proceedings should be correlated. Works Production Committees, comprehensively constituted, should meet on the site weekly, fortnightly, or monthly, according to size and circumstances, and the meetings should be attended by a Government representative, who might be a resident or visiting member of an inspection directorate or of a production department. It would be the duty of that official to report to a "Production Boosting Bureau" all ideas, whether in connexion with production or personnel, which had been put forward at the meetings and tested and adopted by the firm. Such ideas would be described in brief on the lines followed when application was made for a provisional patent, and at the "boosting bureau" they would be classified, grouped, and issued in the form of a monthly bulletin to all Government contractors. The first item on the agenda of every Works Production Committee meeting would be the reading of the relevant pages of the bulletin; and when any item was thought to be of interest to the firm, application would be made to the Bureau for full particulars, which would be obtained from the originator in the form of a complete specification and issued to the inquirer, copies being retained by the Bureau for issue elsewhere if called for. The ideas would be regarded as inventions, and their value would be assessed by the Bureau and payment on account would be made at once the final value being assessed and payment made at the conclusion of the war. It was suggested that, in addition, "Certificates of Merit" should be issued to the individuals concerned, on the lines of the document given to combatants when they were mentioned in dispatches.

It was emphasized that the management in any works engaged on Government contracts could secure a marked improvement in production by careful attention to numerous small items, which, whilst their individual influence on the programme might be small, would nevertheless have a remarkable cumulative effect. Sys-

tems of production sometimes tended to become too rigid, blocking the flow of work, e.g. an operator might be found waiting at some machine until the appointed labourer brought the work to be done. Work should be planned not only for departments and sections, but also for individual machines and men. In this connexion the recording of the standing time of individual machines and its causes might be an uncomfortable revelation to many works managers. Many delays in production could be avoided by ensuring that all operations (drawings, jigs, gauges, and material) were absolutely complete beforehand. Similarly, in regard to stores, the works manager should ask himself whether the things most frequently wanted (oil, paraffin, waste, wipers, nuts, and bolts, etc.) were kept near the counter for prompt service.

Supervision and inspection were now both difficult owing to the calling-up of skilled men. It had been impossible to increase the number of foremen to the extent to which it was desirable, particularly in view of the upgrading of unskilled and semi-skilled labour.

The opinion was expressed that inspection was still unnecessarily complicated. There were too many inspectorates representing different departments, all with large staffs. Some steps had been taken to reduce those staffs but there was still room for considerable improvement. Government Departments were very difficult to move in that respect.

Inspection and testing should be conducted at the factory where the parts were made, so that faults might be remedied immediately. Inspectors and operatives should work together, and not against each other, and operatives should be encouraged to take an interest in output and in the causes of rejections as well as in the programme and performance generally.

Records of output should receive close attention and be given prominence, and the weekly returns of outputs and rejections should be correlated. Such records might show that rejections attributed to bad workmanship might be the result of difficult working consequent upon incorrect design, which might then be rectified.

Not all manufacturers realized that Government inspectors were not supposed to carry out inspection in detail; their business was to prevent a firm from producing faulty manufactures. The firm's inspectors were responsible for the inspection of the article, and they should not submit faulty work to a Government inspector. Moreover, the firm's inspectors should be directly under the manager and not under the works manager, and the former should take as much responsibility for production as the latter.

The criticism that Government inspectors were inclined to over-inspect might be waived until the following questions amongst others were answered:—

(1) Would less inspection cause the defective percentage to go up? It often did, and with a balanced output that was very serious.
(2) What was the effect in service of a defect which had escaped inspection?
(3) Was the expenditure of skilled labour in making jigs, so as to enable unskilled labour to carry out inspection, an economical process in any particular case?

Conditions now demanded a type of inspector conversant with all the implications of his decision to reject. The inspector for repetition work should be guided on the extent to which he should insist on precision and he should never regard himself as a detached critic.

A plea was put forward for the establishment of a Sub-standard Stores Clearance Board, to take components or material which failed to comply with the specification issued to the makers. That would prevent rejected stores from lying about a works. At present it was often the case that the contractor or sub-contractor did not know how to dispose of such material to the best advantage, or even how to get rid of it at all. In each Ministry of Supply area a park store and salvage workshop should be set up, to deal with all rejects from prime contractors or sub-contractors. Such rejects would not necessarily be taken into the park; in many cases instructions could be issued for the direct transference of stores from one firm to another. In other cases rejects could be sent into the nearest sub-standard store. The value would be fixed by the Clearance Board according to subsequent disposal and payment made in due course. The sub-standard store in each area would submit stock lists to the Clearance Board. All Government Departments—Admiralty, War Office, Ministry of Supply, and Ministry of Aircraft Production—could be covered.

Regarding the personal factor in the relations between management and workers, it was generally agreed that promotion from the ranks had a better effect than the appointment of new staff from outside.

A word of praise in the right quarter at the right time could be a great stimulant to the workers who, it must be remembered, were not robots, but human beings who were all contributing to a final result. Special attention should be given to those matters which tended to irritate even the best operatives—late fixing of rates for piece work, improper maintenance of plant, delays in setting up tools, faulty flow of materials and components, and other interruptions in production which tended to cause discontent and absenteeism.

The statement, made by the opener of the discussion, as to the demoralizing effect in the shops which could result from the inability of purchasers sometimes to take delivery of completed plant which had been rushed through the various stages of manufacture at the highest speed, was borne out during the discussion.

One pleasing feature of present-day conditions was the remarkable performance achieved by female labour. Many women were now employed in steel works on jobs for which, two years ago, they would have been thought quite unsuitable.

Works managers would scarcely need to be reminded that the saving of coal was of prime importance at the present time. Numbers of Lancashire, Cornish, dry-back, and vertical boilers were hand-fired, many of them burning bituminous coal which gave off a considerable amount of smoke. Most of those boilers came under the jurisdiction of a smoke nuisance authority, and the problem of stopping excess smoke was solved by leaving the furnace firedoors partially open for a couple of minutes—in the case of careful firemen; but in most cases they were left open all the time. Excess air

in such cases might be as high as 6–12 lb. per pound of fuel consumed. That excess air was heated from about 60 deg. F. to a final stack temperature of 400–800 deg. F., with the result that each pound of excess air carried away about 810–1,620 B.Th.U. per pound of coal burnt.

It was suggested that the Fuel Controller should issue an order suspending for the duration of the war any penalties for the emission of black smoke, and should give instructions that in all hand-fired boilers the furnace doors must be kept closed except when dealing with the fires. Further, the amount of coal fired at any one time should be allowed to exceed that required for 15 minutes steaming, except after cleaning the fires.

Experience had shown that a saving of at least 4 per cent could always be effected by closing the firedoors and burning coal, regardless of the emission of smoke, as compared with the plant where the firedoors were left more or less continuously open. The greatest savings would undoubtedly be made on boiler plants belonging to public bodies where the smoke regulations were rigidly enforced, irrespective of the amount of fuel consumed.

A Lancashire boiler burnt about 1,000 tons of coal a year (assuming a 55-hour week) so a saving of 4 per cent represented 40 tons per annum per boiler. To verify that claim, and at the same time to satisfy the Controller of Fuel and the various authorities whose first aim was to stop smoke, it was suggested that the Fuel Research Station at Greenwich should be asked to conduct, say, three tests, each of 10 hours duration, burning the same bituminous coal and generating the same amount of steam on all tests, under the following successive conditions:—

(*a*) Leaving the firedoors partially open only long enough to stop smoke.
(*b*) Leaving the firedoors partially open all the time between periods of firing, as actually happens in many cases.
(*c*) Keeping the firedoors closed.

Conclusion. The foregoing general picture of war-time problems, planning, and performance, is painted from the viewpoint of a user and designer of installations covering a wide field of products and applications in mechanical engineering, but in a broad sense it should also depict the case of the manufacturer and the installation contractor as the principles must apply in varying degree to all classes of work undertaken by engineers. To achieve success it is evident that still more co-operation is necessary. Difficulties are bound to arise and perfection is not to be expected, and undoubtedly there is always room for improvement. Examination of our problems, frank interchange of ideas and discussion will at least help to secure greater efficiency and speed in the war effort.