W. F. DRYSDALE

The Engineering Institute of Canada

Incorporated 1887
as
The Canadian Society of Civil Engineers

THE MANUFACTURE OF MUNITIONS IN CANADA

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H. H. VAUGHAN, M.E.I.C.

PRESIDENTIAL ADDRESS

ANNUAL MEETING, OTTAWA, FEB. 10TH, 1919

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WHEN the war commenced in August, 1914, Canadian Industries were suffering from a period of severe depression. Certain undertakings that were already under way were being completed but practically no new enterprises were being projected, the volume of business was small and values of all securities had fallen. This condition was, no doubt, principally due to the world-wide disturbance caused by Germany's decision to bring on a state of war in that year, but it was intensified in our case by the extraordinary amount of railroad construction in several preceding years, the great expansion which had taken place in our manufacturing capacity and on account of the general reaction following a period of great development.

During the opening months of the war, the sentiment regarding business conditions was decidedly pessimistic. The immediate prospect was one involving a complete suspension of all development work, a great demand for money in Europe and consequent stringency here and a practical stagnation in all our industries during hostilities. Few foresaw the length to which such a war could possibly extend with the corresponding demand for our natural products and I believe we can safely say that none foresaw our manufacturing capacity would not only be fully utilized but enormously increased to provide for the requirements of the Allies.

The first aid offered by Canada to the British Government was naturally military and munition workers can claim no recognition in comparison with the magnificent contribution she has made in furnishing the troops that have served with such immortal credit to their country and have so nobly succeeded in establishing the freedom of the world. That is to-day a matter of record and history. Our Institute must, however, be eternally proud of those achievements of its membership in this terrible war, 960 have enlisted, of whom 943 were officers before the war ended. 75 have been killed or have died of wounds and 116 decorations have been gained. This constitutes a testimony to the loyalty and ability of the engineering profession to which it can point with honorable pride.

Second only to the help Canada rendered to the cause of the Allies in men was her contribution in the manufacture of munitions, a line of work in which the results that have been obtained were certainly not anticipated when the war commenced. From without, Canada would appear as a country whose wealth lay in her wheat fields, her mines and her forests and whose manufacturing wealth was simply incidental to her local requirements, and it is strange to realize that such a country with her comparatively small population should, for a considerable period, have furnished over fifteen per cent of the total disbursements of the British Ministry of Munitions.

Without any desire to disparage the achievements of the Canadian Manufacturers, it must, however, be recognized that they enjoyed certain latent advantages which were not initially recognized. A lengthy period of prosperity had produced a large number of men who were used to attacking difficulties and overcoming them. A reasonably good supply of labor was available and, on account of the dullness in business in the United States, skilled assistance was readily obtained. Last, and probably most important, was the close connection Canadians enjoyed with the United States machinery manufacturers, which enabled them to obtain promptly information as to the machinery required and quick delivery when it was ordered. These advantages were not, however, appreciated when the work was commenced and in no way detract from the initiative that was displayed by those who acted as the pioneers in the work.

The starting point of munition work in Canada came from a request received by General Hughes, Minister of Militia, from the British Government asking if he would place some contracts on their behalf in the United States and a further enquiry for 100,000 15-pounder and 100,000 18-pounder shrapnel shells, empty, which was a greater quantity than could be produced in the Dominion Arsenals in any reasonable time. General Hughes was anxious that the shells should be manufactured in Canada and requested Colonel Greville Harston, Inspector General of Arms and Ammunition, and Lt.-Col. F. D. Lafferty, Superintendent of the Dominion Arsenal to get in touch with manufacturers whom they thought could undertake the work. As a result, on the 2nd of September, 1914, Colonel A. Bertram of J. Bertram and Sons, Geo. W. Watts of the Canadian General Electric Company, Mr. E. S. Winslow of the Ingersoll Rand Drill Company, Alex. Goldie of the Goldie McCulloch Company, E. Carnegie of the Electric Steel and Metals Company and Colonel Harkom were called to Ottawa to meet General Hughes. At that meeting the nature of the work and the inspection requirements were fully discussed and, while some doubt was expressed, the meeting agreed with General Bertram and assured the Minister that the work could be done in Canada.

At a subsequent meeting held on September 8th at the Dominion Arsenal, the Minister intimated that it was not considered desirable for the Government itself to undertake the work, but suggested that a Committee of manufacturers should act as the Contractor and appointed Colonel

Bertram, Geo. W. Watts and Thos. Cantley as that Committee, whose appointment was confirmed by cable by the British War Office. Colonel Bertram was elected to act as Chairman of the Committee and it was subsequently enlarged by the addition of E. Carnegie as another manufacturer, Colonel Greville Harston, Lt.-Col. F. D. Lafferty and General Benson, Master General of Ordnance. About two weeks later, Mr. David Carnegie was appointed by the Minister as Ordnance Advisor.

This group of men constituted the original Shell Committee and, while the work they undertook was small, compared with our present views of magnitude, it was of vital importance not only for the future of Canada, but to the conduct of the war. They had as assets the assurance of the Minister that he would stand back of them, although, technically speaking, they were individually responsible as contracting parties for the fulfillment of their undertaking with the British Government, and the fact that, at the little Dominion Arsenal at Quebec, shrapnel shells had been forged and completely finished, apart from the fuse, cartridge cases made and fixed ammunition produced, all, however, in small quantities and under adverse conditions. They had as liabilities the absolute unfamiliarity of Canadian manufacturers with Ordnance requirements, the unwillingness of the majority of manufacturers to undertake the work, except as a patriotic duty, specifications and inspection requirements which presented opportunities for unlimited trouble and expense, and a number of minor difficulties which would have to be investigated and overcome before the manufacture could proceed smoothly. The great asset they possessed however was the knowledge and experience at the Quebec Arsenal.

Many have, no doubt, visited this Arsenal before war was thought of and smiled at the conditions under which the work was performed, but this Arsenal was actually producing ammunition, it knew how such work had to be done, the methods and the d fficulties, and it is safe to say that, while shells would have been produced in Canada had no Arsenal been in existence, they could not possibly have been produced as quickly or as economically if it had been necessary to visit the munition plants in the United States or gradually discover the proper way with the assistance of information from England. To Colonel F. D. Lafferty, the Superintendent, all Munition Manufacturers owe a deep debt of gratitude. No trouble was too great for him to go to, any information he possessed was available, any assistance he could render was offered freely; he simply placed himself and his entire staff at the service of every manufacturer to help in every way in the production of the munitions which he knew were so seriously needed.

In view of the numerous firms that have so successfully manufactured munitions, there is a tendency to consider it a comparatively easy kind of work. There is a certain degree of truth in this view, in the sense that, once all the difficulties attendant to any particular line of work have been mastered by a group of manufacturers, who are willing to freely impart their knowledge and experience to others engaging in the same work, the balance of the ability necessary is largely of an executive character. Without, however, desiring to unduly exaggerate the difficulties that at first confronted the Shell Committee, their task was by no means easy. Their first inquiry was for a quantity of empty shrapnel shells and it may not be out of place to mention that an empty shrapnel contains everything but the bursting charge and pellets. The Committee began by dissecting an 18-pounder shrapnel shell, and obtained from the Quebec Arsenal their manufacturing cost for each component part. Estimates were made of the cost of producing them in quantities and of machining and assembling the shell and a price at which the Committee could undertake to supply 200,000 shells was cabled to the War Office in London. This resulted in two orders being placed, one for 100,000 empty 15-pounder shrapnel and the other for 100,000 empty 18-pounder shrapnel, both of which were received on September 22nd, 1914.

The first stage in this shell is a blank of steel Fig. 1; this blank is pierced on a forging press to form the forging from which the shell is machined. During the machining process, the shell is heat treated to put the steel in the required condition, the disc is inserted and the end of the shell nosed in. The shell is completed by the assembly of the powder cup, ignition tube, bullets and socket, and the final machining required after the assembling. Fig. 2.

The steel required the first consideration. This is required to conform to quite a rigid specification, which does not define the chemical composition but the physical requirements after heat treatment. The first difficulty experienced by the Committee was the specification that this steel should be acid open hearth. There was only one acid furnace in Canada and that was of small capacity and it was, therefore, practically imperative to induce the authorities to accept basic steel. Col. Thos. Cantley obtained the suitable analysis from some acid steel in the possession of the Arsenal, made up a heat of basic steel to correspond with it and rolled it into bars. These were forged at the Arsenal, made up into shells and tested with satisfactory results. Colonel Carnegie went to England with two of the shells and word came back that basic steel that met the balance of the specifications would be accepted. I have no doubt that the authorities were realizing by that time that if they wanted shells they would have to accept basic steel, but this does not detract from the importance of the concession that the experiment justified, a concession that made the entire steel making capacity of the country available for munition work.

The permission to use basic steel did not conclude the steel makers' difficulties by any means. He still had to determine the exact quality of steel that would comply with the balance of the specifications which, during the first four months, gave him considerable trouble. Experience developed that a minimum about 0.42 per cent of carbon was necessary in order to meet the physical requirements but many failures occurred before the steel makers obtained sufficient experience to ascertain the exact grade required. The Nova Scotia Steel Company took the pioneer part in this work and were unsparing in their efforts to produce the proper steel as rapidly as possible, and they deserve great credit for their patriotic enterprise.

After the steel was secured, it next had to be converted into forgings. This work was handled in a small way at the Arsenal, but many difficulties were experienced by the firms who undertook to execute it on a manufacturing basis. Again the Nova Scotia Steel Company was one of the pioneers and the Canada Forge Company also took the work up energetically and rendered good service in obtaining successful production. An interesting example of the universal desire to assist in the work was afforded when the Nova Scotia Steel Company, who commenced forging on one of their large hydraulic presses, Fig. 3. required additional capacity. The Canadian Pacific designed, made the patterns and castings, and constructed and shipped complete four 250-ton presses with 45-inch stroke Fig. 5. and one 300-ton press with 36-inch stroke Fig. 4. the first one in twenty days from the time the order was originally discussed and the last one ten days later.

The machining of the first order for 18-pounder shells was distributed amongst ten firms and that for 15-pounder amongst five firms who, in addition to actually performing the machining and heat treatment, were required to assemble the various components into a complete shell that would satisfy the War Office Inspection. The actual machining was not particularly difficult as the limits of accuracy are not close. There are, however, a number of different dimensions to be gauged, each with a definite tolerance, while in certain cases the maximum tolerance could not be used on all of several different dimensions. It was interesting to witness the difficulties experienced by men, who regarded the accuracy specified as comparatively easy, when they were required to produce a piece to pass a number of different gauges in the hands of an inspection staff that cared nothing about a thing being " almost right." There were also a number of practical points that required experience but in all such things the Quebec Arsenal was an invaluable guide. The usual procedure was to visit the Arsenal, ascertain exactly how to do the work, come back, get into difficulties and go back to the Arsenal to find out what the trouble was. On the whole, given a proper forging, the machining troubles on shrapnel were comparatively slight. One firm did nose in a perfectly good lot of shells before inserting the disc, which cannot be entered after nosing, and several melted the bullets by overheating the resin, but the only real trouble occurred in the heat treatment.

At the time this work was commenced, heat treatment was only a theory in the majority of plants. In a few automobile and tool making shops, heat treating equipment was in use but even in those shops it was exceptional to require results of the exactitude demanded for a shell. It was specified that the heat number should be marked on each forging and stamped on the shell machined from it. The shells from each heat were grouped together and a test shell selected by the Inspector from each heat. Test pieces from this shell must give a tensile strength not less than 56 tons per square inch, an elastic limit not less than 36 tons per square inch

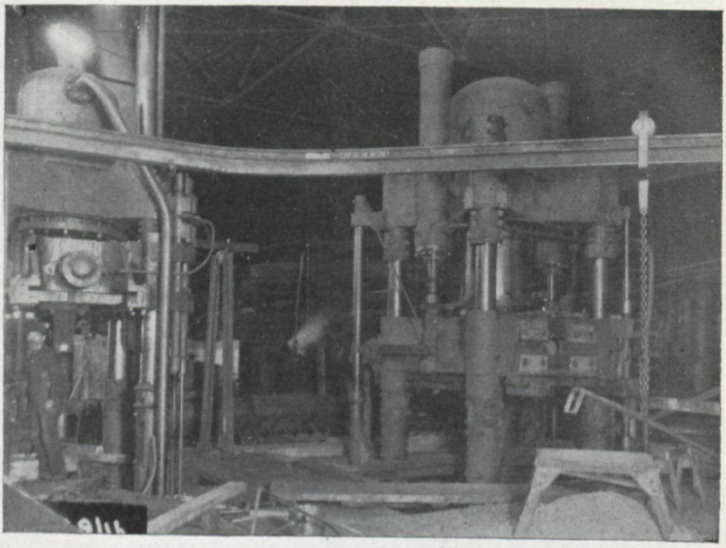


Fig. 3. Nova Scotia Steel Co. Forging Plant.

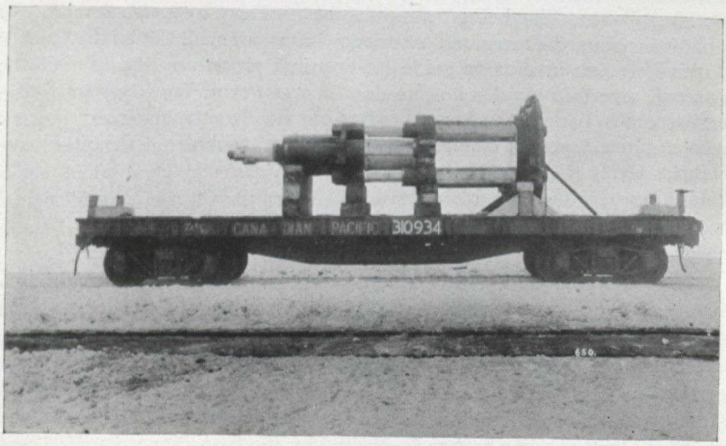


Fig. 4. C.P.R., 300 ton Hyd. Press.

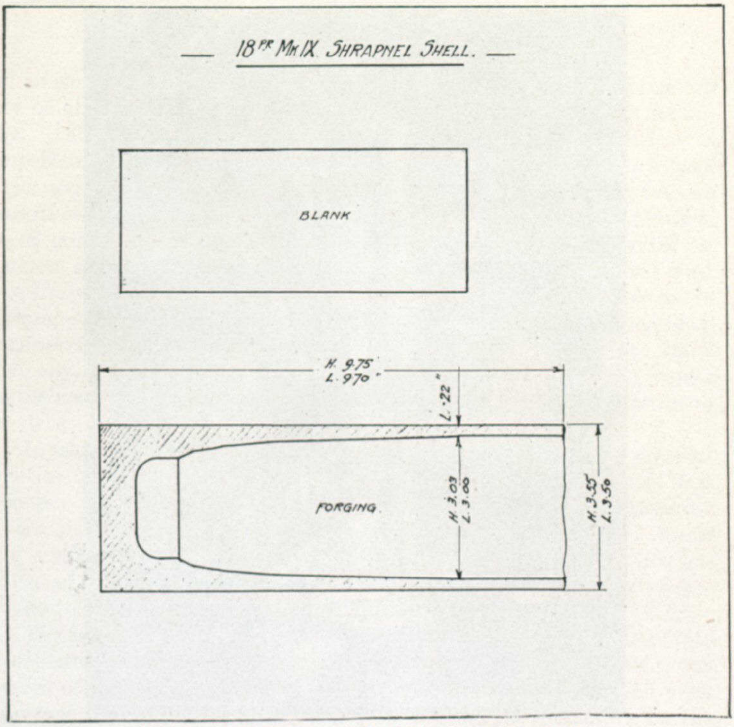


Fig. 1. 18 Pr Shrapnel Steel Blank and Forging.

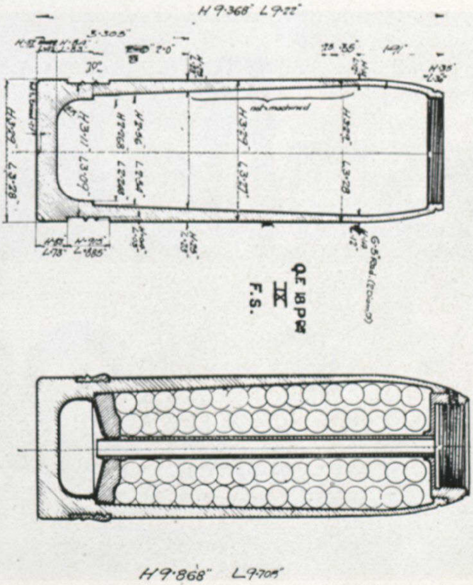


Fig. 2. 18 Pr Shrapnel Shell.

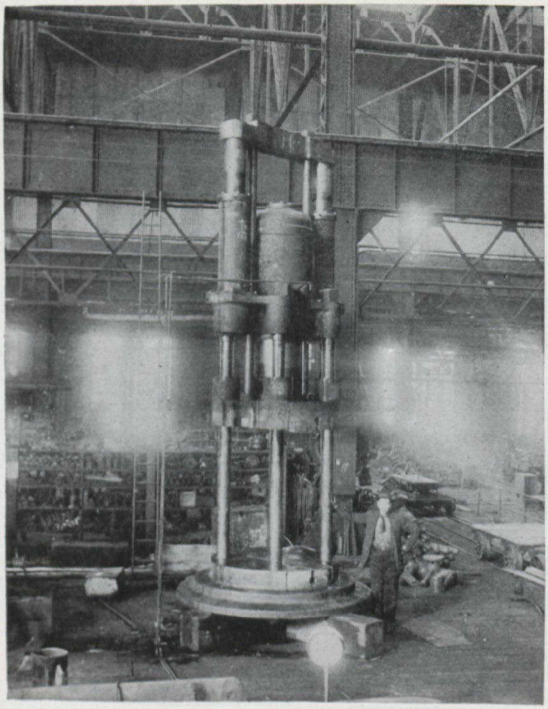


Fig. 5. C.P.R. 250 Ton Hyd. Press.

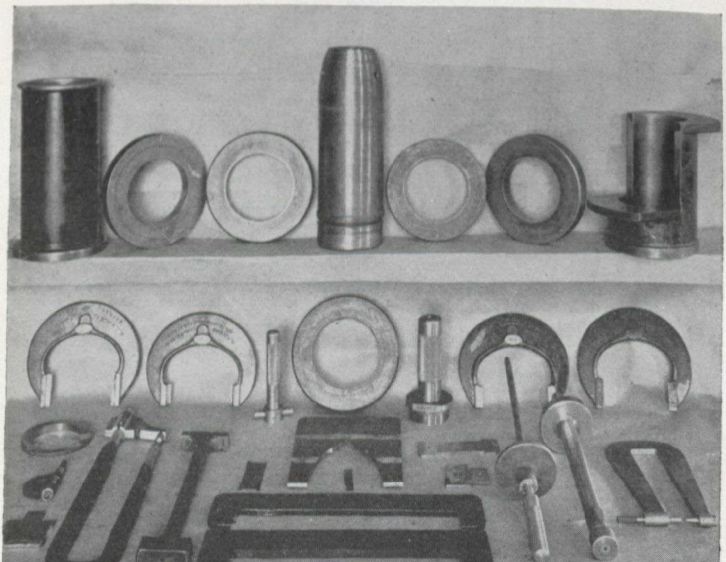


Fig. 6. Set of Gauges for 18 Pr Shrapnel Shell.

and an elongation of not less than 8% on two inches. These qualities can only be obtained with steel of the proper composition heated in a certain way. This results practically in the shells being quenched in oil from a temperature only slightly higher than the critical point and drawn back if necessary. To do this, however, the correct design of heating furnace must be used, the temperature must be accurately regulated by a pyrometer, the oil must be maintained at the proper temperature, the shell tested for hardness after quenching and, if drawing back is required, the shell must be re-heated to the proper temperature. Excellent service was rendered in working out the details of this process by Mr. W. A. Peterson, then Shop Engineer for the Canadian Pacific and Mr. E. S. Winslow of the Rand Company, the latter being, I believe the first man to introduce into regular use the magnetic detector to determine the point of critical temperature of the steel.

In many cases it was found impossible to obtain the required physical qualities from the steel furnished and in other cases re-treatment was necessary. While this work was finally developed into a manufacturing system, in the initial stages it was one of the most troublesome problems that confronted the manufacturers, although it has certainly accomplished an incidental benefit in the education of our workshops in the science of heat treatment.

The machiner, while responsible for assembling the components into a complete shell and for its acceptance by the Inspection Department, was relieved of their manufacture. This constituted one of the first and most important decisions of the Shell Committee and laid the foundation for the enormous output that was subsequently obtained. The components consisted of the powder cup, the disc, the pellet tube, the bullets, the resin, the grub screw and the socket and plug, and the powder cup was about the only one in which some little difficulty was not encountered in the manufacture. The disc, which is made by drop forging or stamping, is of steel of similar quality to the shell and must conform to physical requirements which, while less rigid than those for the shell, still required careful handling or a simple form of heat treatment to meet them. It was partially machined and had to pass its own set of gauges to be accepted. Fig. 7. The bullets were made by a machine specially constructed for that purpose and are of a mixture of lead and antimony. The pellet tube and socket are of brass, of specified quality, and required to meet physical tests, which cannot be uniformly obtained with cast brass and consequently the tube must be of extruded or drawn material and the socket forged or stamped. There is no great difficulty in meeting the requirements, but special equipment is employed in each case, there are details in the manufacture which had to be investigated to obtain the correct results and each piece must pass the War Office Inspection both as to dimensions and quality. Had contracts been let for the manufacture of the shell complete, the difficulties of the work would have been greatly increased and only those firms possessing a competent technical staff and strong financial backing could have undertaken it. Each firm would also have been obliged to purchase

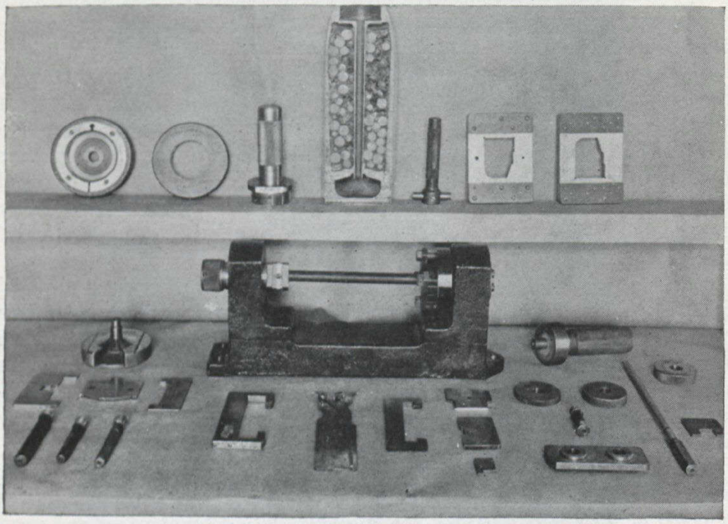


Fig. 7. Set of Gauges for Component Parts of 18 Pr Shrapnel Shell.

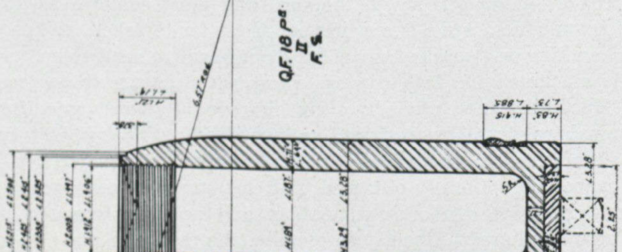


Fig. 8. 18 Pr High Explosive Shell.

part of their components and, as they would each have asked for quotations from a number of sub-contractors, the volume of inquiries would have been greatly increased and created a fictitious demand for materials and correspondingly enhanced prices. By dividing the original order amongst a few leading manufacturers, the Shell Committee could have relieved themselves of all trouble and anxiety and transferred the difficulties to the other fellow but they had confidence in the capacity of the country to produce munitions and the vision to realize that this capacity would be wanted. The principle of the arrangement they adopted, that of the sub-division of work, was old, and we have become so accustomed to this method that I doubt if we at all realize the importance of the step taken by the Shell Committee when they introduced this system, its comparative novelty and the foresight they exercised in its adoption. It entailed the independent purchase by a central body of each firm's product, the allotment of that product to other firms to perform a succeeding operation on the material or assemble it with other parts, such firms having no connection with each other, but each being individually responsible to the Shell Committee. The scheme is so manifestly efficient that we are apt to overlook its importance and its influence in rapidly obtaining production, which proved such a vital factor within the next few months. It was certainly an entirely new step in the manufacture of munitions and was not contemplated either in the specifications or the War Office system of inspection.

In so far as certain requirements were specified in the steel as rolled, the War Office could inspect the steel for those requirements at the Mill, but, if additional requirements were specified after the steel was forged or machined, the War Office could accept no responsibility for the steel meeting those requirements until presented to them in the specified state. They also could not accept any responsibility for a forging, for instance, being of the proper dimensions to permit of machining into an acceptable shell, nor were the correct dimensions for that forging determined. As any one manufacturer's product might be shipped to any of the firms engaged on a succeeding operation, the Shell Committee instituted their own system of inspection, which was carried out by the Canadian Inspection and Testing Laboratory and established the dimensions for the components which were produced in an uncompleted state. This enabled them to accept the work of any manufacturer and pay him promptly, placing all allocation of responsibility between the manufacturer and the Committee instead of between one manufacturer and another.

Like many other apparently simple things, the scheme of sub-dividing munition work is not so simple as it looks, and when it is considered that the Shell Committee had to design and obtain the gauges for the component inspection, place the contracts, attend to the shipping, financing and accounting and that they furnished the various manufacturers with master gauges and organized a staff for assisting in technical matters, the apparently easy business of letting contracts for shell manufacture is evidently a task of considerable magnitude.

While all of the work I have described was not undertaken in connection with the original order I have discussed it at some length in an attempt to portray something that I do not believe is properly appreciated, the magnitude of the original venture undertaken by the Shell Committee, the amount of hard earnest work it required and the ability with which it was executed. The whole development of munition work in Canada grew from the satisfactory execution of these preliminary orders and General Sir Alexander Bertram and his confreres deserve the greatest credit and recognition for their success.

As quickly as the Shell Committee felt assured that Canadian Manufacturers could and would undertake the work, the Minister of Militia, General Hughes, cabled Lord Kitchener pointing out that large contracts could be taken. This resulted in orders being placed on December 4th for 400,000 additional 18-pounder empty shrapnel shells and for 200,000 18-pounder fixed ammunition complete without fuse. These additional orders were justified by the rapid and satisfactory production obtained by the Canadian Manufacturers. In spite of the initial delays, which unavoidably occurred in getting the work started, deliveries were made on the first order, which was formally received 22nd September, 1914, in the month of December in that year, in which 3294 shells were shipped. This was followed by 32,961 in January and 48,264 in February and the entire order was completed well within the promised time.

As the production increased, greater confidence was felt, at the War Office, in Canada's ability to produce munitions and other orders followed until in April, 1915, the first really large order was placed for 5,000,000 rounds, divided into equal quantities of 18-pounder shrapnel, 18-pounder high explosive and 4.5-inch howitzer fixed ammunition complete.

The 18-pounder high explosive shell was Fig. 8. a new type introduced on account of the lack of effectiveness of shrapnel when used against entrenchments or wire. It is made from a plain blank, the bore being drilled out from the solid. This was the first shell made here in which a base plate was used to prevent the flash from the explosion of the propellant penetrating through any piping or seams in the base of the shell and exploding the charge. This base plate gave little trouble on the 18-pounder shell, but it was the source of endless grief on the larger shells subsequently manufactured, on which it was also employed. It was originally screwed into the base and riveted over and, although the design was subsequently changed and the threading done away with, it was responsible for the introduction of thread milling, a process up to that time very little used in Canadian Plants, which has since come into almost universal use.

The 4.5-inch high explosive shell Fig. 10 was of a different type to either of the 18-pounder. It is made from a forging like the shrapnel but is completely finish bored. It is nosed in after boring, but this operation is considerably more difficult than on the shrapnel as the shell has to be heated in a particular way to obtain the correct form after nosing, the form and material of the nosing die required lengthy experimenting with before they were properly determined and a press of about 250 tons capacity

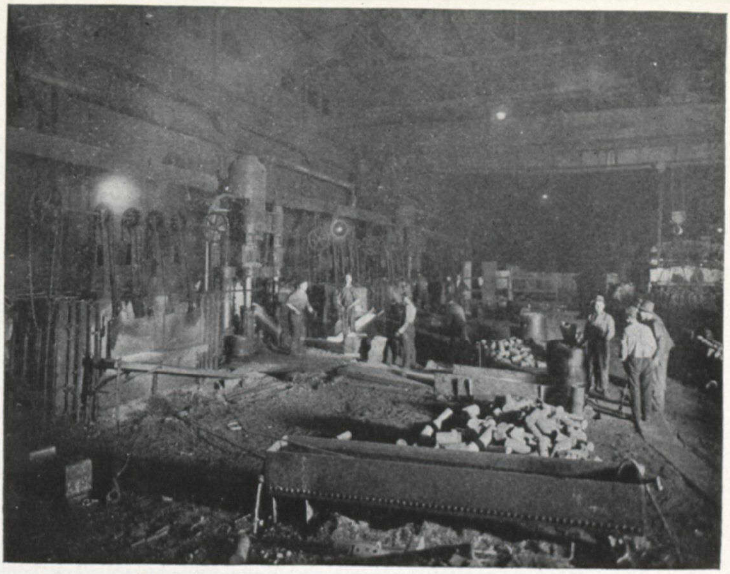


Fig. 9. Canada Car & Foundry Shell Forging Plant.

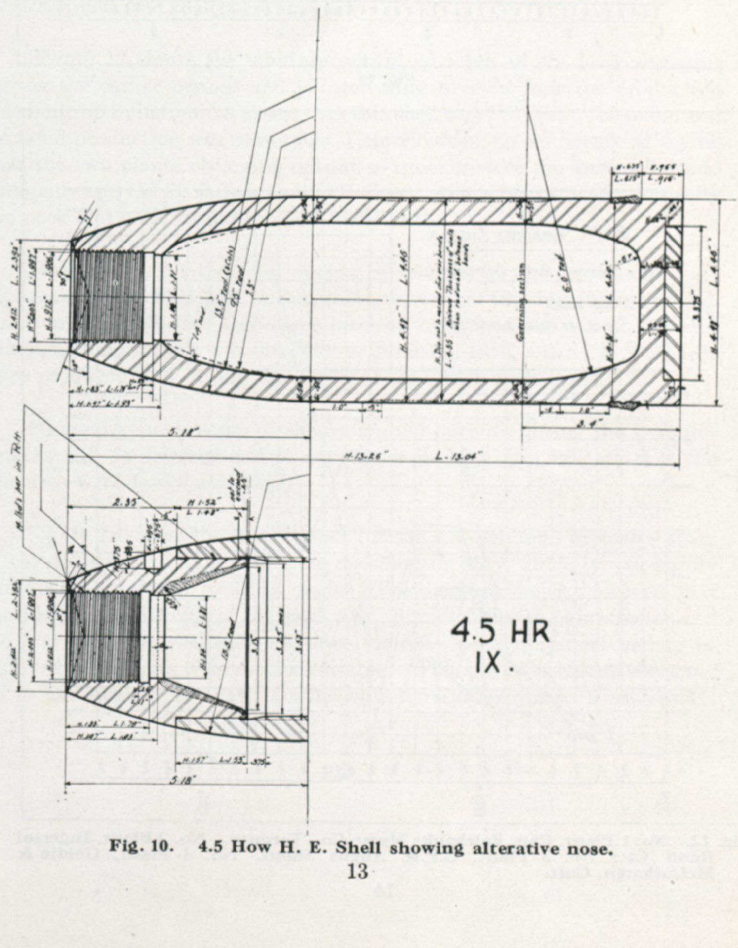


Fig. 10. 4.5 How H. E. Shell showing alterative nose.

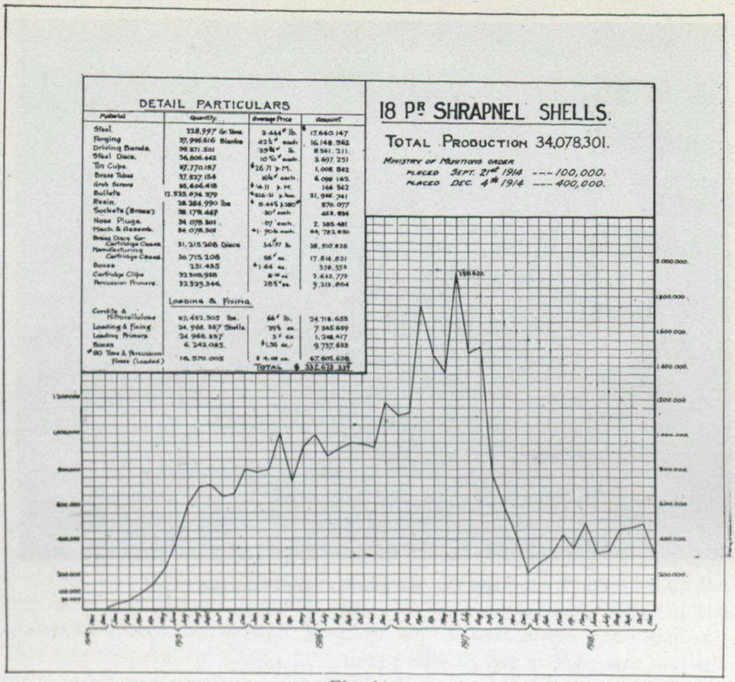


Fig: 11.

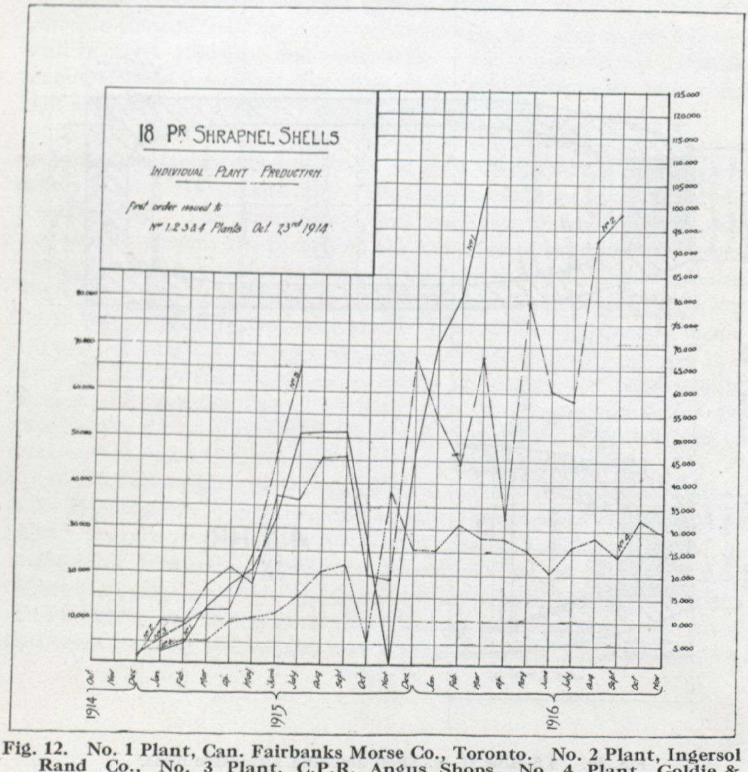


Fig. 12. No. 1 Plant, Can. Fairbanks Morse Co., Toronto. No. 2 Plant, Ingersol Rand Co., No. 3 Plant, C.P.R. Angus Shops. No. 4 Plant, Goldie & McCullough, Galt.

was required. After the shell was nosed it was necessary to machine it inside near the nose, or " internal profile " it, as it was called, to remove the irregularities caused by the nosing and obtain a sufficiently smooth contour. This is not a difficult shell to make; in fact, I should call it the easiest of the larger high explosives but, as it was the first of this type to be made, quite a lot of difficulties had to be overcome before it was produced successfully.

I have already referred to the rapidity with which production was obtained in Canada and I have prepared diagrams showing the output by months of the three shells I have described. These diagrams show the output on all orders and not only the earlier ones mentioned, but they are especially interesting in connection with the earlier stages of the industry. Figure 11 shows the output of 18-pounder shrapnel and you will note the delivery mentioned in December, 1914, and the rapid increase that took place in the succeeding periods. As the war went on, the total output varied with the requirements but the maximum was obtained in June, 1917, when 1,931,620 18-pounder shrapnel were produced and, in all, 34,078,301 of this shell were made.

Figure 12 shows the monthly output of a few of the large concerns during the earlier periods and is interesting to show how the production was built up in individual cases. As this shell was the first to be made and its rapid production was so notable, I am violating no confidence in saying that the two plants obtaining output so quickly were the Ingersoll Rand Company and the Canadian Pacific Railway, Angus Shops, who practically ran neck and neck during the first few months.

Figure 14 shows the total output by months for the 18-pounder high explosive shell. This shell was urgently required at the time it was ordered, but comparatively few were made later on until near the end of the war. The maximum output was obtained in January, 1916, when 608,355 shells were produced and, in all, 5,682,834 of this shell were made.

Figure 15 shows some of the individual outputs during the first few months and as delivery was to commence in May you will see that the promises were fairly well kept.

Figure 18 shows the total output for the 4.5-inch high explosive shell. While deliveries on this shell were specified in May, 1915, it was hardly anticipated that they could be made. The diagram shows, however, that considering the novelty of the work and the difficulties to be overcome and the fact that, in practically all cases, entirely new equipment had to be installed, the results were most creditable. This shell was extensively used up to the summer of 1918, but the output required varied considerably.

The drop in July and August, 1916, was caused by the more stringent inspection requirements put into effect at that time, but in the summer of 1917, the demand was reduced and, although there were occasional periods in which the shops were worked to capacity, their output was, as a rule, regulated by the demand. The maximum output was in June, 1917, when 636,394 shells were produced and in all 12,607,091 of this shell were made.

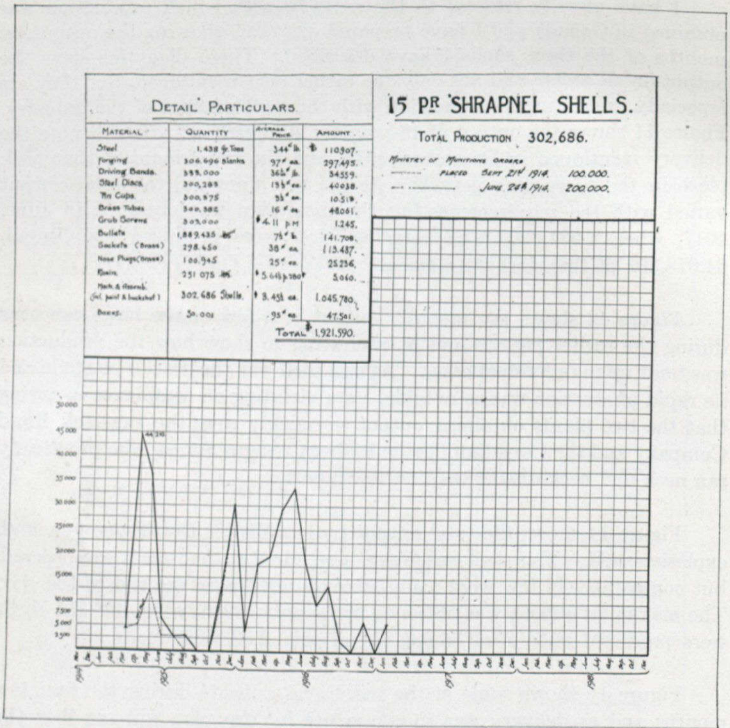


Fig. 13. 15 Pr Shrapnel Shell production showing total production by full lines and that of Electric Steel & Metals Co., Welland by dotted line.

Figure 19 shows some of the individual outputs during the earlier periods and demonstrates, I consider, that production was rapidly obtained.

I have discussed the output of the shells themselves as though they constituted the entire contract executed by the Shell Committee but, when they obtained the first order for fixed ammunition and the larger orders that followed, they assumed a far more complicated undertaking.

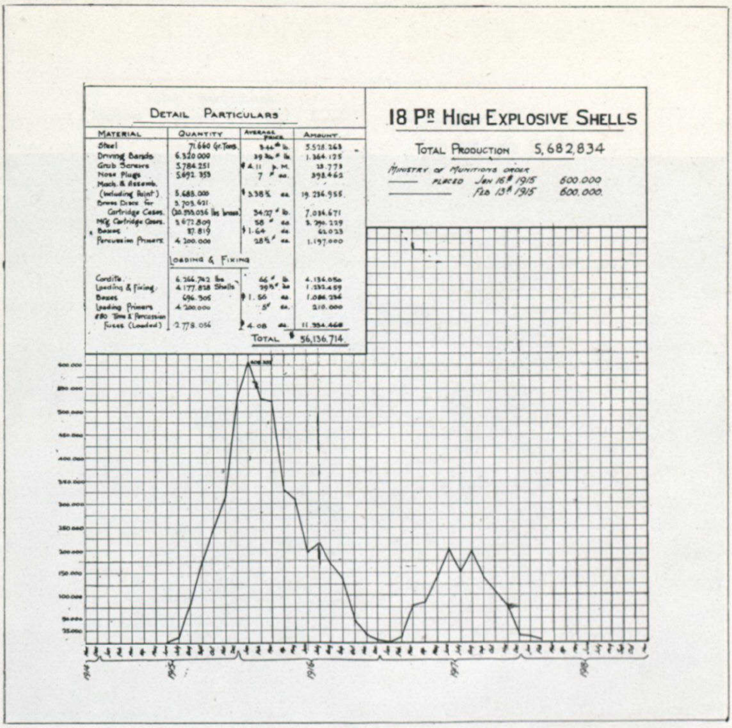


Fig. 14.

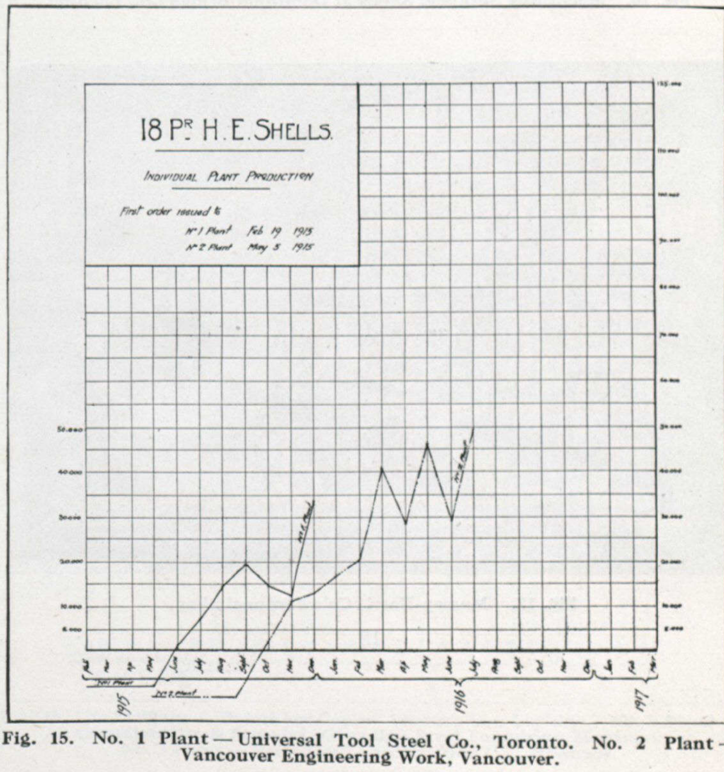


Fig. 15. No. 1 Plant — Universal Tool Steel Co., Toronto. No. 2 Plant — Vancouver Engineering Work, Vancouver.

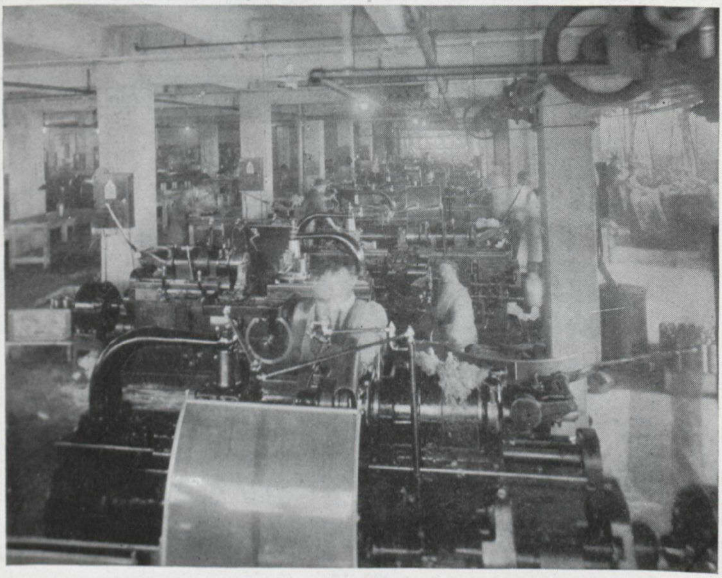


Fig. 16. Machining Shrapnel Shells at Dominion Bridge Co., Lachine.

Fig. 17. Massey-Harris Co's Shrapnel Shop.

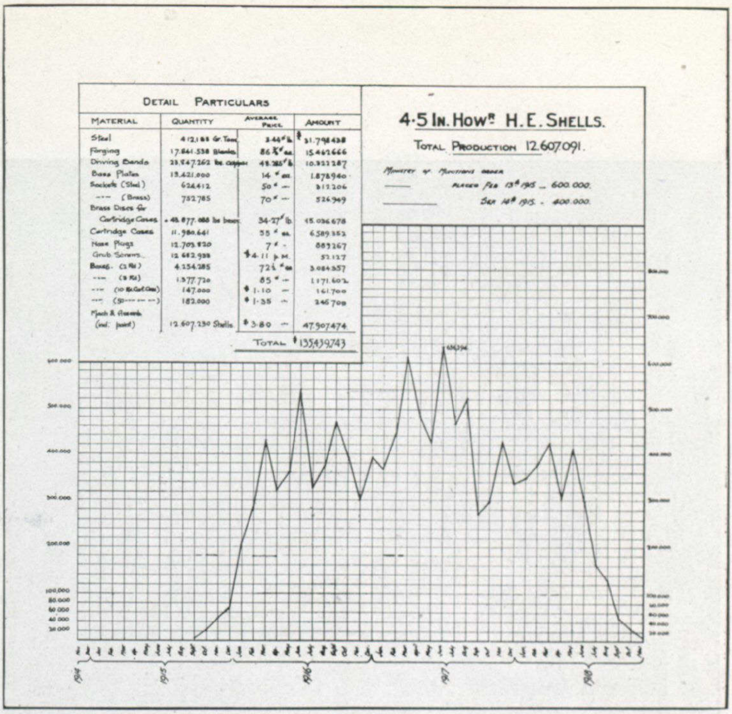


Fig. 18.

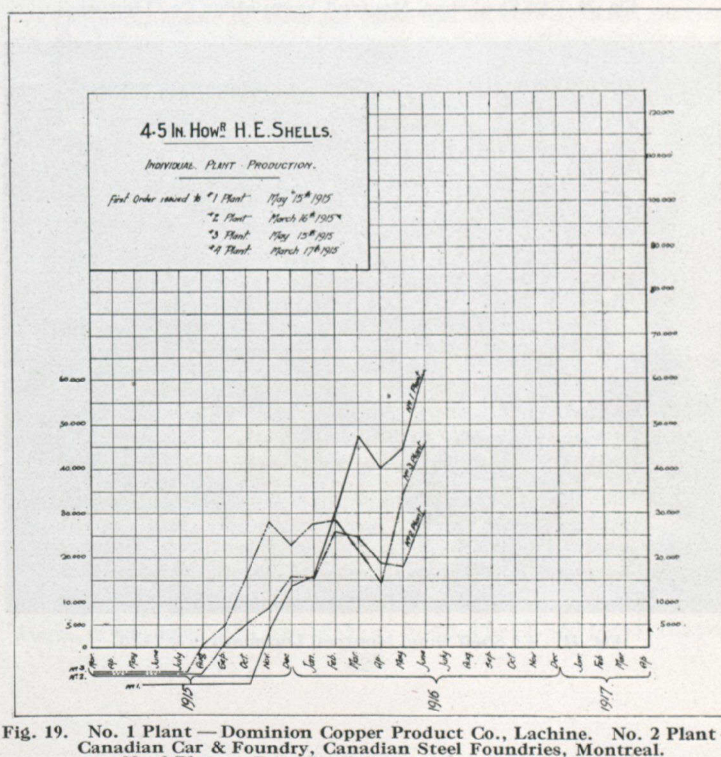


Fig. 19. No. 1 Plant — Dominion Copper Product Co., Lachine. No. 2 Plant — Canadian Car & Foundry, Canadian Steel Foundries, Montreal. No. 3 Plant — Peter Lyall Construction Co., Montreal.

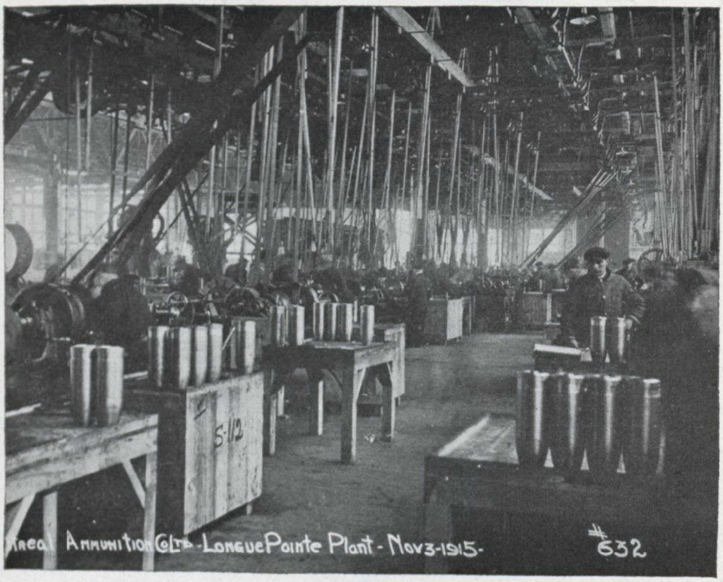


Fig. 20. 4.5 Shell Shop, Montreal Ammunition Co., Limited.

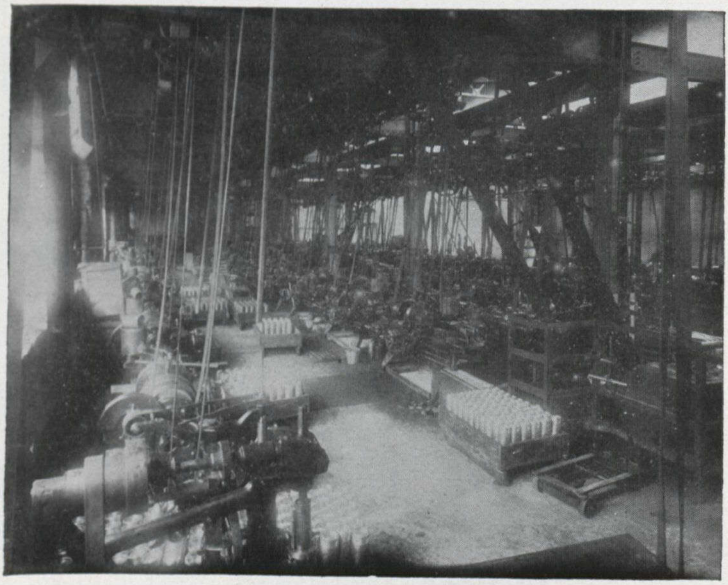


Fig. 21. 4.5 Shell Shop, Montreal Locomotive Co., Ltd.

A round of fixed ammunition, see page 59, without fuse includes, in addition to the shell, the cartridge case, the primer and the propellant and each of these components involved its own assortment of investigations, difficulties and failures before its manufacture was reduced to a science.

In the case of the 18-pounder fixed ammunition, both shrapnel and high explosive, the rounds had to be assembled at a loading plant and placed in ammunition boxes ready for direct shipment to France. In the case of 4.5-inch high explosive shells the shell, cartridge case and propellant were shipped separately, but a cartridge clip was furnished to hold the propellant in the case. The shipment of 18-pounder fixed ammunition involved the erection of loading plants to which the various components could be shipped, including buildings for storing the propellant and the machinery for assembling the completed rounds.

The primer, Fig. 22 although comparatively small, is quite a difficult article to manufacture. The tolerances are small and it must be accurately to gauge. This was one of the earliest articles requiring a high grade of workmanship and, in spite of the gauging, it was found impracticable at first to secure interchangeability among the parts made by different firms. These parts are assembled when the detonator is inserted and the primer loaded with powder and many troubles were experienced at the loading plants before the necessary quality of workmanship was obtained.

The manufacture of cartridge cases was an entirely novel problem. The Mark I, 18-pounder case, had been made in small quantities at the Quebec Arsenal, but its production in large quantities would evidently require a different class of machinery and a modification of the methods used. The order for the 200,000 cases required for the first fixed ammunition was placed with the Canadian Cartridge Company, who proceeded to immediately install a completely new equipment. While this was being constructed, an urgent call came for additional cases and the Canadian Pacific undertook to make on its car department bulldozers and other ordinary machinery. Figs. 25 to 27. Col. Lafferty lent the tools from the Arsenal to the Angus Shops to test the practicability of the scheme and, on this being demonstrated, some 800-ton hydraulic heading presses were designed and constructed in about five weeks. Figs 28 and 29. Cases were actually produced within three months and on this makeshift equipment the first cases were commercially produced, the first howitzer case was made and two million cases were completed before the plant was turned back to its regular output. In the meantime further orders were received and the work distributed among other firms, all of whom installed elaborate equipment.

I doubt very much if anyone had much more trouble than the earlier case manufacturers. One difficulty was the change made from the Mark I to the Mark II case. The case made at the Arsenal and at the Angus shops was the Mark I, on which the Mark II was an improvement. The Mark I case presented no unusual difficulty. Both at the Arsenal and at Angus, it was made with a satisfactory internal finish and passed the proof

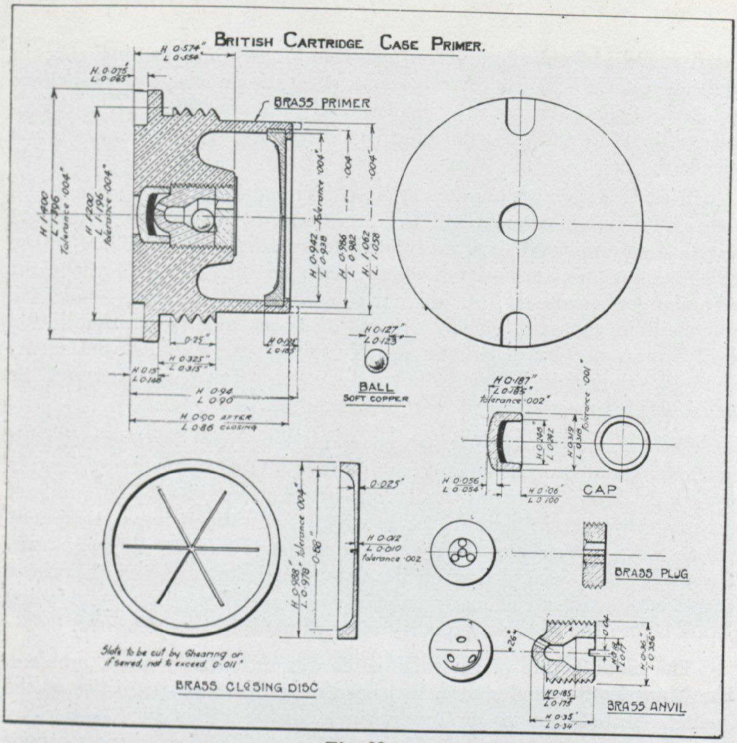


Fig. 22.

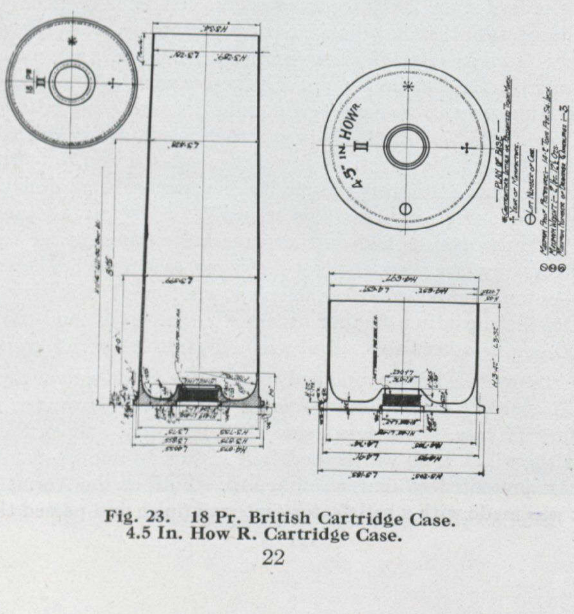


Fig. 23. 18 Pr. British Cartridge Case.
4.5 In. How R. Cartridge Case.

test. In undertaking to make the Mark II case, no special trouble was anticipated, but it was found that not only was it most difficult to obtain an acceptable finish, but that, when this was accomplished, the cases were liable to fail in the firing test. One firm, after producing 4,900 accepted cases, lost 28,000 through rejection at the proof test, which required a complete investigation of the difficulty, and a revision of the methods employed. This was not an isolated example. Each firm that went ahead in an endeavour to obtain their output had more or less trouble of the same kind. Later experience developed the correct method of making the Mark II case successfully, but a slight change in the design was quite generally made, which greatly reduced the difficulty. An inspection of cases made by various English manufacturers, which were sent over for rectification, showed a similar change in almost every instance, so that our early troubles and delays were really justifiable. Other serious troubles developed from the machinery breaking down as its total capacity was approached. It takes a pressure of about 900 tons to form the head on an 18-pounder case and, while the presses furnished for this work would probably have stood up reasonably well if the work had been intermittent, they were not constructed to stand this pressure being applied six or eight thousand times daily and had no reserve strength if it were increased by a heading post that was too high or if a punch were brought down in the wrong position. Fig. 30 shows a breakdown of one of the Montreal Ammunition Co's Hyd. Presses. The result was a great education in the design and the factor of safety required for this class of work and an exhaustive experience not only in the fatigue of the material, but in the fatigue of the superintendent.

Like any other new industry, there were a number of minor problems, simple and obvious in their solution once they were thoroughly understood, which entailed experiment and delay when delay meant the holding up of the output of ammunition. These were gradually overcome and the output of the cartridge cases from the Canadian plants was most satisfactory. The record was obtained by the Canadian Cartridge Company, who, in October, 1917, actually produced one million cases. The Montreal Ammunition Company was a good second with 797,000 cases in the month of November. Both these Companies made almost identical records in certain output. Both machined over 1,000 cases in a shift on lathes sold to machine 250. Both headed over 10,000 cases in 24 hours on one header when other machines were broken down and both obtained extraordinary service from their men when the cases were urgently required. In the winter of 1915-16, when howitzer cases were so badly needed, the men at the Ammunition Company for three months worked in two shifts 11¼ hours per day each, Sundays, Christmas and New Year's Day, which showed very forcibly the interest they had in the work. In addition to the two firms mentioned, six others were engaged in this work, who all produced successfully.

Diagrams 31 and 32 show the total monthly output and confirms what I have stated about the early delays but it shows that, once the work was

Fig. 24. Operations in the Manufacture of Cartridge Case.

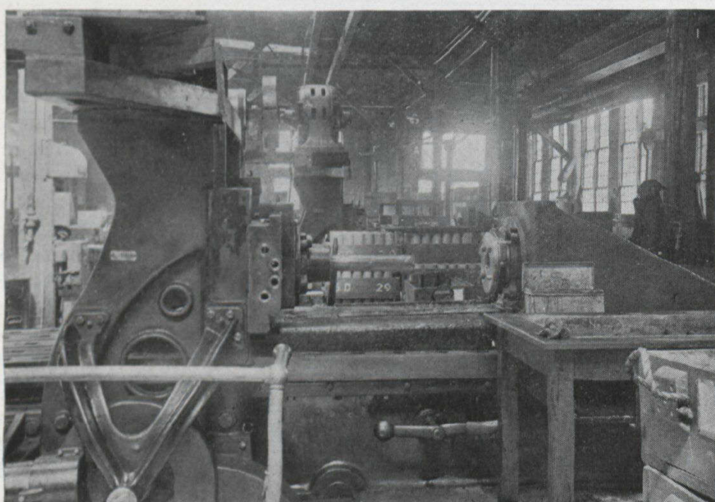


Fig. 25. Frog Planer equipped for drawing Cases.

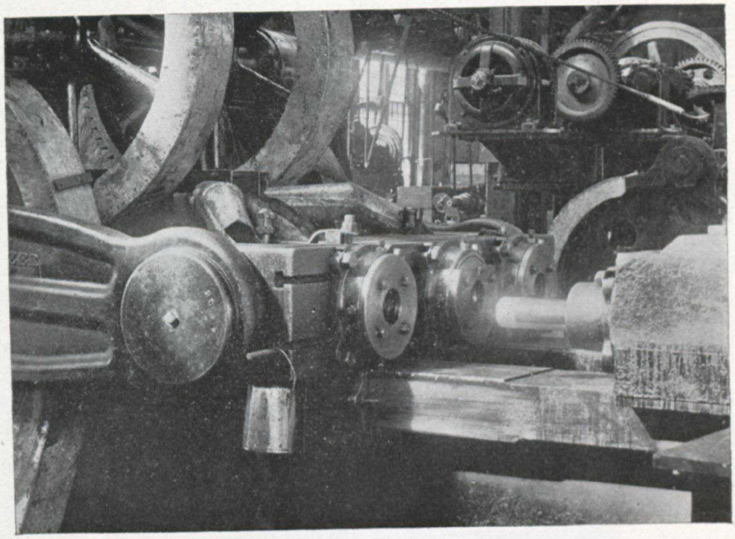


Fig. 26. Bulldozer equipped for drawing cases.

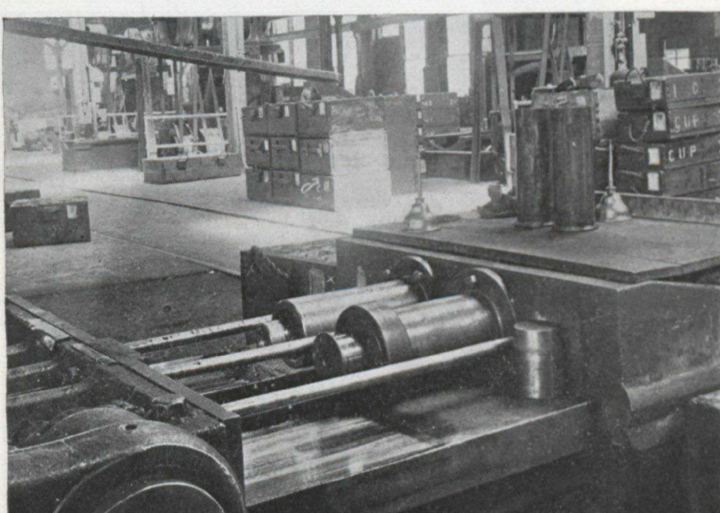


Fig. 27. Bulldozer equipped for tapering cases.

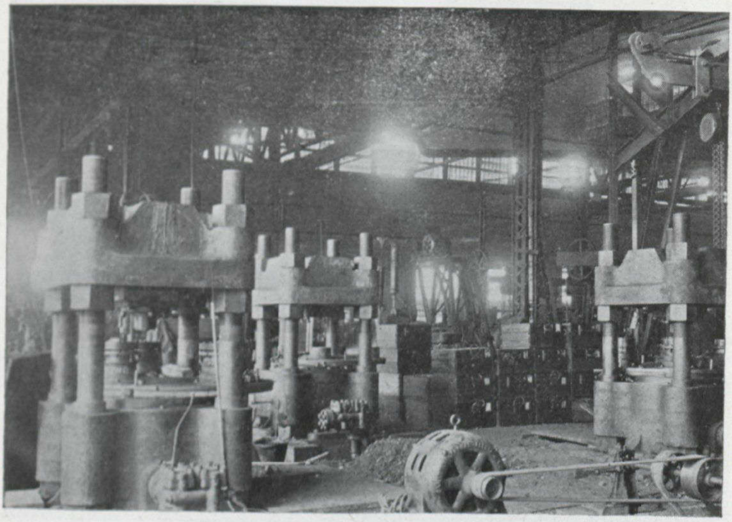


Fig. 28. 800-Ton Hyd. Presses at Angus Shops, C.P.R.

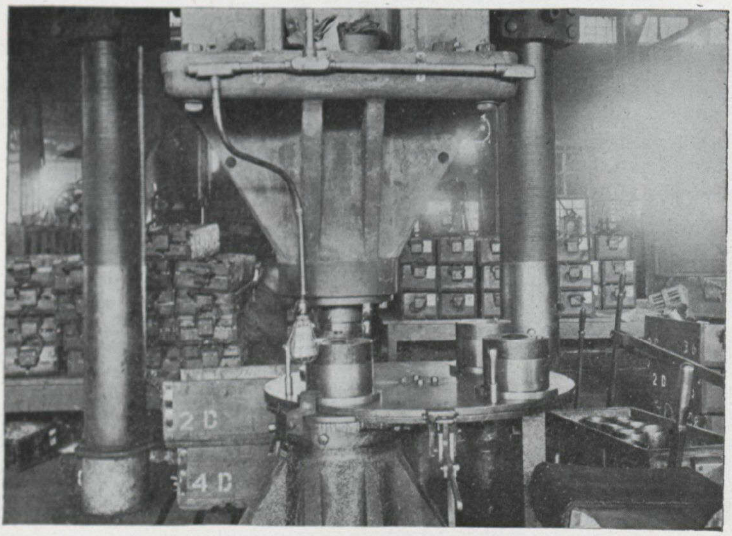


Fig. 29. Revolving Platen of 400-Ton Hyd. Press, C.P.R.

fairly started, the output grew at a rapid rate. The maximum output of 18-pounder cases, 1,893,000, was obtained in June, 1917, and that of 4.5″ cases, 824,000, in December, 1916, but both these cases were made in the same plants, and the maximum combined output was 2,560,000. obtained in December 1916, or over two and a half million in a month. The total number of 18-pounder cases produced was 34,715,208 and of 4.5″ cases, 11,980,641, or a combined total of 46,695,849, to which may be added 600,000 cases ordered by the Board for the Belgian Government, making a grand total of over 47,000,000 cases.

Diagrams 33 and 34 show some of the individual outputs during the first few months and you will notice that in Diagram 33, line No. 1 delivery commenced in three months from the date of the order and in the case of line C, which refers to a firm installing an entirely new plant, deliveries were made in four months.

I have devoted more time to the cartridge case than its importance perhaps justifies, but it was interesting on account of its being handled by comparatively few firms and the extraordinary rates of production that were obtained when it is considered that it was an absolutely novel class of manufacture.

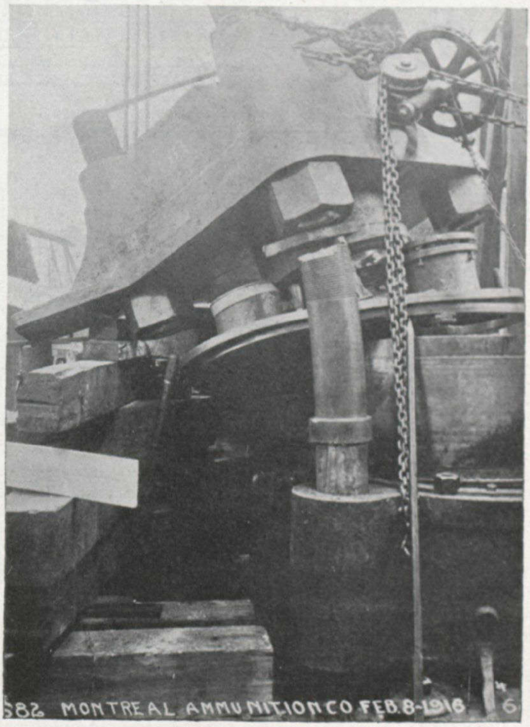
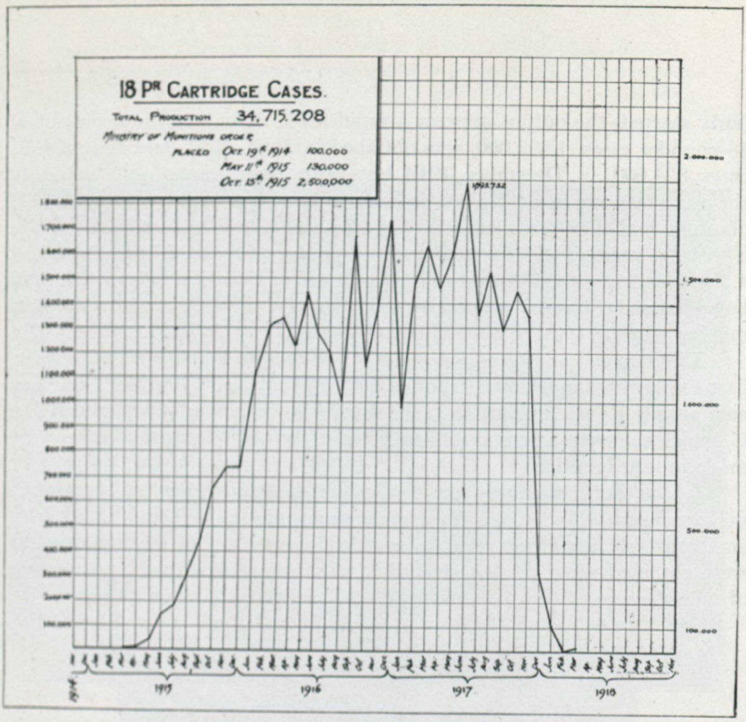
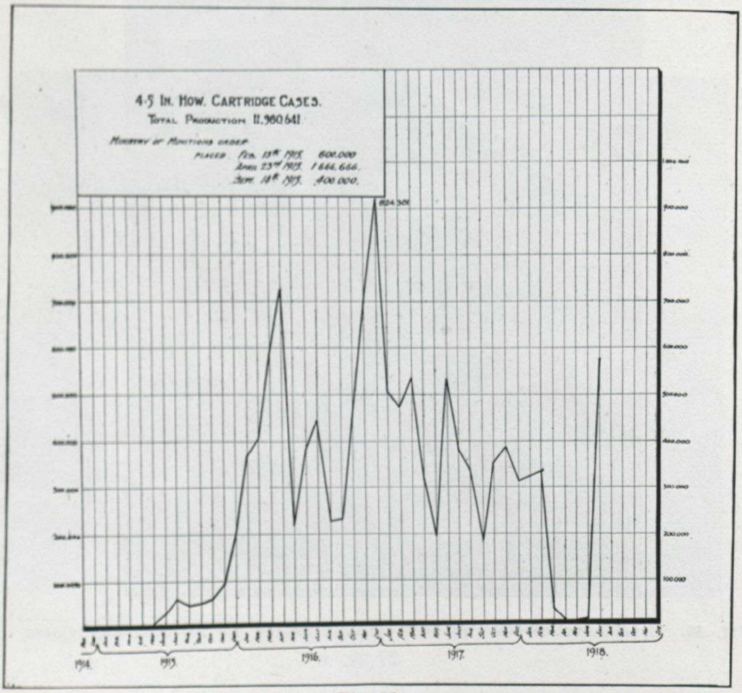


Fig. 30. Breakdown of 900-Ton Hyd. Press Heading 4.5 in. Cartridge Cases.



18 Pr Cartridge Cases.
Total Production 34,715,208
Ministry of Munitions order
placed Oct 19th 1914 100,000
May 11th 1915 130,000
Oct 15th 1915 2,500,000
1915
1916
1917
1918

Fig. 31.



4·5 In. How. Cartridge Cases.
Total Production 11,980,641
Ministry of Munitions order
placed Feb. 13th 1915 600,000
April 23rd 1915 1,666,666
Sept. 14th 1915 400,000
1914
1915
1916
1917
1918

Fig. 32.

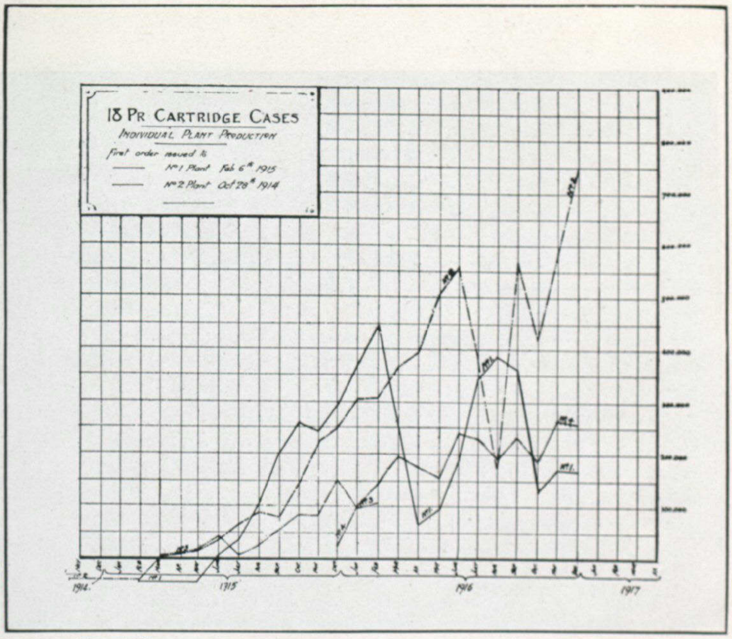


Fig. 33. No. 1 Plant — Dominion Copper Products Co., Lachine. No. 2 Plant — Can. Cartridge Co. No. 3 Plant — Angus Shops C.P.R. No. 4 Plant — Montreal Locomotive Co.

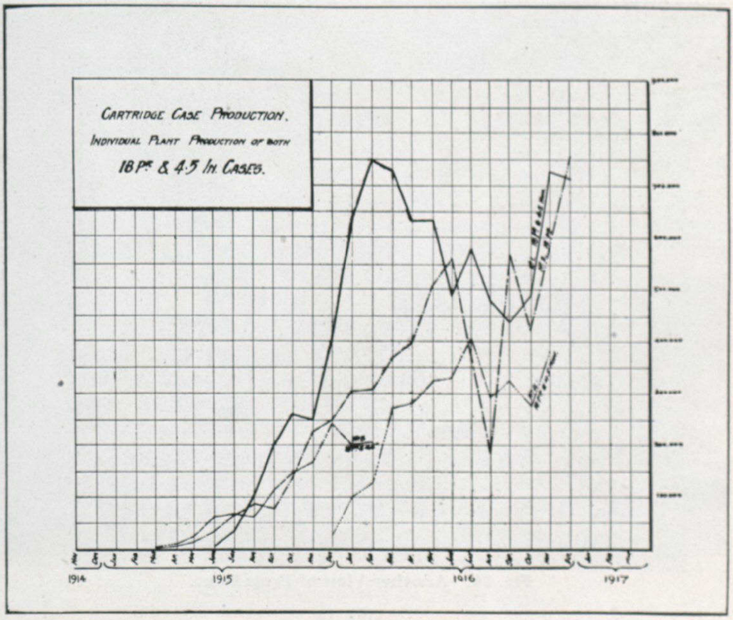


Fig. 34

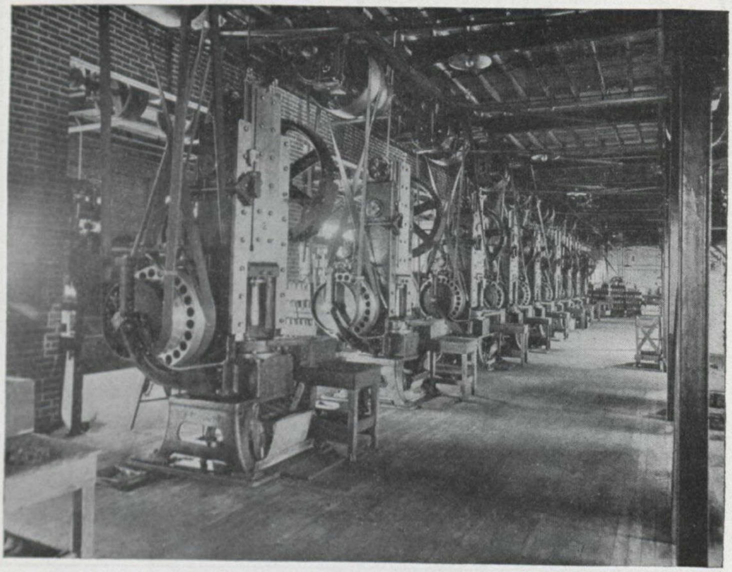


Fig. 35. Canadian Cartridge Co., Press Dept.

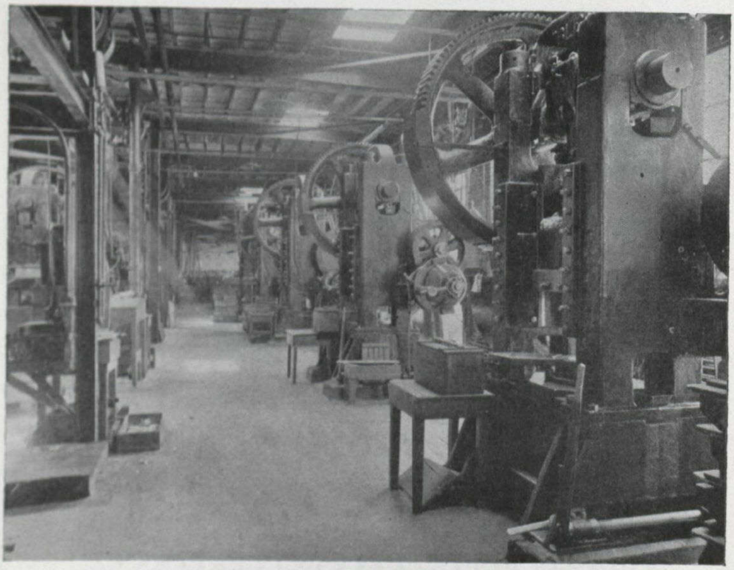


Fig. 36. Another View of Press Dept.

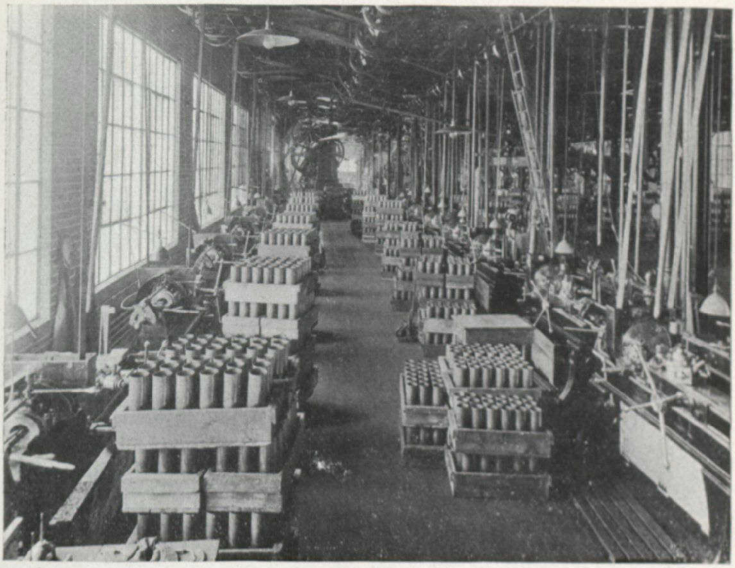


Fig. 37. Canadian Cartridge Co., Finishing Dept.

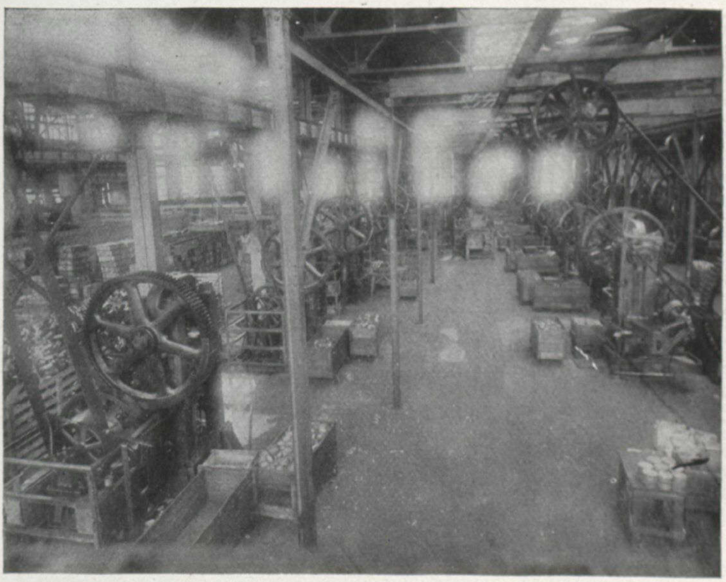


Fig. 38. Montreal Locomotive Co., Press Dept.

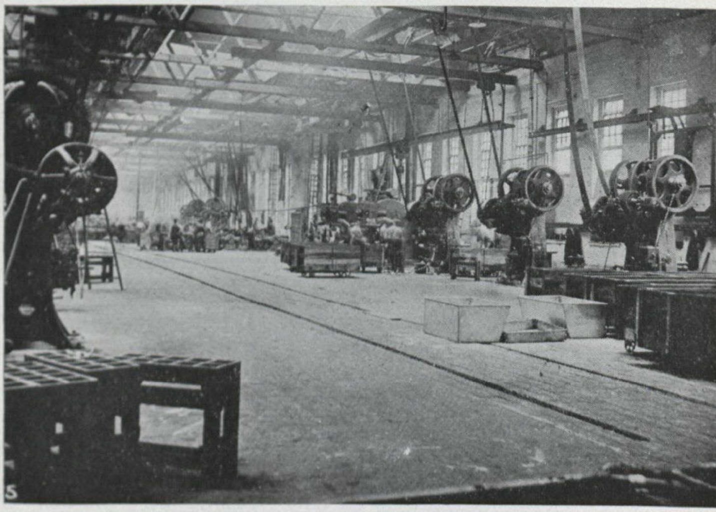


Fig. 39. Montreal Ammunition Co., Ltd., Press Dept.

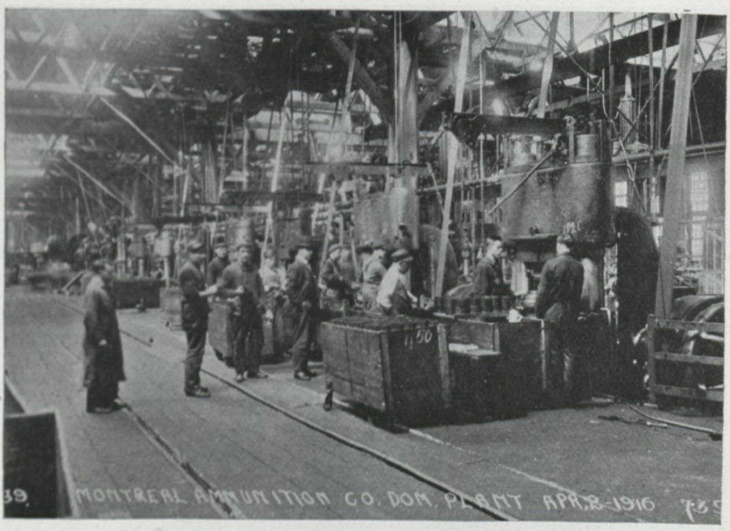


Fig. 40. View showing battery of 1200-Ton and 900-Ton Heading Presses.

A really more difficult problem, from a technical view-point, was the production of the cordite required as a propellant. This explosive has been used by the British Government since 1889, and had been manufactured by the Canadian Explosives Company at Beloeil in small quantities for the rifle ammunition required by the Militia Department. It is made from a mixture of Gun Cotton and Nitro-glycerine, both of which must pass rigid tests as to the quality, and a mineral jelly. The Gun Cotton and Nitro-glycerine are first mixed together, then kneaded with a solvent of Acetone and Alcohol and the mineral jelly added to form a dough. This dough is extruded through dies, under pressure of about 3,000 lbs. per square inch, in the form of cords, from which the material gets its name. The cordite is then dried to remove the solvent, inspected and divided into batches, each batch being tested in a gun to determine its ballistic properties, a test that involves a complicated determination of pressure and velocities, which are also dependent on the temperature and humidity at the time. The whole process is a highly scientific one from start to finish. It involves great danger and extraordinary precautions are required, on account of the extreme sensitiveness and inflammability of the material, to avoid explosion and accidents and to safeguard the lives of those engaged. This work was undertaken by the Canadian Explosives Company, who completed an extension to their plant at Beloeil in April, 1915, of 300,000 lbs. per month capacity. Another plant was commenced in March, 1915, at Nobel, which, in September of the same year, reached its maximum capacity of 1,500,000 lbs. per month. Later on, a second plant at Nobel was completed in August, 1917, with a capacity of two million pounds per month, and these plants, together with those subsequently erected by the Board, turned out over fifty-four million pounds of cordite and forty-eight million pounds of nitro cellulose during the course of the war. The same firm also erected a loading plant at Vaudreuil early in 1915, in which the ammunition was loaded and assembled, which attained a maxiumm output of 22,000 rounds per 10-hour day, and erected a similar plant at Nobel, with about the same capacity, which was in operation from October, 1915, to August, 1916. They also assembled about 15,000,000 primers at Vaudreuil and in all this work it is a pleasure to be able to report that the quality of their product has compared most favorably with that furnished by any other country.

With the exception of some forgings purchased in the United States, the only parts of the shells so far contracted for that were not entirely made in Canada were the copper driving bands and the brass discs from which the cartridge cases were drawn. A proportion of the discs were made by Brown's Copper and Brass Rolling Mills, but their capacity was not sufficient for the entire requirements and the copper and spelter used by them were purchased from the States. While large quantities of both copper and zinc were mined in Canada, no refineries were in existence to produce these metals in a suitable condition for use and we were entirely dependent on the United States for our requirements. Some uncertainty also existed

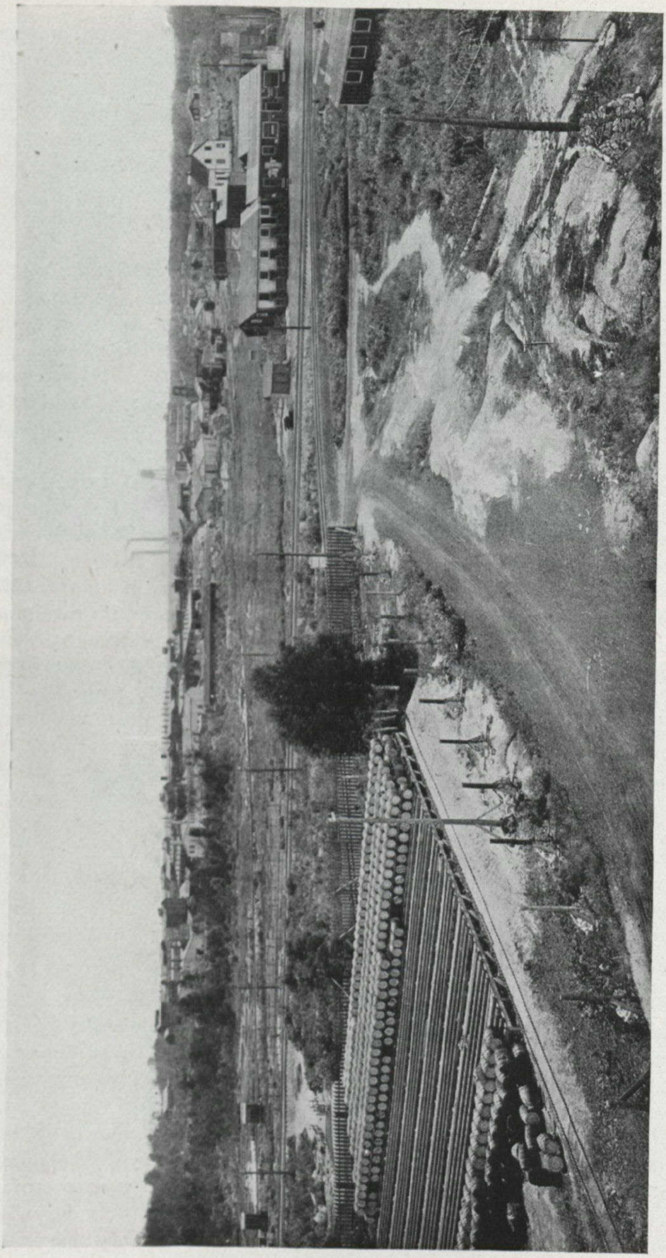


Fig. 41. Canadian Explosive Co's., old plant.

in the early part of 1915 as to what position that country might take regarding the exportation of such materials for war purposes. A Commission was formed consisting of Colonel D. Carnegie, Dr. A. G. W. Wilson and Dr. A. Stansfield, who recommended a contract entered into with the Consolidated Mining and Smelting Company of Canada, Limited, under which they installed electrolytic refineries at Trail for both copper and zinc. In this undertaking they were entirely successful and obtained productions of 500 tons of copper and 1,500 tons of zinc per month, both being of excellent quality and perfectly satisfactory for making cartridge brass. The Committee also made a contract with the Dominion Copper Products Company to install the machinery and equipment for making cartridge brass discs and copper bands. Figs 42 and 43 show two views of the plant. With the additional capacity later provided for, this contract required an output of 800,000 discs and 500 tons of copper bands per month. This output was exceeded and, through this arrangement, there were produced in Canada over ten million discs, weighing 35,000,000 lbs. and 19,000,000 bands, weighing 23,000,000 pounds, which would otherwise have been purchased abroad. This plant also installed copper melting furnaces with a capacity of 35 tons of copper per day, in which over 10,000 tons of the scrap resulting from the turning of the copper driving bands has been refined and converted back into new bands or ingot copper with a corresponding saving in expense.

A similar initiation of a new industry was accomplished in connection with the manufacture of trinitro-toluene. When Col. Carnegie was in England, in December, 1914, he was asked by Lord Moulton, Chairman of the Explosives Committee, what coke oven capacity was available in Canada for the production of toluol. The matter was investigated and it was found that the Dominion Coal Co. was coking 750,000 tons annually, which would enable them to produce 15,000 to 20,000 gallons of toluol per month. It was estimated that the necessary plant could be completed in six months. Mr. Plummer, the President of the Company, interested himself actively in the project and obtained the valuable assistance of Mr. Edison in the construction of the Toluol plant while the Canadian Explosives Company were concurrently erecting a plant at Beloeil for the manufacture of trinitro-toluene, or T.N.T., from the toluol with a capacity of 675,000 lbs. per month. The first T.N.T. was actually produced on May 23rd, slightly under four months from the time the undertaking was commenced. This industry, producing the high explosive which became almost exclusively used towards the latter periods of the war, attained very large proportions. Other plants for the production of toluol were installed, one at Toronto Chemical Company, and the Canadian Explosives Company erected a T.N.T. plant at Shand, B.C., with a capacity of 1,250,000 lbs. per month and the Imperial Munitions Board one at Trenton with a capacity of 1,200,000 lbs. per month, the total quantity produced being over 55,000,000 pounds.

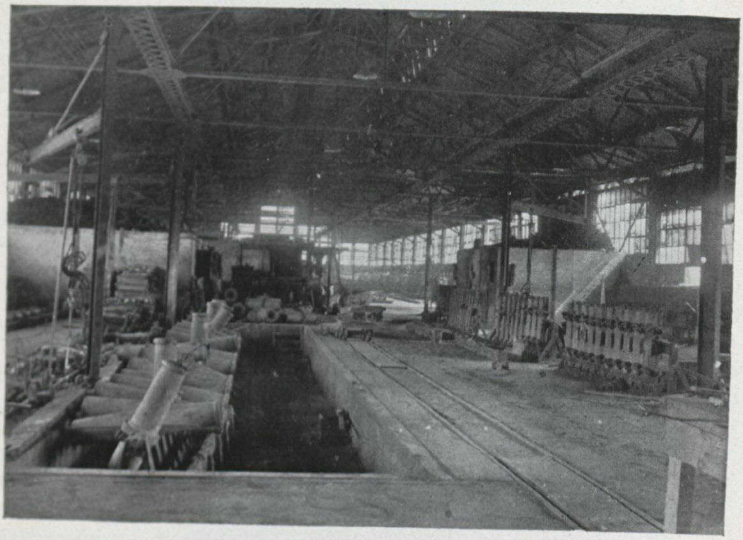


Fig. 42. Dominion Copper Products Co., Ltd., Cast House

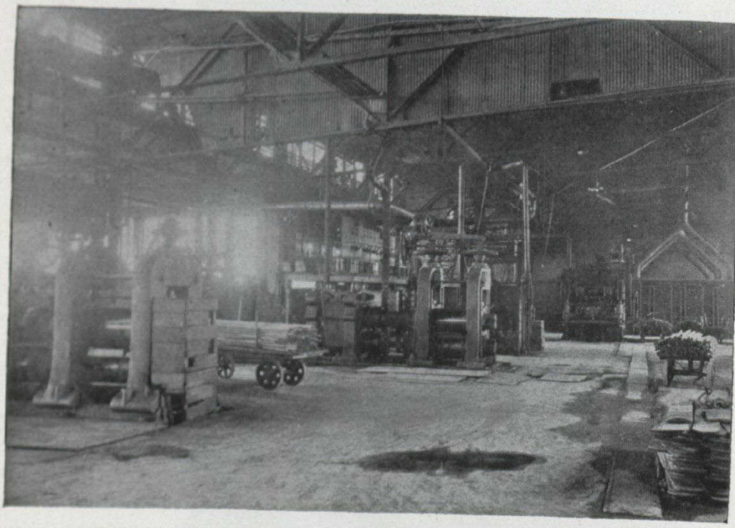


Fig. 43. Dominion Copper Products Co., Ltd., Rolling Mill.

A number of other contracts were let, such as the one for five million fuses and those for small arms ammunition and a quantity of other materials, but the work I have described may fairly be considered as the accomplishment of the original Shell Committee and it constitutes an achievement for which I sincerely believe they deserve the gratitude of every Canadian, both for the employment it afforded to our people at home and the assistance it rendered to our Armies overseas. The energy displayed by the Canadian Manufacturers enabled shipments of shells to be made at a time when they were seriously needed, a vital factor during the dangerous periods in 1915 when both the British troops and our own were so terribly short of ammunition, and I have been creditably informed, although I cannot absolutely vouch for the statement, that the first shells supplied by any firm that had not previously produced them were from Canadian workshops.

I do not wish to pose as claiming any credit for the Shell Committee that has not been accorded them but I do not believe that the difficulties of the work they undertook or the ability with which they carried it out is generally recognized. They made their mistakes, but these were of minor consequence compared to their success in establishing a great industry in a wonderfully short time. One point I wish to refer to, about which I consider there is considerable misapprehension, is in connection with the prices they paid for the work which are popularly thought to have been high. There were only three methods in which it could have been handled —by the Government furnishing the money for the plant and paying the Contractor for the output, by letting the work on a " cost plus " basis or by letting the work at a price which would enable the contractor to pay for his plant provided he successfully completed his contract. The last was the one adopted as, apart from any other consideration, the War Office insisted that the manufacturer must both assume the entire responsibility and finance the project. The other plans have both been employed in the last year or two, but they depend for successful results on the interest and patriotism of the manufacturer while the last one put him in a position where he must make good, or lose not only what profit he may have estimated he could make on his contract, but the money he has invested in his plant. To justify a man taking work under these conditions, that involved the completion of a contract for a novel class of product in large quantities by a definite date, liberal prices were a necessity to enable him to spend money freely to obtain his output and increase his plant without regard to cost, looking only at the main question of fulfilling the specified deliveries. This is just what occurred. The Munitions Manufacturer, in the early days, aimed at one thing only and that was output and this is shown in the results he obtained. It is true that the work was carried out as a commercial proposition and every manufacturer had to aim at a commercial success, for the people that would invest their money in a munition enterprise with the expectation of losing it, when they could satisfy their patriotism by purchasing a government loan with an assured return, were scarce and hard to find. At the same time most of those engaged in munition work, both owners and operators had friends or relations at the front and put an energy and interest into their work which had never been approached in ordinary experience. The money was well spent and subsequent events have proved that the policy adopted not only got results quickly, but got them cheaply and probably more cheaply than they could have been obtained in any other way.

Figure 44 shows the prices for each order of shrapnel shells and the upper horizontal line shows the average price. The lower horizontal line shows the average price paid less an estimated allowance for the cost of the machining capacity required for the maximum output divided by the total number of shells made. A plant for machining 1,000 shrapnel per day costs about $75,000.00, so that for 60,000 per day the investment is $4,500,000.00. Dividing this by 34,000,000 (the number of shells made) the cost of plant averages 13c. per shell so that the average price, exclusive of plant, is $1.77, or very slightly over the price reached after two years' experience. This figure for the cost of the plant is quite conservative and does not include buildings or starting and experimental expense, which amounted to from 50 to 100 % of the plant cost in the case of the small shells and from 20 to 50% for the larger.

Figures 45 to 50 give the same information for various sizes of shell and you will note that the prices at the commencement of the order, in which the cost of the plant is included, show a very similar relation to the price finally arrived at and these prices on the later types of shells were established after considerable experience had been gained in actual manufacturing costs, while the Shell Committee were dependent entirely on estimates. I believe these figures show conclusively the good judgment which, on the whole, the Committee exercised in the letting of contracts, and, when you realize that the prices they submitted were accepted and approved by the War Office, that they technically undertook the responsibility for the execution of these contracts at the prices so determined and that they returned to the War Office $34,000,000 out of a total of $340,000,000 which they were authorized to spend, I think you must agree with any praise and recognition I have been able to render them.

During the summer of 1915, Mr. D. A. Thomas, afterwards Lord Rhondda, visited Canada and investigated our capacity for producing an increased quantity of munitions. He was agreeably surprised at the progress that had been made here and the manner in which the work was conducted. As a result, the Ministry of Munitions, which in England had taken over from the War Office the work of providing the supply of munitions, decided to considerably increase the amount ordered in Canada and, in doing so, naturally thought it advisable to supersede the Shell Committee, which was actually a small group of manufacturers, neither incorporated nor chartered, by a branch of their own organization. Mr. L. Hichens and the Hon. R. H. Brand were sent over and, on the 1st December, 1915, Mr. (afterwards Sir) Joseph W. Flavelle, Mr. (afterwards Sir) Charles B.

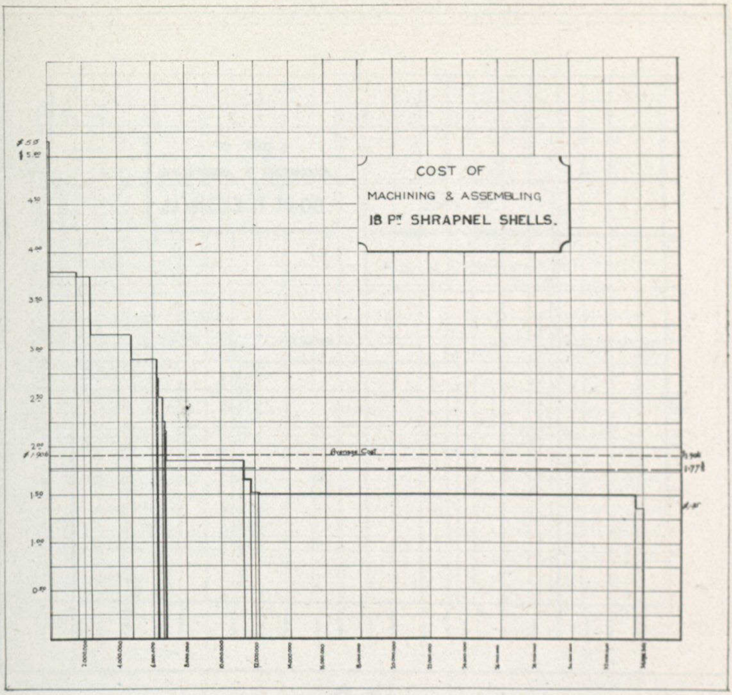

COST OF
MACHINING & ASSEMBLING
18 Pr SHRAPNEL SHELLS.
Average Cost

Fig. 44.

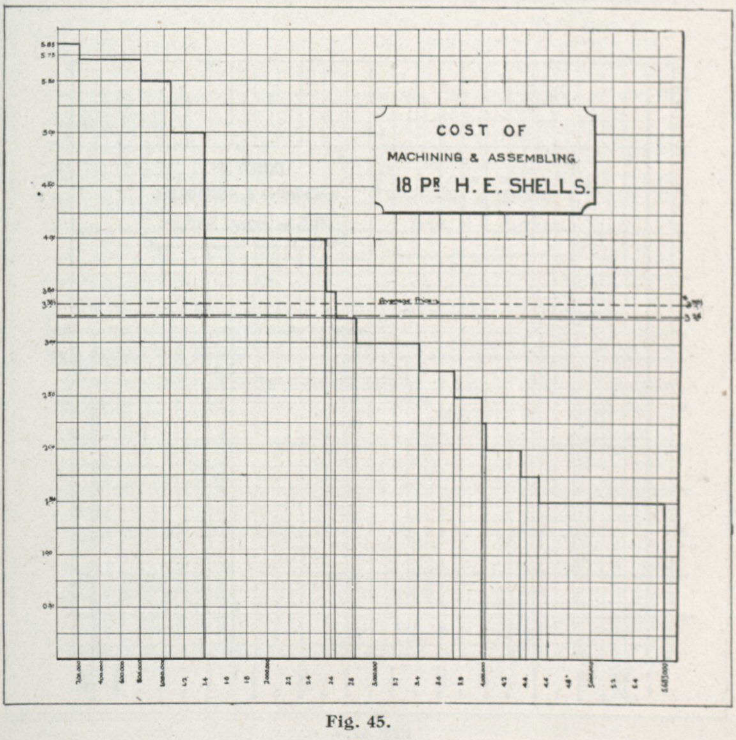

COST OF
MACHINING & ASSEMBLING
18 Pr H. E. SHELLS.
Average Cost

Fig. 45.

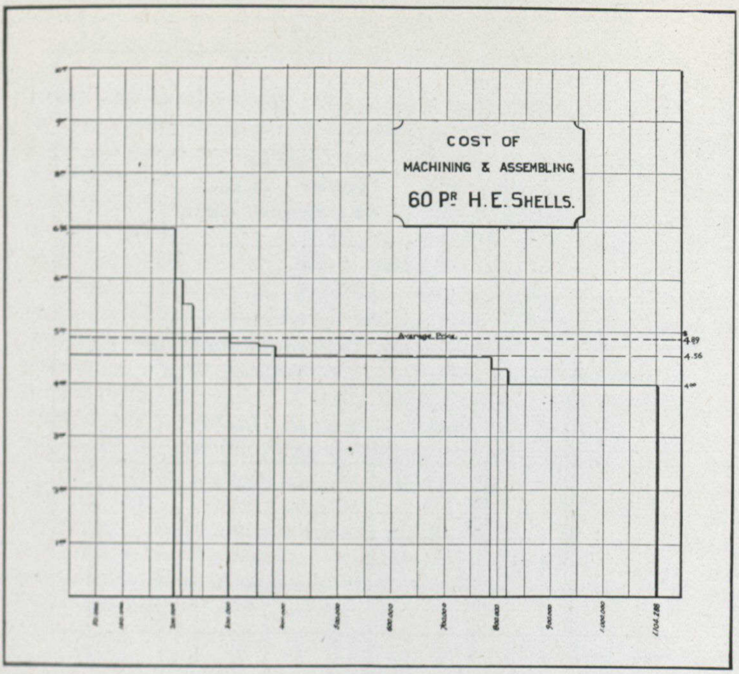

COST OF
MACHINING & ASSEMBLING
60 Pr. H. E. SHELLS.
4.89
4.56

Fig. 46.

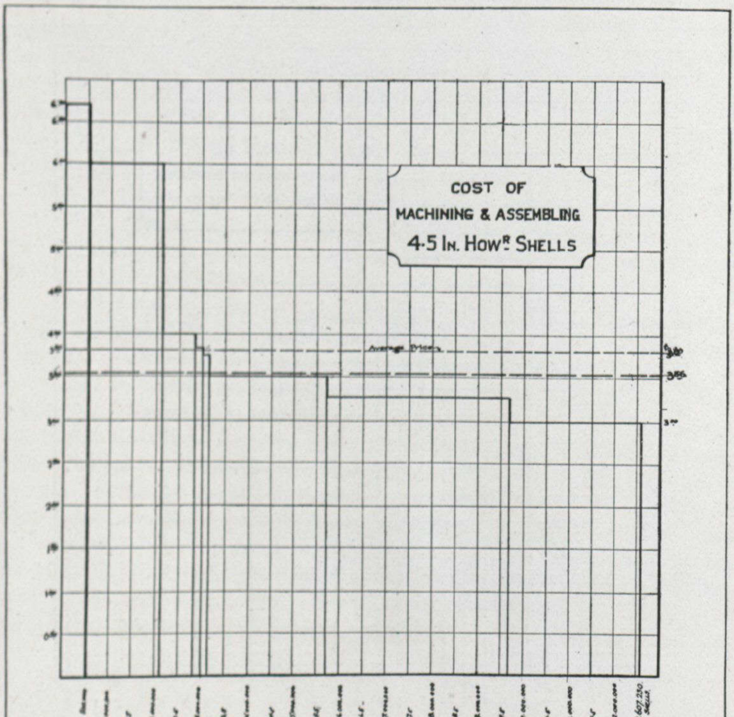

COST OF
MACHINING & ASSEMBLING
4·5 IN. HOWR. SHELLS

Fig. 47.

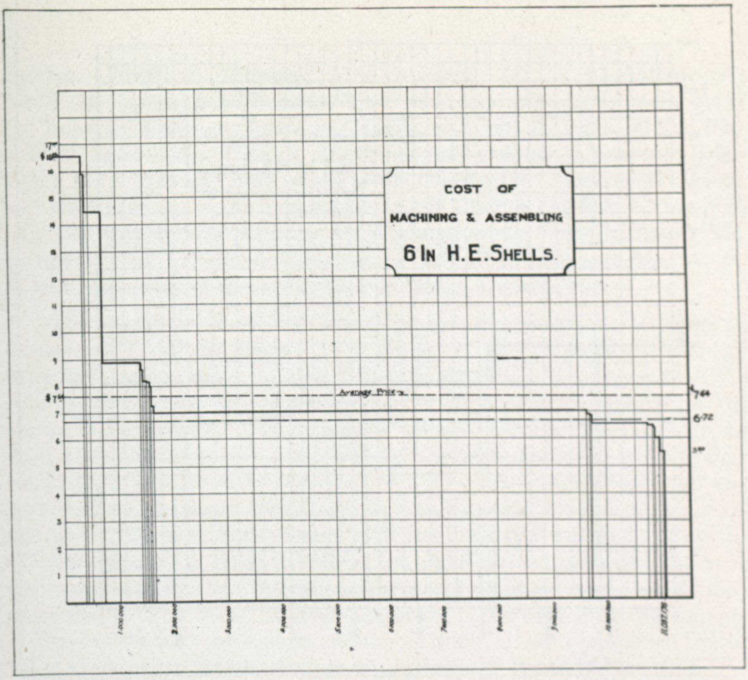

COST OF
MACHINING & ASSEMBLING
6 IN H.E. SHELLS.
Average Price
7.64
6.72
1,000,000
2,000,000
3,000,000
4,000,000
5,000,000
6,000,000
7,000,000
8,000,000
9,000,000
10,000,000

Fig. 48.

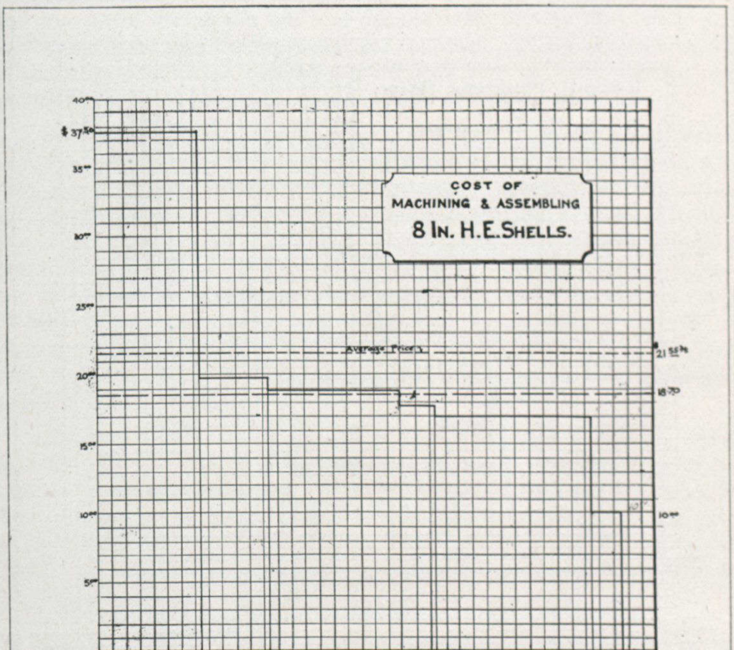

COST OF
MACHINING & ASSEMBLING
8 IN. H.E. SHELLS.
Average Price
$ 37.50
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
18.70
10.00
100,000
200,000
300,000
400,000
500,000
600,000
700,000
753,921

Fig. 49.

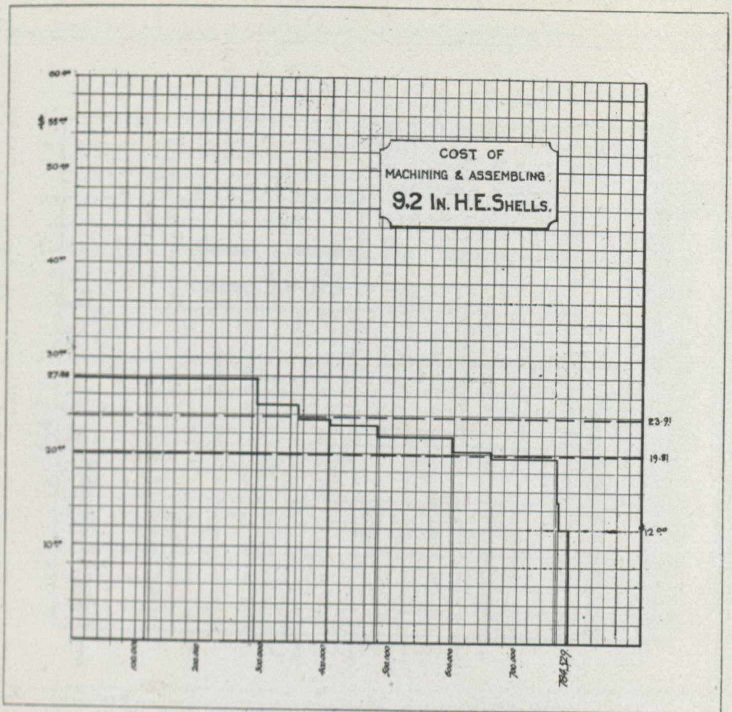

COST OF
MACHINING & ASSEMBLING
9.2 IN. H.E. SHELLS.
23.91
19.81
12.00

Fig. 50.

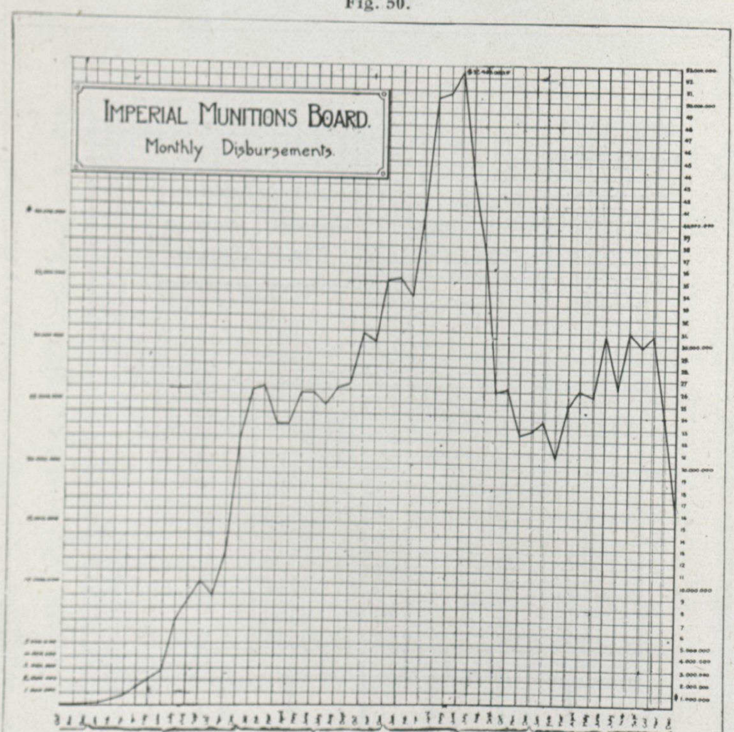

IMPERIAL MUNITIONS BOARD.
Monthly Disbursements.

Fig. 51.

Gordon, Colonel D. Carnegie, Mr. F. Perry, Mr. J. A. Vaillancourt, Mr. G. H. Dawson and Mr. E. R. Wood were appointed as the members of the Imperial Munitions Board of Canada with Mr. E. Fitzgerald as Purchasing Agent. The Hon. R. H. Brand and Colonel (afterwards Brig.-Gen.), W. E. Edwards were added to the board later. Sir Joseph Flavelle was the Chairman of the Board and, on Sir Charles Gordon leaving it to join the British War Mission at Washington as Vice-Chairman, Mr. Fitzgerald was appointed Assistant to the Chairman and Mr. A. G. Woodhouse assumed charge of the Purchasing Department.

The appointment of the Board placed the munitions industry in Canada on a rational basis. As a branch of the Imperial Ministry of Munitions, orders could be placed that would utilize the resources of the country to the best advantage and render its capacity available for the service of the Empire. The increasing volume of work undertaken by the Shell Committee had far outgrown their organization and, in fact, they would have been severely criticized had they attempted to develop any such staff as the Board found necessary to, properly supervise their transactions. The Munitions Board, with the authority vested in it by the Ministry, was in a position to build up an organization commensurable with the magnitude of their operations on sound business lines, which they proceeded to do at once. The advantages of this arrangement were amply justified in the next three years and this, I think, is best exemplified by the value of the orders which were placed through the Board in that time.

Figure 51 shows the monthly disbursements of the Shell Committee and the Board during the war and demonstrates vividly that, while the shell Committee laid the foundation for the work, the organization of the Board carried it to the successful conclusion that so fully engaged our capacity.

Prior to the formation of the Board, the Shell Committee had placed orders for a 60-pounder H.E. shell Fig. 52 which was very similar to the 4.5-inch, being simply a little larger in every way. This shell introduced no special difficulties that had not already been encountered in the 4.5-inch but, as a matter of record, I have prepared Figures 54 and 55 showing the monthly output and that obtained from individual firms. As the diagram shows, the output was quite irregular which was chiefly caused by the difficulty in obtaining the forgings. New equipment for machining had to be obtained but few delays were experienced on this account and the production of the shell as a whole was comparatively easy and the quantities required were not large.

The next shell for which orders were placed was the 6-inch H.E., which subsequently became one of our principal products. Negotiations for its manufacture had been carried out in the summer of 1915 and a number of firms had laid out plants and obtained options for their machinery. Definite orders were, however, delayed pending the formation of the Board with the result that, when they were finally placed, machinery was more difficult

OMISSION.--In the statement of the names of the members of the Imperial Munitions Board the name of Brig.-Gen. Sir Alex. Bertram, Vice-Chairman of the Board, was omitted.

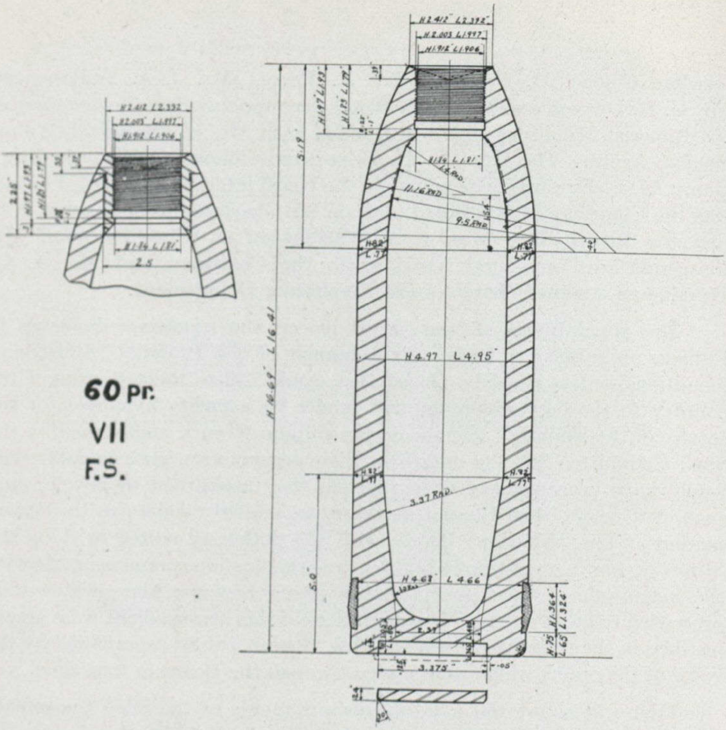


Fig. 52.

Fig. 53. Reproduced from British Official Photo.

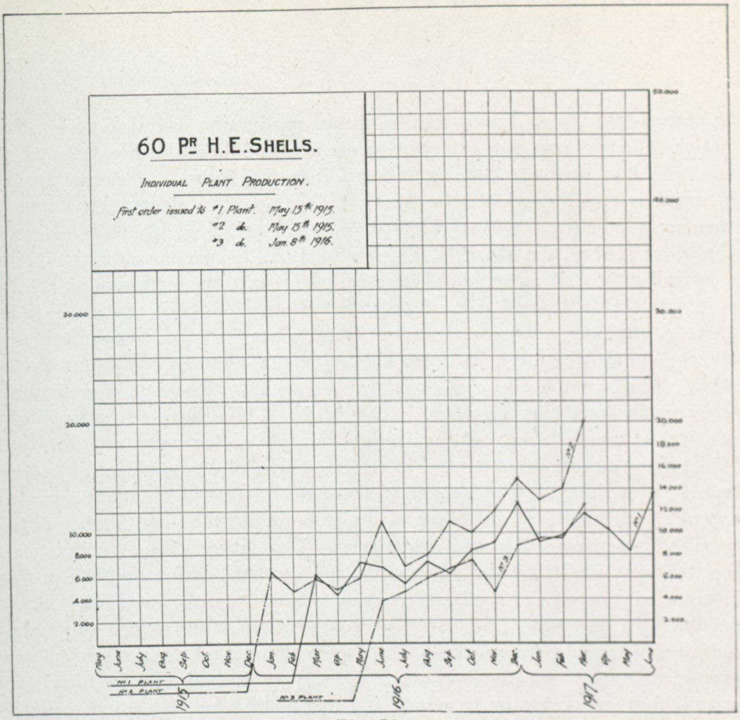
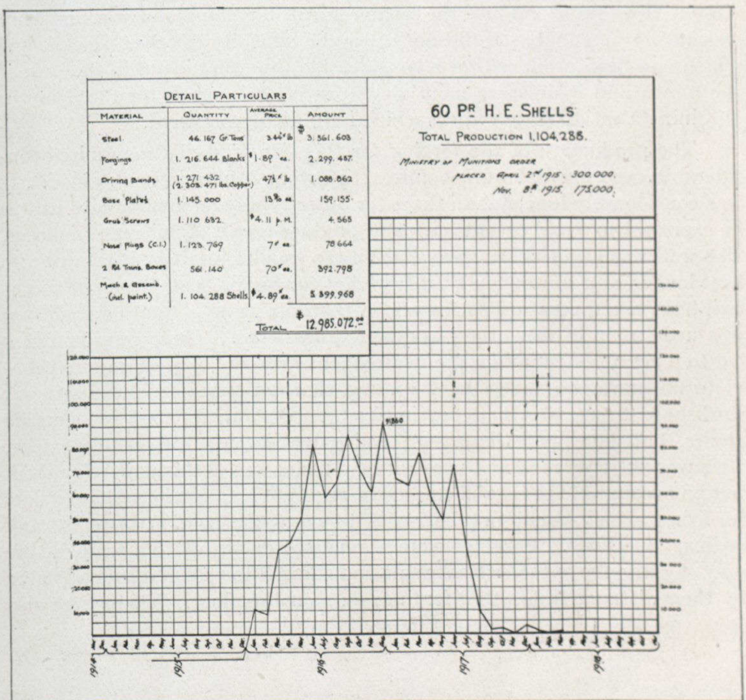


Fig. 54.



Material	Quantity	Average Price	Amount
Steel	46. 167 Gr. Tons	3.44¢ lb	$ 3. 361. 603
Forgings	1. 216. 644 Blanks	$1.89 ea.	2. 299. 487
Driving Bands	1. 271 432 (2. 303. 471 lbs. Copper)	47½¢ lb	1. 088. 862
Base Plates	1. 145. 000	13⅞ ea.	159. 155
Grub Screws	1. 110 632.	$4. 11 p. M.	4. 565
Nose Plugs (C.I.)	1. 123. 769	7¢ ea.	78 664
2 Rd. Trans. Boxes	561. 140	70¢ ea.	392. 798
Mach & Assemb. (incl. paint.)	1. 104. 288 Shells	$4. 89¢ ea.	5 399. 968
		Total	$ 12.985.072.00

Fig. 55. No. 1 Plant — E. Leonard & Sons, London. No. 2 Plant — E. Long Mfg. Co., Orillia. No. 3 Plant — Munitions & Machinery Co., Toronto.

to obtain and it was impossible to obtain production as quickly as anticipated. The first orders for this shell were for the Mark XVI Fig. 57, in which the nose is a separate forging screwed into the body. This was shortly afterwards superseded by the Mark III, a nosed-in shell, which was in turn superseded by the Mark IX Fig. 56. The principal difference between the Mark III and the Mark IV consists in the addition of a seat for the gaine containing the detonator found necessary to ensure the explosion of T.N.T. and, while this change was made in all the shells about the same time, greater difficulty was experienced in forging the 6-inch nose to obtain the correct amount of metal to form the gaine seat than in any other size of shell. The 6-inch shell for a considerable time gave, I believe, more trouble than all the rest put together. The Mark XVI difficulties were chiefly caused by inexperience and an irregular supply of forgings, but the Mark III and its modified successors were the source of a great deal of serious trouble and delay. The length of the shell increased to an unexpected extent the difficulty of obtaining a proper bore and the maintenance of the specified tolerances for wall thickness. The larger diameter increased the difficulty of fitting the baseplates to a perfect bearing and the proper internal contour of the shell after nosing was not readily obtained. These peculiarities had been fairly well overcome when it developed that more rigid requirements for workmanship were demanded on account of the premature explosions that had occurred, a type of accident so serious in its results that every factor to which it can possibly be attributed must be most carefully avoided, Fig. 53 gives an idea of the result of this in a 4.5-in. How. gun. While the requirement for improved workmanship was entirely justifiable, it did not cause the difficulty in other sizes of shell which had been produced for a considerable time that it did in the case of the 6-inch and it deserves mention as one of the reasons for the delay in obtaining a satisfactory output which indubitably occurred.

The production of the forging for this size of shell also required considerable experimental work before satisfactory results were obtained. It was considerably longer than those for other types and greater care had to be exercised to avoid eccentricity and produce a wall of uniform thickness. The wall was also thicker than that on the smaller forgings, it retained its heat longer, and consequently, if forged at too high a heat, the metal might cool from a temperature so far above the critical point that its condition was unsuitable to meet the physical requirements. These considerations led to a great education on the microscopic structure of steel and its behaviour under various methods of cooling, that not only introduced into our workshops terms that had previously been only understood in scientific circles, but developed the art of cooling metals to a remarkable extent. This was not only rendered necessary by the design of this particular shell, but on account of the careful treatment required by a good deal of the steel furnished which could not be made to meet the specifications by any ordinary methods. Forgings were normalized or heated to a temperature only slightly above the critical point and allowed to cool at a rate adjusted by their distance from other forgings on a cooling floor. There were also

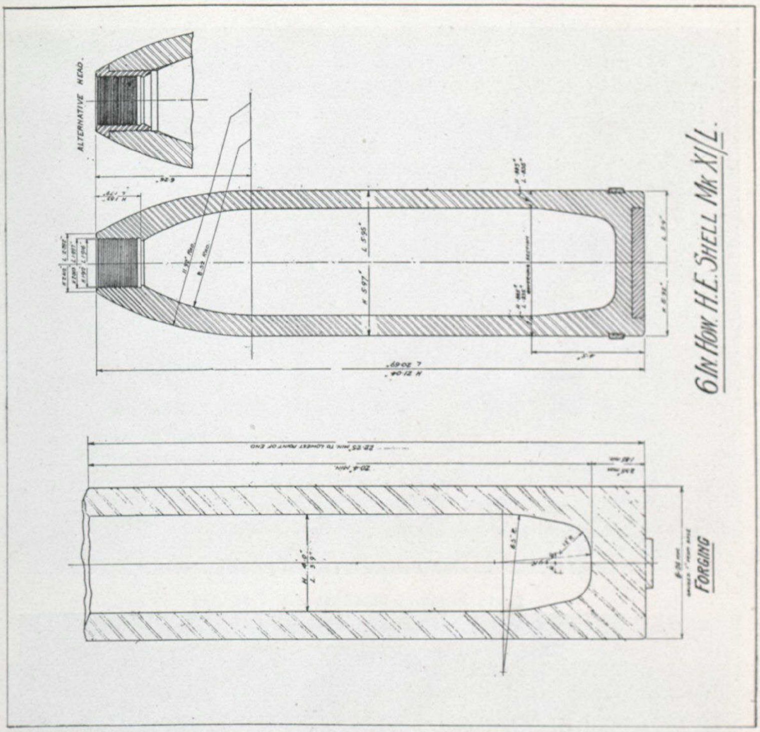


Fig. 56.

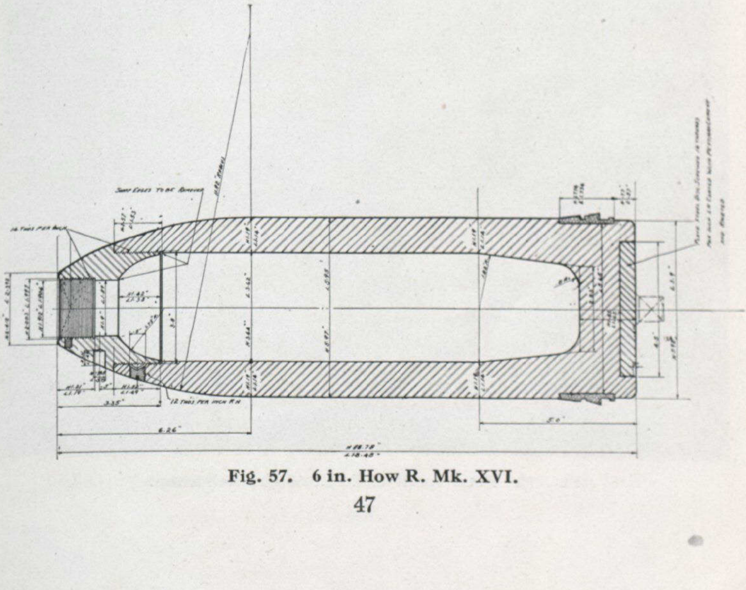


Fig. 57. 6 in. How R. Mk. XVI.

Fig. 58. Dominion Bridge Co's., 60 Pr Shell Shop.

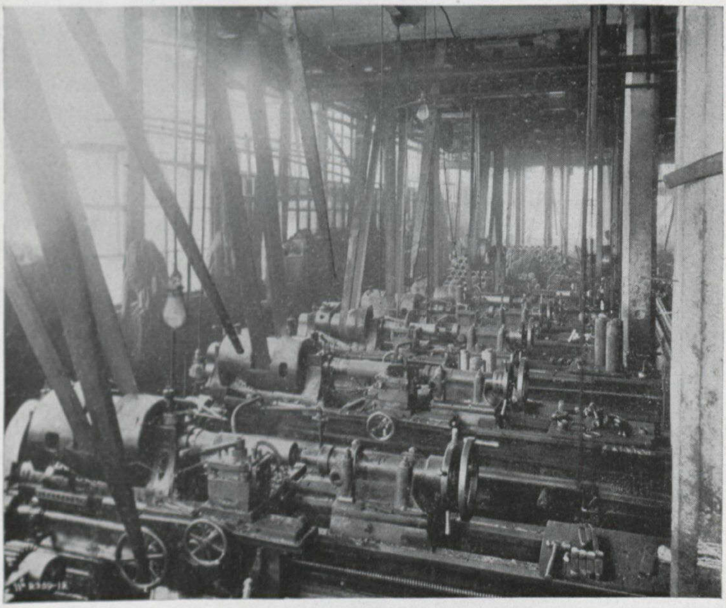


Fig. 59. Peter Lyall & Co's., 60 Pr Shell Shop.

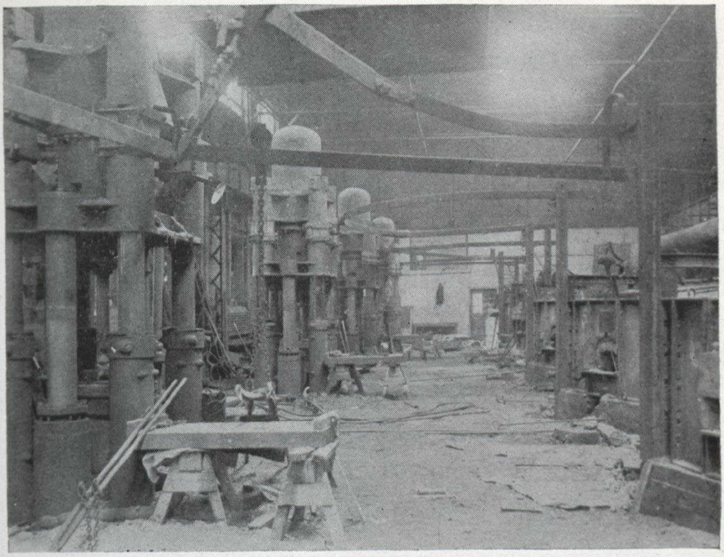


Fig. 60. 6 inch Shell Forging Plant.

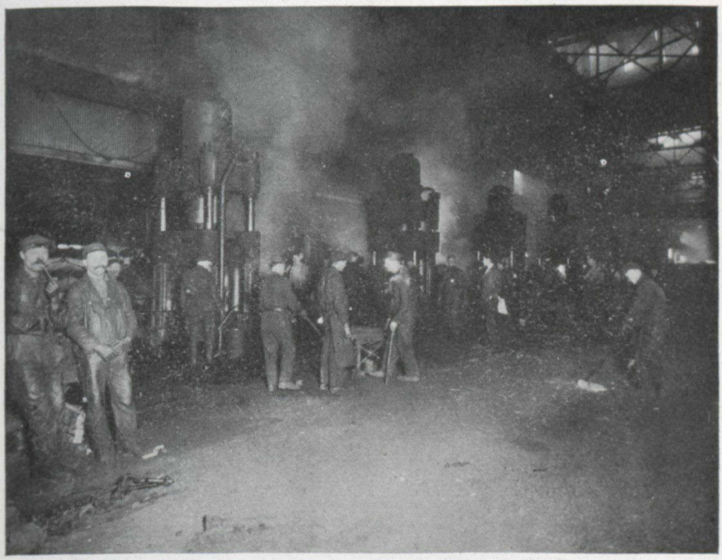


Fig. 61. Canada Car & Foundry, Forg Dept., Forging 6 inch Shells.

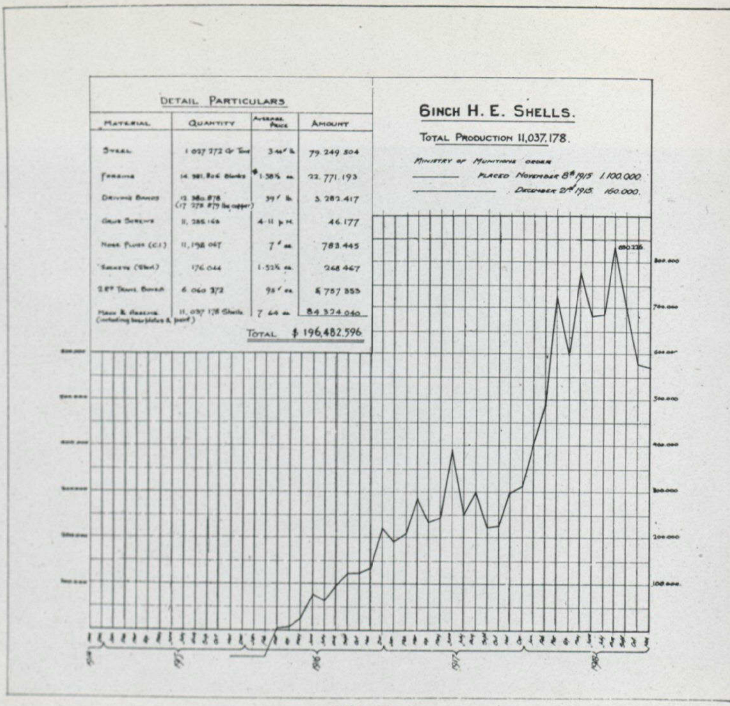


Fig. 62.

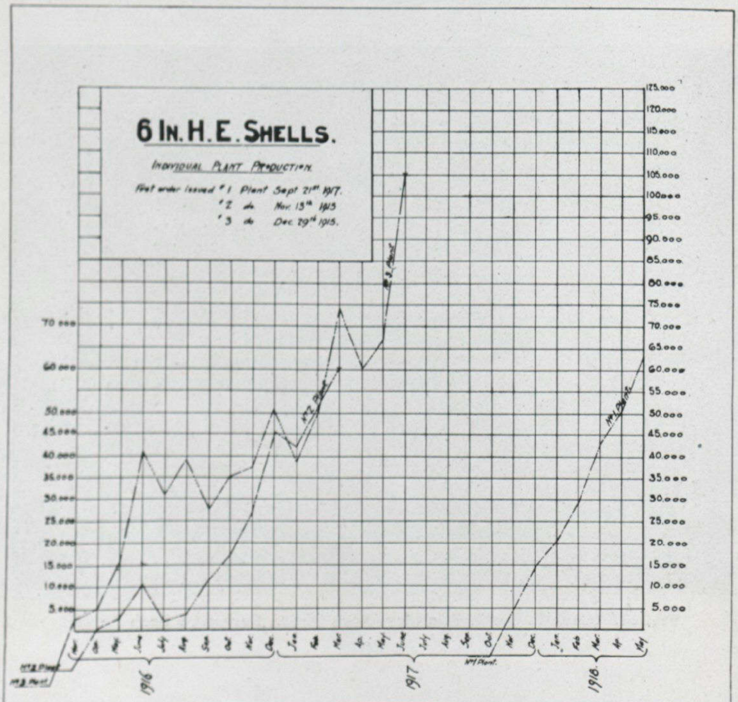


Fig. 63. No. 1 Plant — Leaside Munitions. No. 2 Plant — Peter Lyall Construction Co. No. 3 Plant — Montreal Locomotive Co.

Fig. 64. Montreal Locomotive Co's., 6 in. Shell Shop.

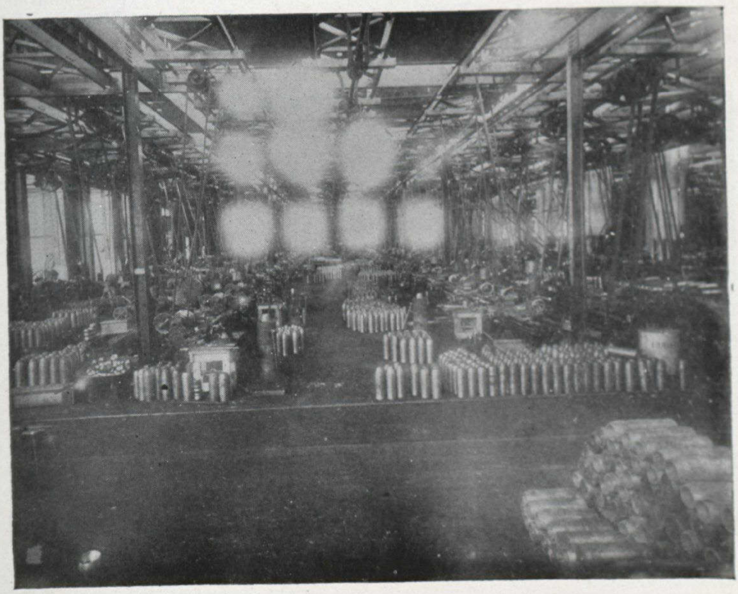


Fig. 65. Montreal Locomotive, 4.5 Shell Shop.

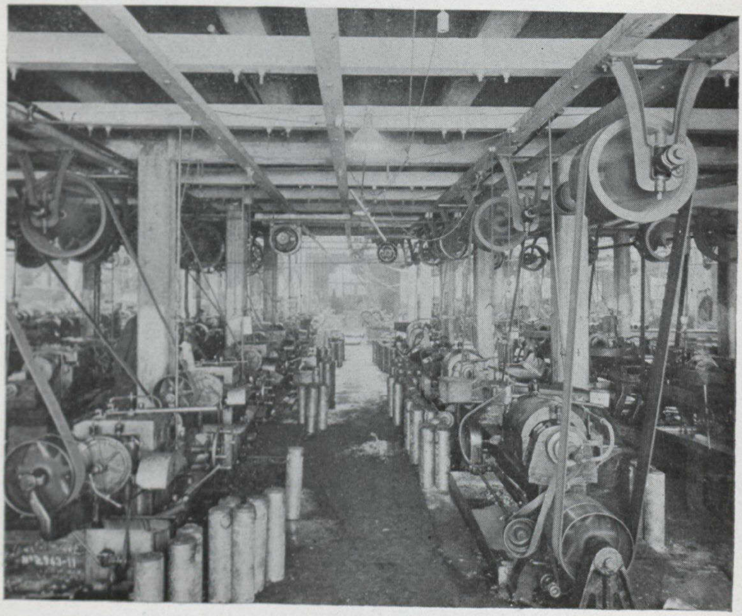


Fig. 66. Peter Lyall & Co's., 6 in. Shell Shop, Westmount Plant.

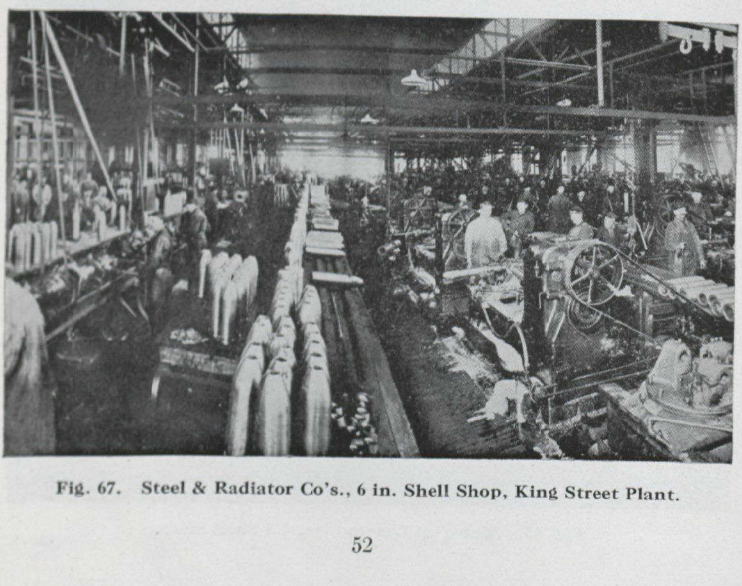


Fig. 67. Steel & Radiator Co's., 6 in. Shell Shop, King Street Plant.

air-cooled, first by high pressure air, under a process introduced by Mr. Sandberg, and subsequently by a process using low pressure air in which advantage was taken of the fact that the transfer of heat varies with the speed at which the current of air passes over the surface of the hot body, which enabled a fan blast passing through a special apparatus to control the rate of cooling to any desired extent. Such methods were actual advances over anything previously employed and in some plants the metallurgist would actually determine from the composition of the steel the spacing between the forgings in special cooling sheds that would best obtain the desired physical qualities.

When the various plants concerned did, however, overcome these troubles, the production grew rapidly and the value of the output of 6-inch shells was greater than that of any other size. The total output is shown by Figure 62, while Figure 63 shows the output for some of the individual firms during the earlier period which is very creditable when it is considered that new plants had to be installed in every case.

The next sizes of shells undertaken by the Board were the 8-inch and the 9.2-inch, which are practically alike in design, but entirely different to any of those previously described. The body of the shell is forged to the finished shape and a plug or adapter is screwed into the bottom of the shell to form the base. These shells were considerably larger than any of the earlier sizes, the 8-inch shell Fig. 68 weighing 200 lbs. and the 9.2-shell Fig. 69, 290 lbs., compared with 100 lbs. for the 6-inch. Entirely new plants for both forging and machining were required and in one case, that of the Canada Cement Company, a new steel making plant was installed as well. While these shells appear more difficult to produce than some of the smaller sizes, experience showed that, with a sufficiently heavy class of machinery, their manufacture could be quickly reduced to a satisfactory basis. The firms engaged on this work undoubtedly handled it with great ability and the results were correspondingly good. Figure 70 shows the total output, and Figure 71 that of some individual firms for 8-inch shells, and Figure 72 and Figure 73 the corresponding output for the 9.2-inch. The quantity of 8-inch shells was limited by the requirements and the maximum output of 9.2-inch shells in the early part of 1917 was reduced on account of lack of orders, but, when the size of this shell is considered, the installation of the plant and the development of such an output is evidently a piece of work of great importance.

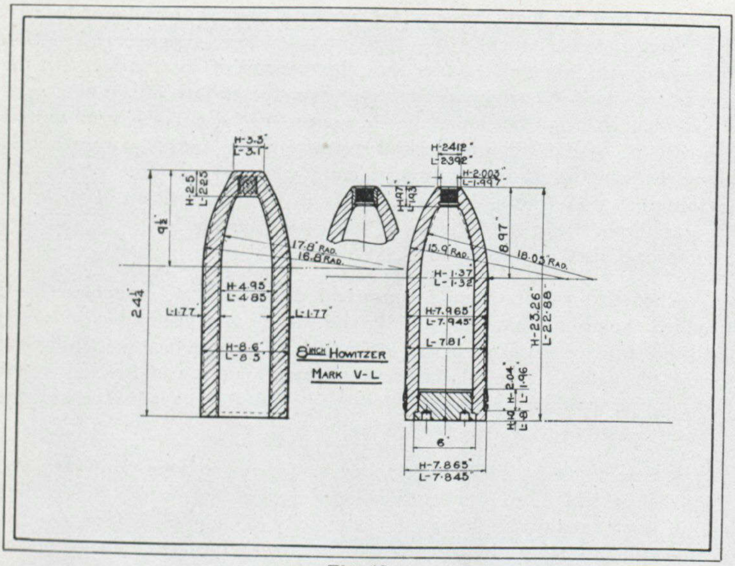


Fig. 68.

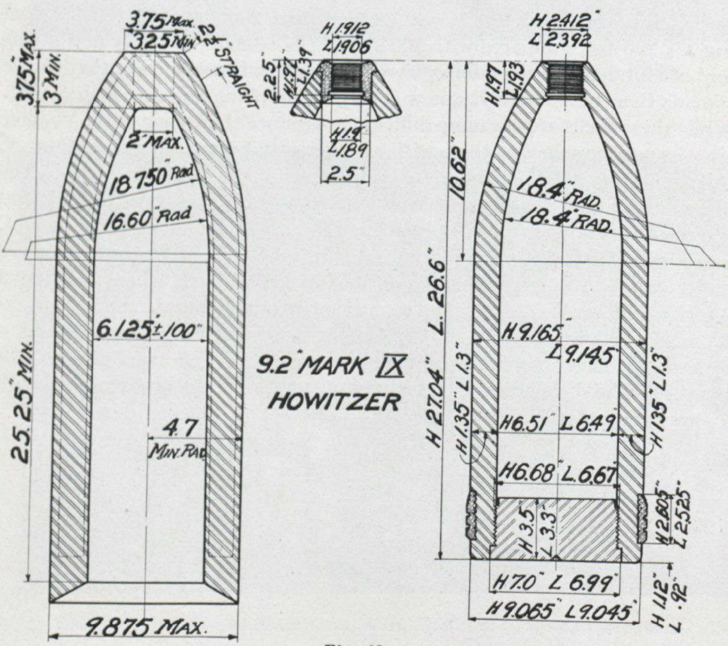


Fig. 69.

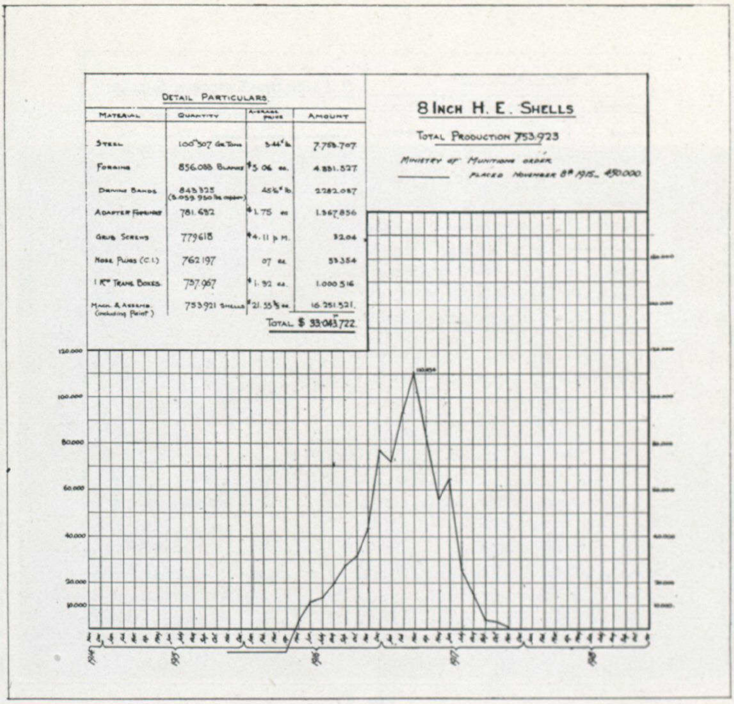


Fig. 70.

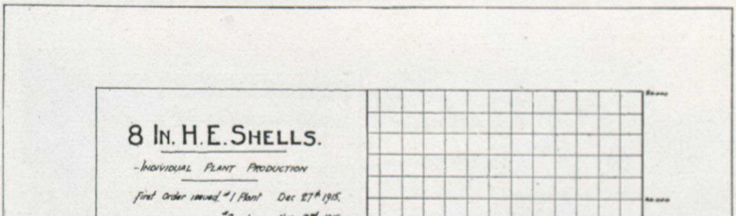


Fig. 71. No. 1 Plant — Can. Fairbanks Morse Co., Toronto. No. 2 Plant — Can. Ingersol Rand Co., Sherbrooke. No. 3 Plant — Universal Tool Steel Co., Toronto.

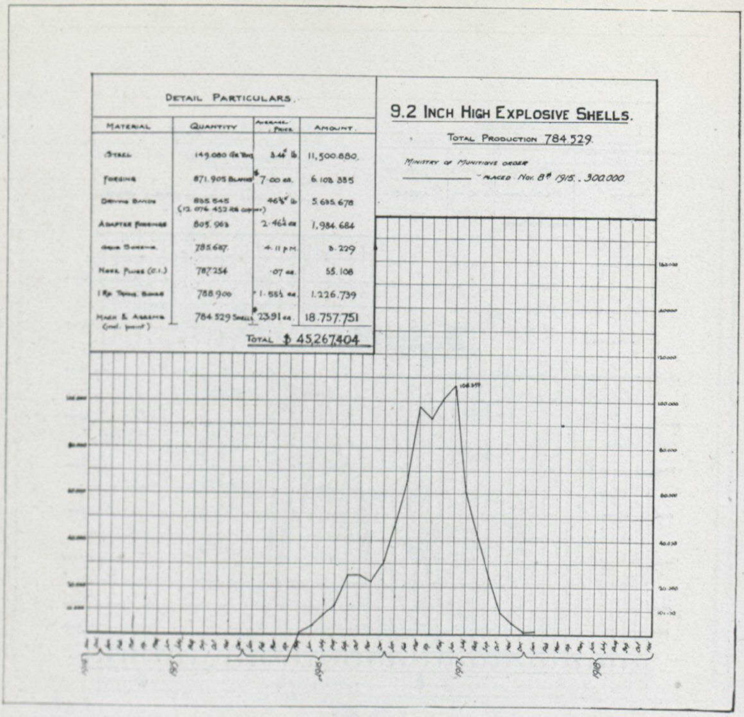


Fig. 72.

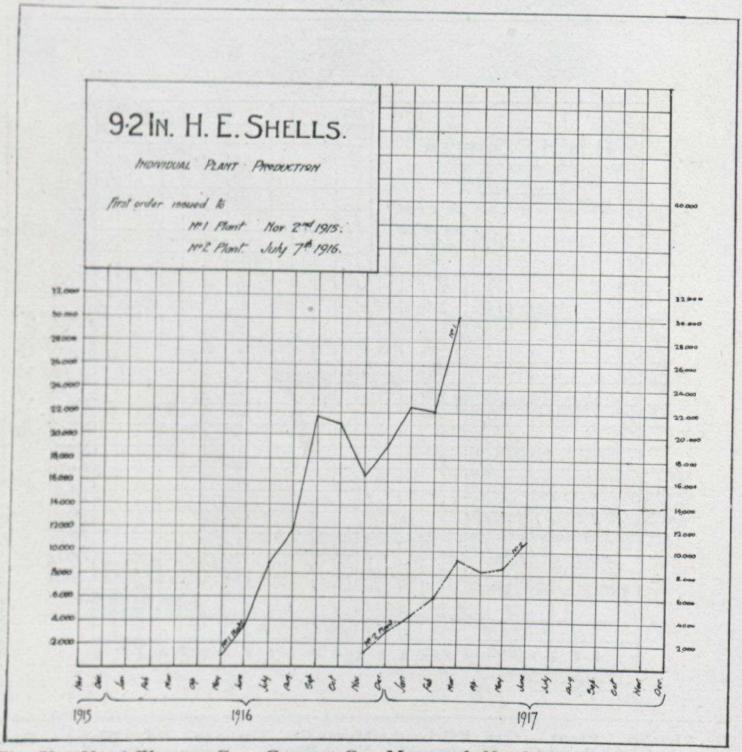


Fig. 73. No. 1 Plant — Can. Cement Co., Montreal, No. 2 Plant — Fisher Motor Co., Orilia.

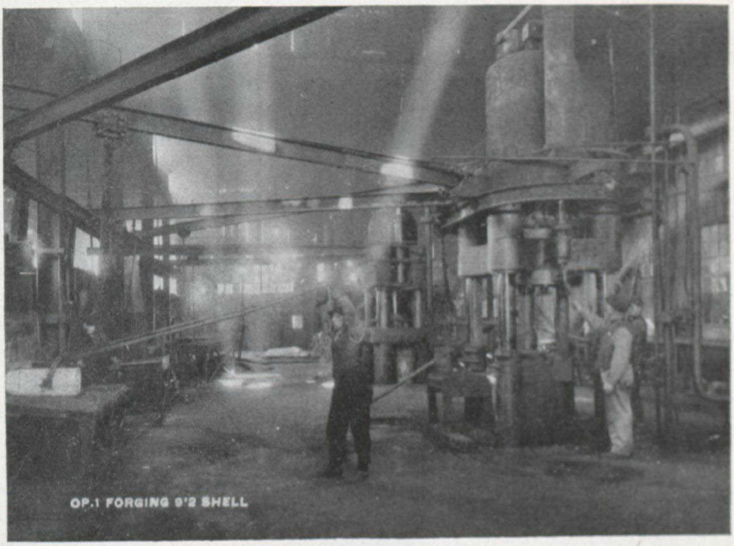


Fig. 74. Forging 9.2 inch shells.

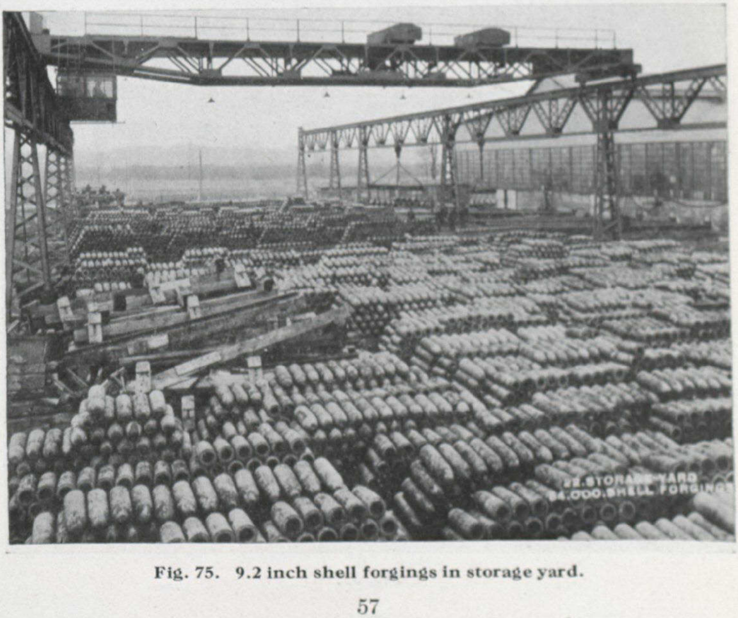


Fig. 75. 9.2 inch shell forgings in storage yard.

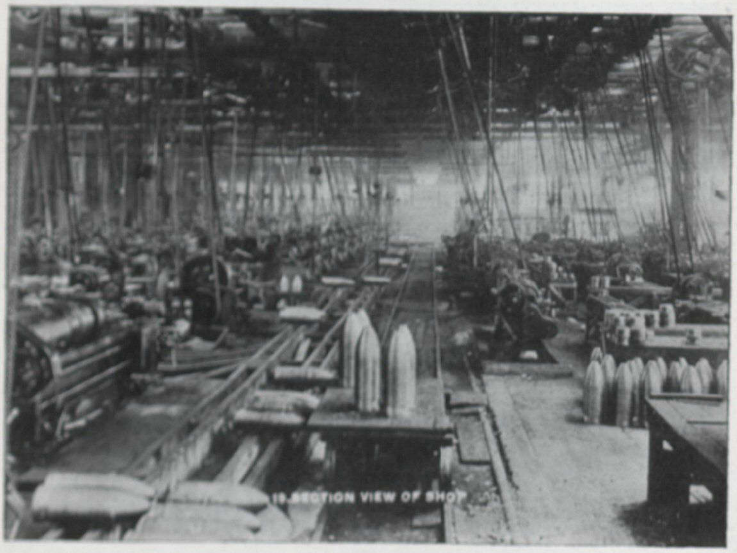


Fig. 76. 9.2 inch shell shop, St. Lawrence Bridge Company.

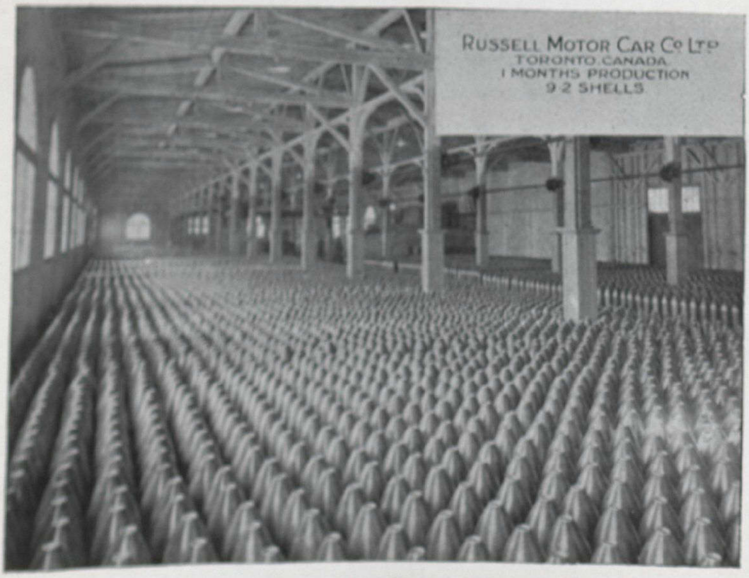
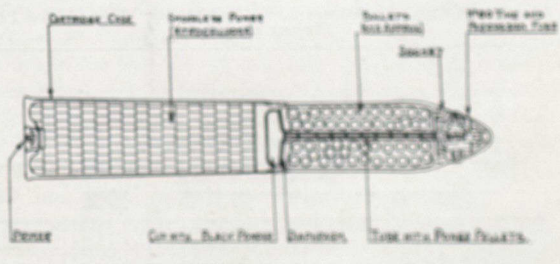


Fig. 77.

While I have discussed the orders for certain sizes of shells as being placed either by the Shell Committee or the Board, it must, however, be clear from the diagrams I have shown that the Board also continued to develop the production of all sizes and varieties of ammunition, in many cases in greatly increased quantities. One interesting feature of the output is shown in Figures 78 and 79, which gives the production of 18-pounder fixed ammunition For a considerable period this averaged 350,000 round per week, most of which was shipped direct to France ready for immediate use in the guns. Another fact that indicates the quantity of munitions produced is that during 1917 Canada manufactured 55 per cent of the 18-pounder shrapnel, 42 per cent of the 4.5-inch, 27 per cent of the 6-inch, 20 per cent of the 60-pounder, 15 per cent of the 8-inch and 16 per cent of the 9.2-inch shells obtained by the British Government, a fact which is remarkable when the enormous production in Great Britain and her extensive purchases in the United States are considered.



The BRITISH 18PR SHRAPNEL SHELL

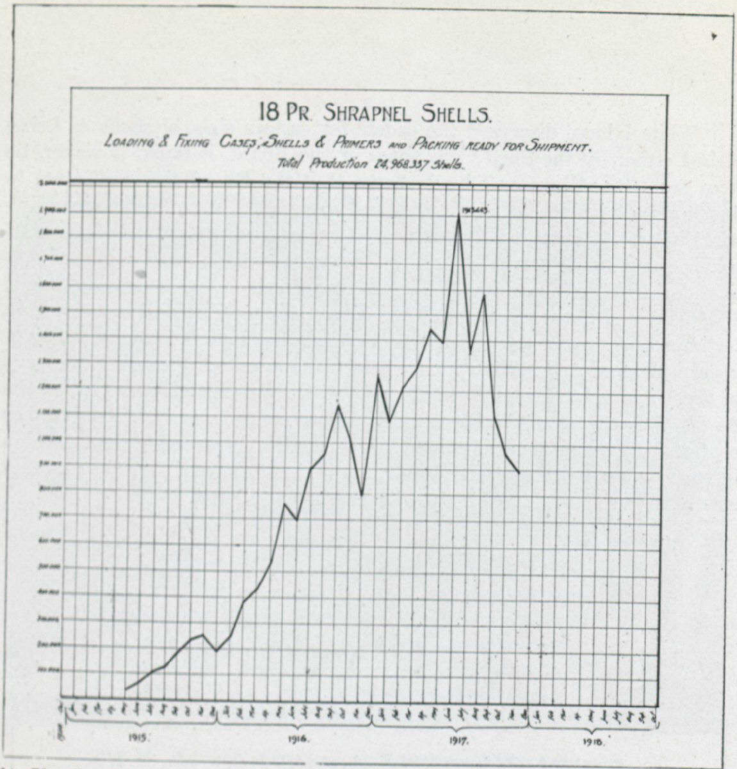


Fig. 78. Loaded at Can. Explosives Ltd., Vaudreuil. Can. Nitro Products Co., Mount Dennis.

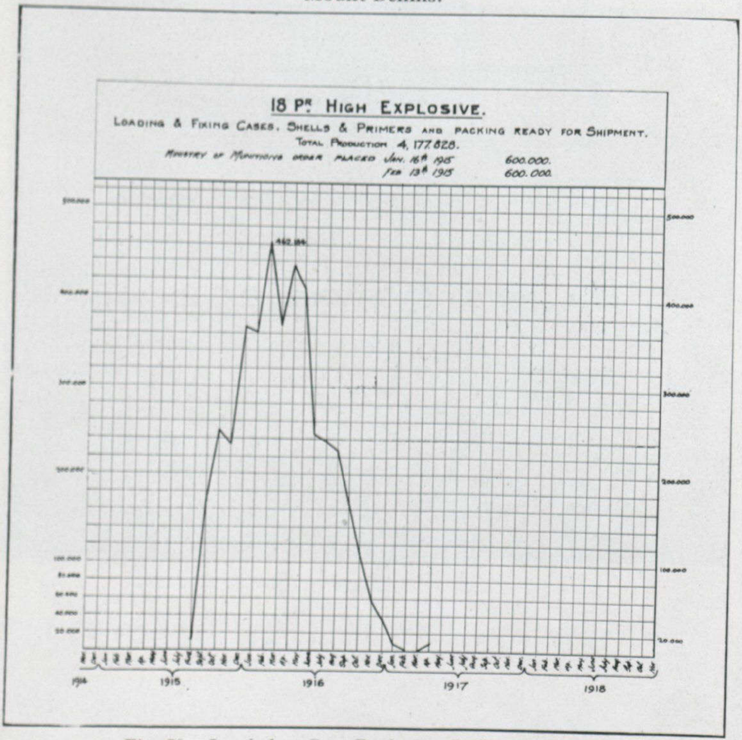
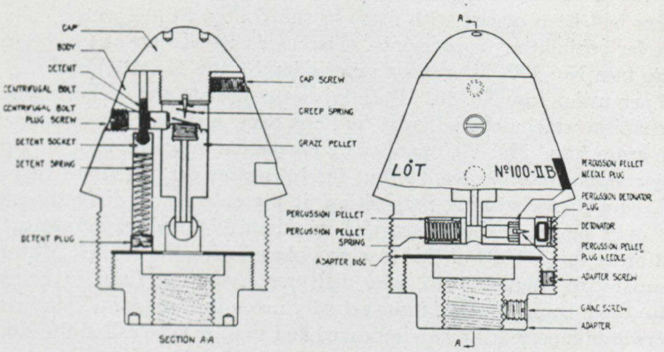


Fig. 79. Loaded at Can. Explosives Ltd., Vaudreuil.

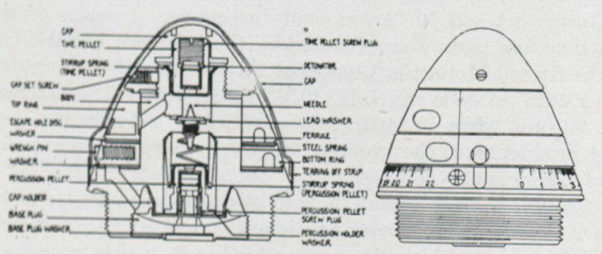
Up to the end of 1915, no fuses had been produced in Canada although orders had been placed with firms in the United States whose deliveries were far behind the requirements. The fuses needed were of two types, the graze fuse No. 100 (afterwards superseded by the No. 101) and the time and percussion fuse No. 80. Both types are delicate and accurate pieces of mechanism which demand great skill and experience in their manufacture. The graze fuse, Fig. 80, operates by percussion only and is of far simpler construction than the No. 80, but the tolerances permitted are very close and, as a manufacturing proposition, it presents many difficulties which can only be overcome by careful workmanship and experiment. The first order for 500,000 of this fuse was placed with the Russell Motor Car Company in August, 1915, who delivered their first fuses in February, 1916, these being the first fuses actually made in Canada. This fuse was afterwards superseded by an improved and simpler type called the No. 101, which was produced in large quantities, the total number made by the Russell Company and other firms who engaged in the work being 9,829,898.

The time and percussion fuse, Fig. 81, is more difficult to produce than the No. 100. It is far more complicated as it contains 52 separate parts and the tolerances permitted are still closer, in some cases the allowance being only half of one thousandth of an inch. The inspection of this fuse is most elaborate, which is well illustrated by Fig. 83, which shows the 162 gauges which are used. Probably a comparison of the relative difficulty of making this fuse and the No. 100 is best illustrated by the experience of the Russell Company that for every 100 operatives engaged in producing the No. 100 fuse, 28 Company Inspectors and 5 Government Inspectors are required, while for the No. 80 fuse the corresponding figures are 50 Company Inspectors and 10 Government Inspectors. In spite of these difficulties, time fuse parts were produced by the Northern Electric Company and the Russell Motor Car Company, with whom orders were placed in December 1915, in June and July, 1916, respectively. The machining of the No. 80 fuse, while an intricate proposition, is actually the easiest part of its production. The greatest technical difficulty occurs in its loading and assembling. This fuse can be set to explode the shell at any time up to 22 seconds after leaving the gun by setting a graduated ring on the outside of the fuse to the correct position. The accuracy of this timing depends on the rate at which the gunpowder burns, which is packed in grooves in the face of the timing rings, and as it is of vital importance to control the time and, consequently, the range at which the shell bursts, the degree of accuracy demanded is very great. From every lot of 4,000 fuses 1% are taken for a " rest test " or a test in the factory. The fuse is set to burn 22 seconds and all fuses must be accurate within 0.4 seconds. The result is automatically recorded on a chronograph which can be read to one twentieth of a second. Other fuses are then tested by actual firing, in which the absolute timing of a fuse is not as important as the uniformity of timing of any lot. With fuses set at 16 seconds, the difference between



The BRITISH CRAZE FUZE
Nº 100

Fig. 80.



The BRITISH TIME AND PERCUSSION FUZE
Nº 80

Fig. 81.

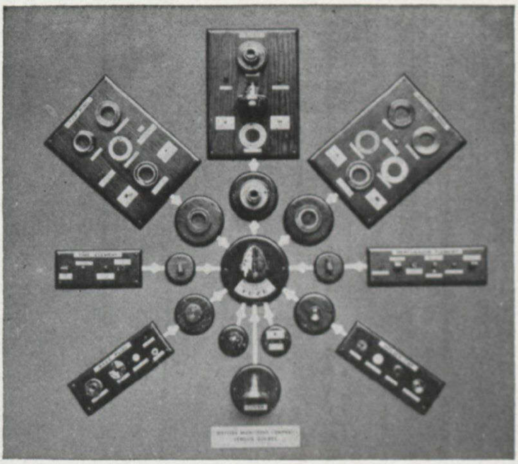


Fig. 82.

the fastest and slowest fuse in any lot must not exceed 6/10ths of a second, while with fuses set at 11 seconds the average variation from the mean must not exceed 0.12 seconds, the latter being the most important requirement.

When it is considered that the rate of burning of the powder varies with its grade, the humidity of the air, the barometric pressure and the temperature, that it is packed in the grooves under a pressure of 68,000 lbs. per square inch and that any variation in the form or accuracy of the groove has its effect the problem of loading and assembling was evidently one of great importance. After careful consideration the Board decided to erect its own plant for this purpose and enlisted the services of the Northern Electric Company to supervise its construction and operation. This plant, The British Munitions Company, was built in Montreal and operated by Mr. Hathaway, General Superintendent of the Northern Electric Company, who carried out his difficult task with the greatest success. The order to organize the Company was given on December 29th, 1915, the contracts for the buildings were let on Feb. 7th, 1916, and the first fuse was loaded, assembled and passed on June 17th. Mr. Hathaway had the advantage of the experience of the American Locomotive Company, who had been successfully handling this work on a direct contract with the British Government but this does not detract from the merit of this remarkable accomplishment. The plant is a model of its kind and shows most careful and scientific planning in its arrangements. It was organized for a capacity of 15,000 fuses per day and instructions were given in October, 1916, to enlarge it to 45,000 per day. It was not operated at this capacity, but over 40,000 fuses were assembled in one day in June, 1917, and in July 768,000 were assembled, an average of over 30,000 per day. The plant is the largest of its kind in the Empire and its operation, without any serious failure and without a single serious accident, is a noteworthy achievement. (Figs 86 to 90.)

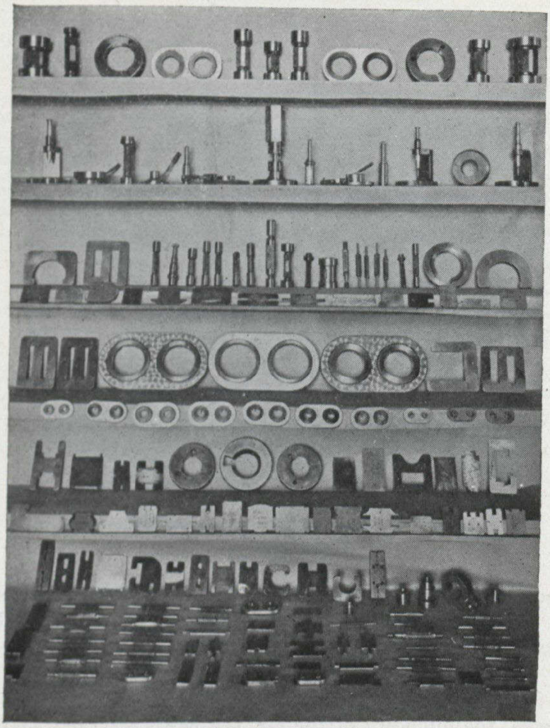


Fig. 83. Gauges Reqd for No. 80 Fuse.

Fig. 84. 250,000 Fuses awaiting shipment.

Fig. 85. Russel Motor Co., Machining Fuses.

Fig. 86 Russel Motor Co., Finishing Dept.

Fig. 87. British Munitions Co., Govt. Inspection Dept.

Fig. 88. British Munitions Co., Routing Dept.

Fig. 89. British Munitions Co., Soldering.

Fig. 90. British Munitions Co., Loading Dept.

During 1917 and 1918, the Board carried out on an extended scale the plan of installing its own plants for certain of its requirements, and converted or erected four large plants for explosive materials and one for steel making and forging.

British Acetones at Toronto was installed to manufacture Acetone and Butyl Alcohol by a process consisting of the conversion of corn by certain bacteria. The adjoining distilleries belonging to Messrs. Gooderham & Worts, and the General Distilling Company, were loaned to the British Government, free of cost, for this purpose. It was originally estimated that the plant would produce 300 tons of Acetone per annum and double that quantity of Butyl.

The process was so successful that plant was extended until latterly it was producing approximately 7½ tons of Acetone daily. As a result of experiments made by the staff a process was evolved whereby the Butyl Alcohol was converted, by catalytic action, into Methyl Ethyl Ketone, and, as this was proved to be a good substitute for Acetone in the manufacture of Cordite, a plant for this conversion was erected costing in the neighbourhood of $600,000. Methyl Ethyl Ketone was successfully produced at the plant before the Armistice was signed. The total cost of structural alterations, including the erection of the Methyl Ethyl Ketone Plant was approximately One Million Dollars, and from the commencement of operations 5,580,360 lbs. of Acetone and approximately 12,000,000 lbs. of Butyl Alcohol were produced.

British Chemical Company at Trenton was installed to produce the necessary Pyro Cotton for the manufacture of Nitro-cellulose Powder at the British Explosive Plant at Renfrew instead of purchasing it in the United States. This also involved the erection of a 60-ton Chamber Sulphuric Acid Unit and a plant to produce Nitric Acid. The plant was authorized and ground broken early in December, 1916. The construction work had hardly started when instructions were received to erect a T.N.T. Plant and Nitrocellulose Powder lines. This, of necessity, entailed the erection of a further Pyro Cotton Unit, another 60-ton Chamber Sulphuric Acid Plant and doubling the Nitric Acid Units. In May, 1917, six months after breaking ground, 450,000 pounds of Pyro Cotton and 380,000 pounds of T.N.T. were produced whilst the production of Nitrocellulose Powder began in July of that year.

The total expenditure on the Trenton Plant was approximately $5,000,000 and it produced 14,212,665 lbs. of Nitrocellulose powder and 13,980,000 lbs. of T.N.T.

British Explosives at Renfrew was leased from the O'Brien Munitions in December, 1916. The first shipment of Nitrocellulose was made on January 27th, 1917, and the total production from this plant amounted to 16,268,046 lbs.

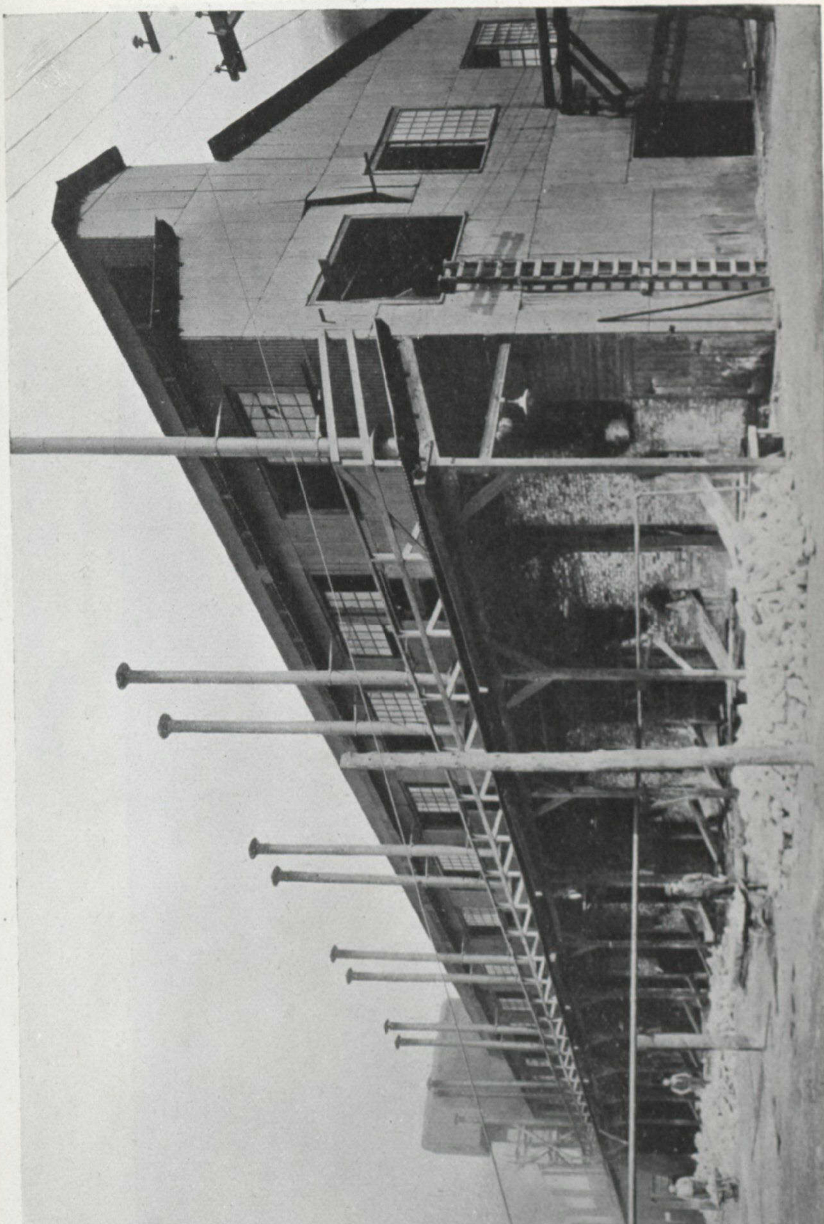


Fig. 91.

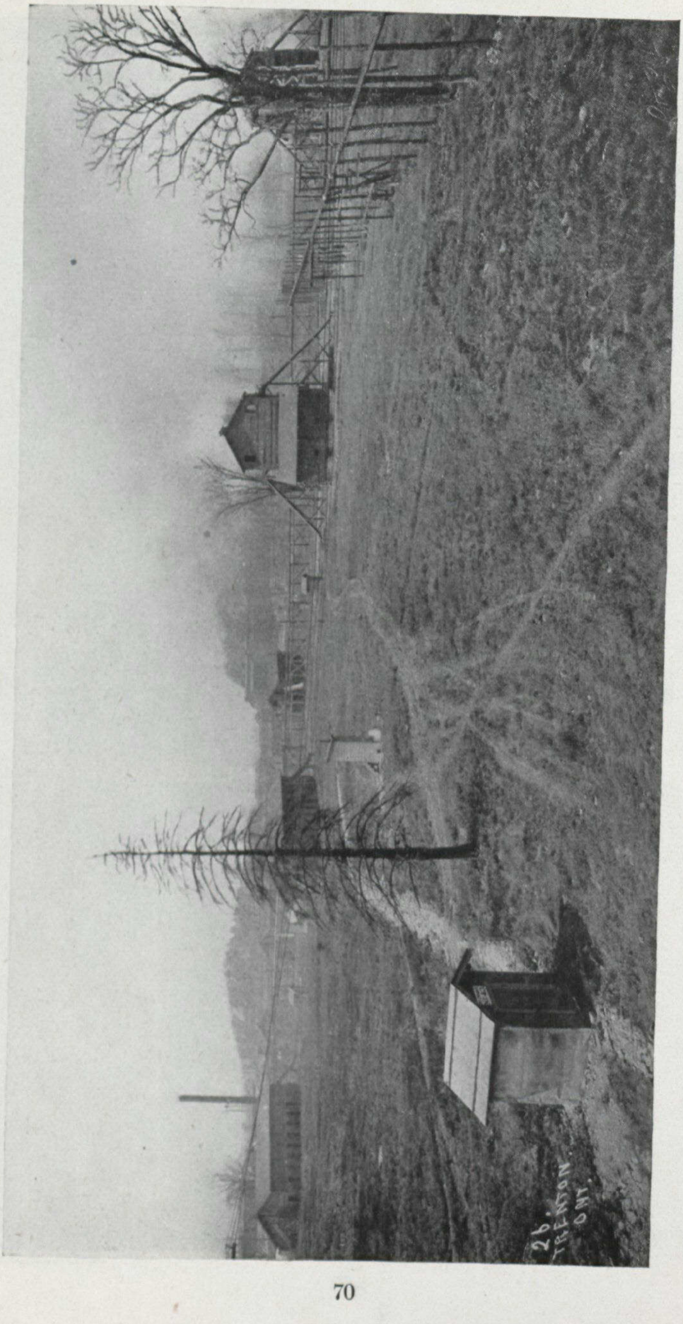


Fig. 92. Views of British Chemical Plant at Trenton.

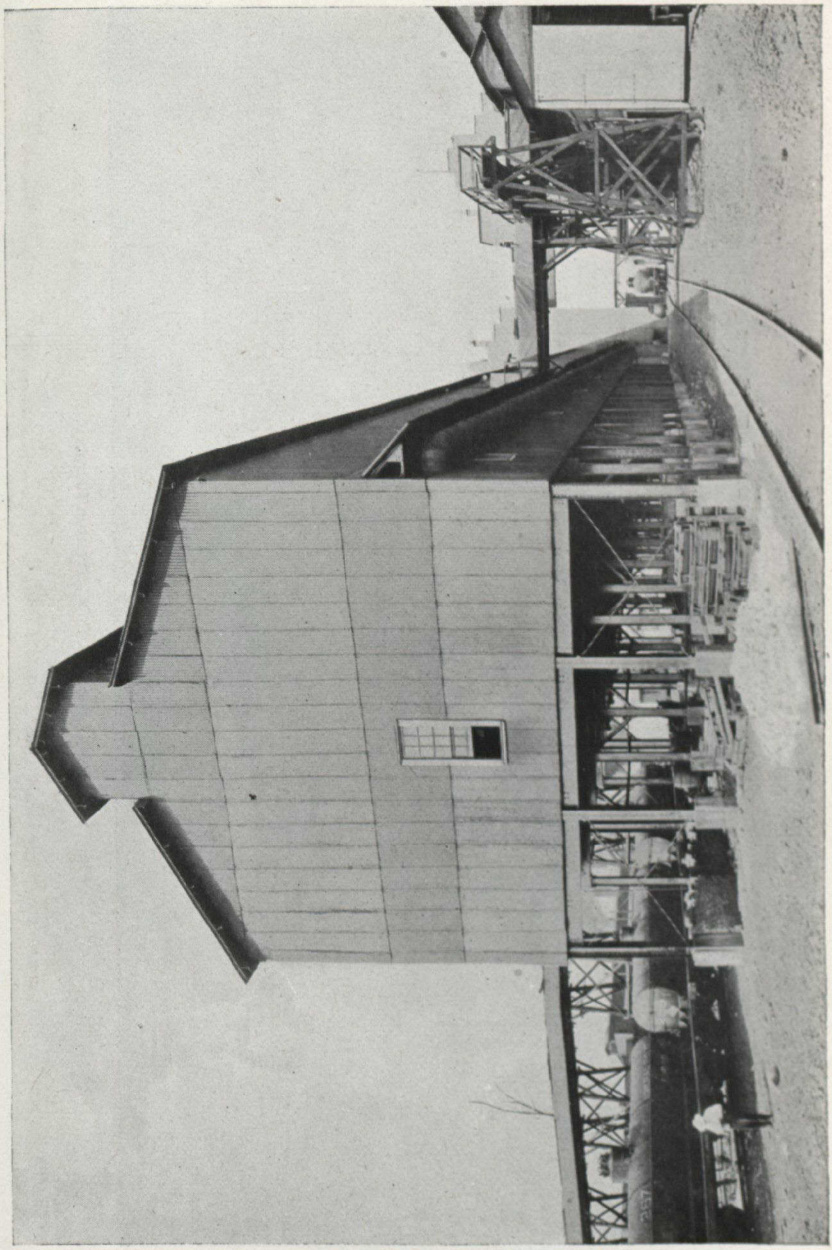


Fig. 93.

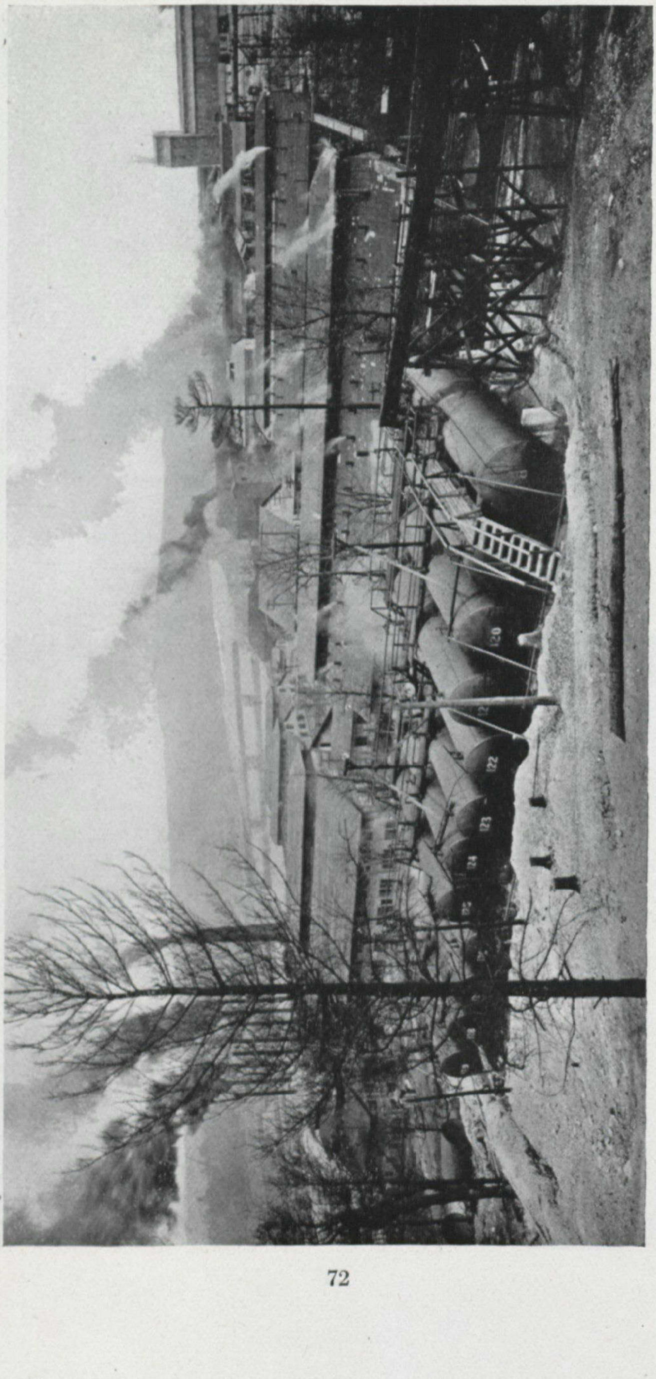


Fig. 94. British Chemical Co's., Trenton Plant.

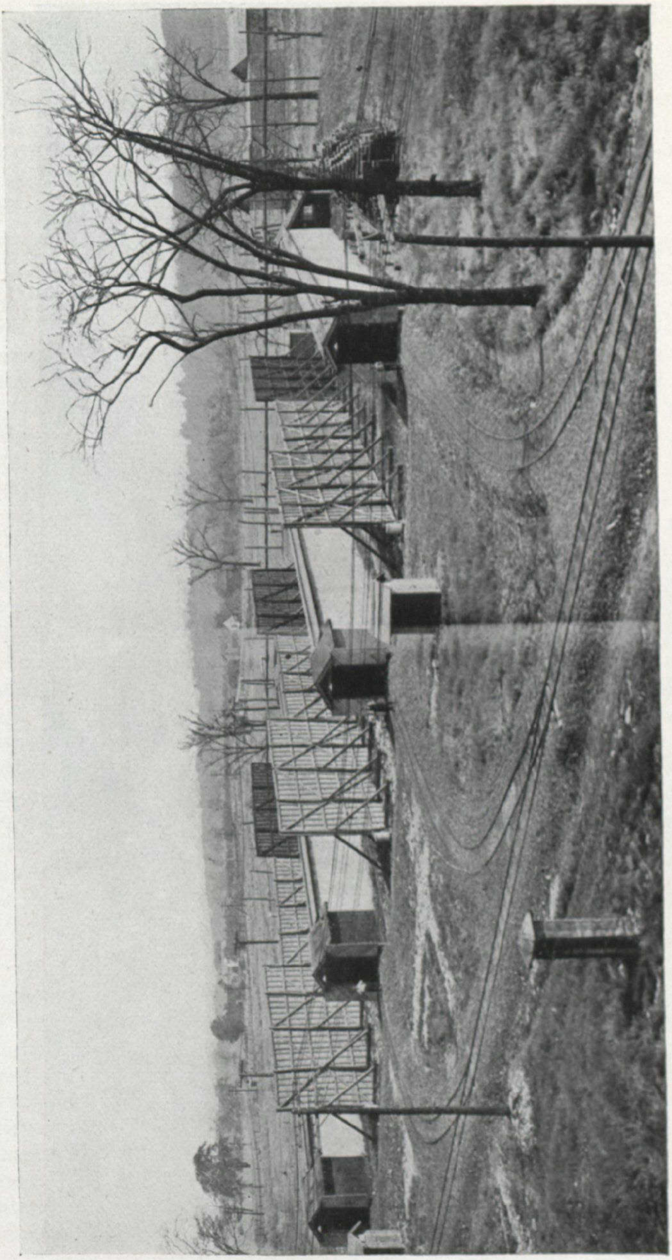


Fig. 95.

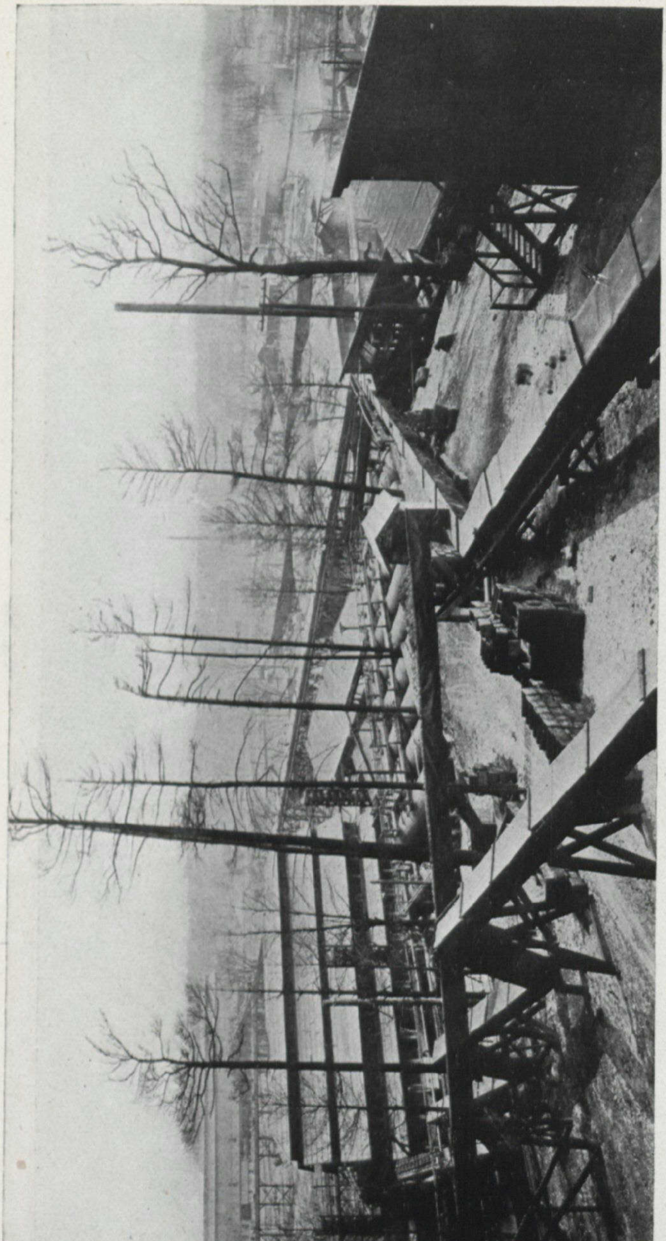


Fig. 96. British Chemical Co's., Trenton Plant.

British Cordite Company at Nobel was erected and operated as a National Plant under a contract with Canadian Explosives Limited. The plant cost in the neighbourhood of $3,500,000. The production of Cordite commenced in August, 1917, and the total production of Cordite from the plant was 21,687,900 pounds. The plant was designed for 2,000,000 pounds per month, but owing to a change in the Ministry's programme, due to over-production, the output was limited to the lowest limit commensurate with economic production.

The British Forgings at Toronto was constructed at an expenditure of approximately $2,500,000, primarily with the purpose of utilizing the large amounts of steel turnings accruing from the machining of shells, etc., which at the time were a drug on the market. This plant, which is the largest Electric Steel plant in the world, consists of 10-six ton Herault Electric Furnaces, having an average capacity of 350 tons of steel ingots per day and two forging plants each with a capacity of 5000 six-inch forgings per day. Ground was broken for the erection of this plant in December, 1916, the first heat of steel was poured in June, 1917, and the total production was 99,808 tons of steel and 2,916,047 forgings.

Reference has been made, throughout this address, to the inspection to which the various shells and components were subjected and the Inspection Department in charge of the work was a formidable organization. It was originally under the direction of Colonel (afterwards Brigadier-General) Greville-Harston, a member of the original Shell Committee and, after the formation of the Imperial Munitions Board, under Major (now Lieut.-Col.) G. Ogilvie, formerly of Colonel Harston's staff. These officers rendered considerable assistance to the manufacturers during their early difficulties, but the attitude in general of the Inspection Department was that a certain grade of work was required and that it could and must be attained. There is no doubt of this attitude being the correct one in the inspection of munitions and that it was responsible for the satisfactory quality of the shells made here. The chief difficulty that the Inspection Department, and consequently the manufacturers, suffered from was that of obtaining a sufficient number of competent inspectors and most of the troubles pertaining to inspection arose from this cause.

When the department was re-organized in 1916, as the Department of Inspection for Canada of the Imperial Ministry of Munitions under Colonel (afterwards Brig.-Gen'l) W. E. Edwards, this situation was, apart from a considerable increase in the expert staff, greatly bettered by the establishment of training schools for examiners, which also led to uniformity of inspection throughout the various plants and a decided improvement in every respect. The amount of work handled by this Department is not generally realized although its importance is easily understood. They were absolutely responsible for the acceptance or the rejection of the raw materials, such as steel, brass, etc., supplied by the Board, as well as of any component or complete item of ammunition presented to them and the staff

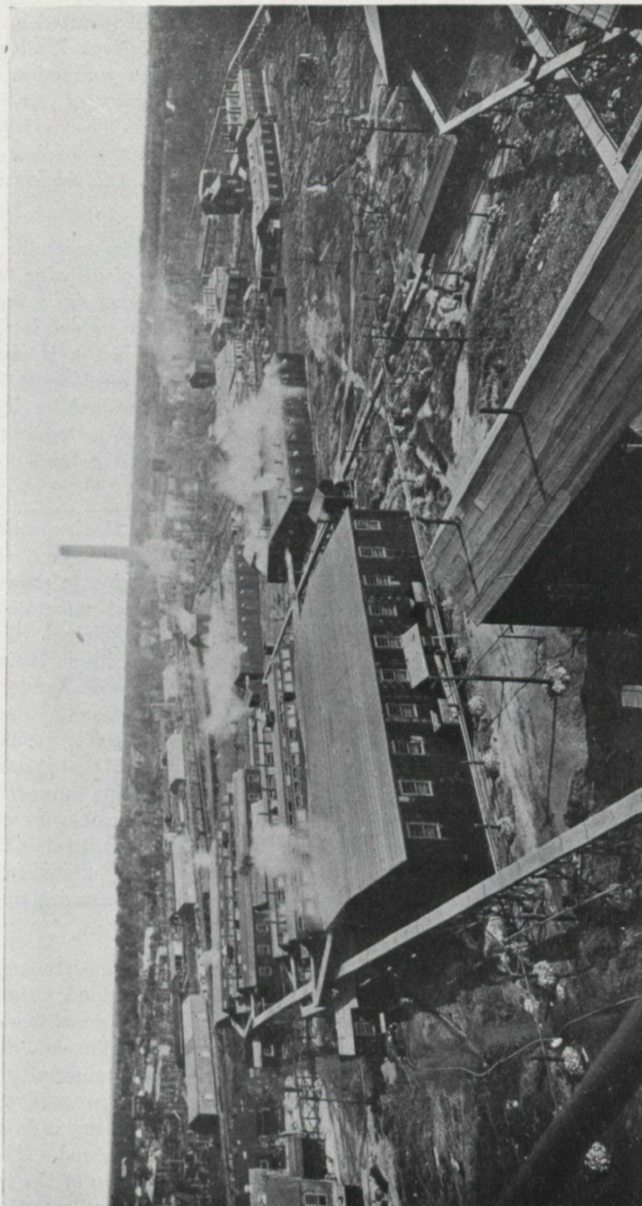


Fig. 97.

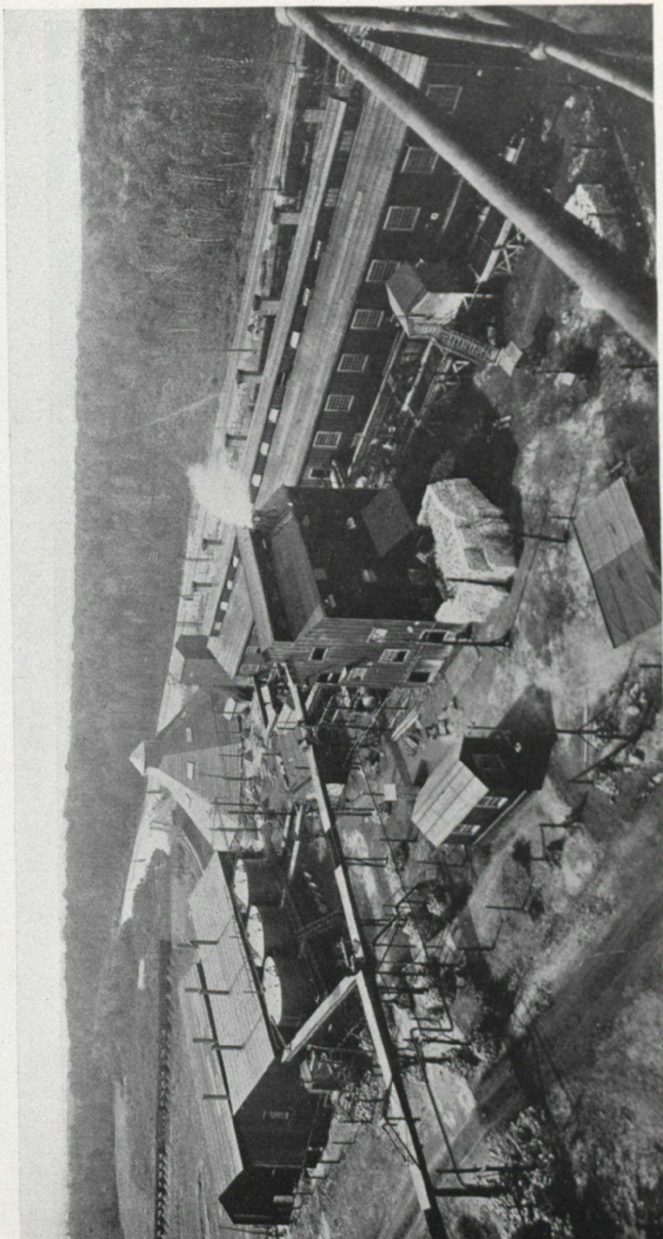


Fig. 98. Views of British Cordite Co's. Plant.

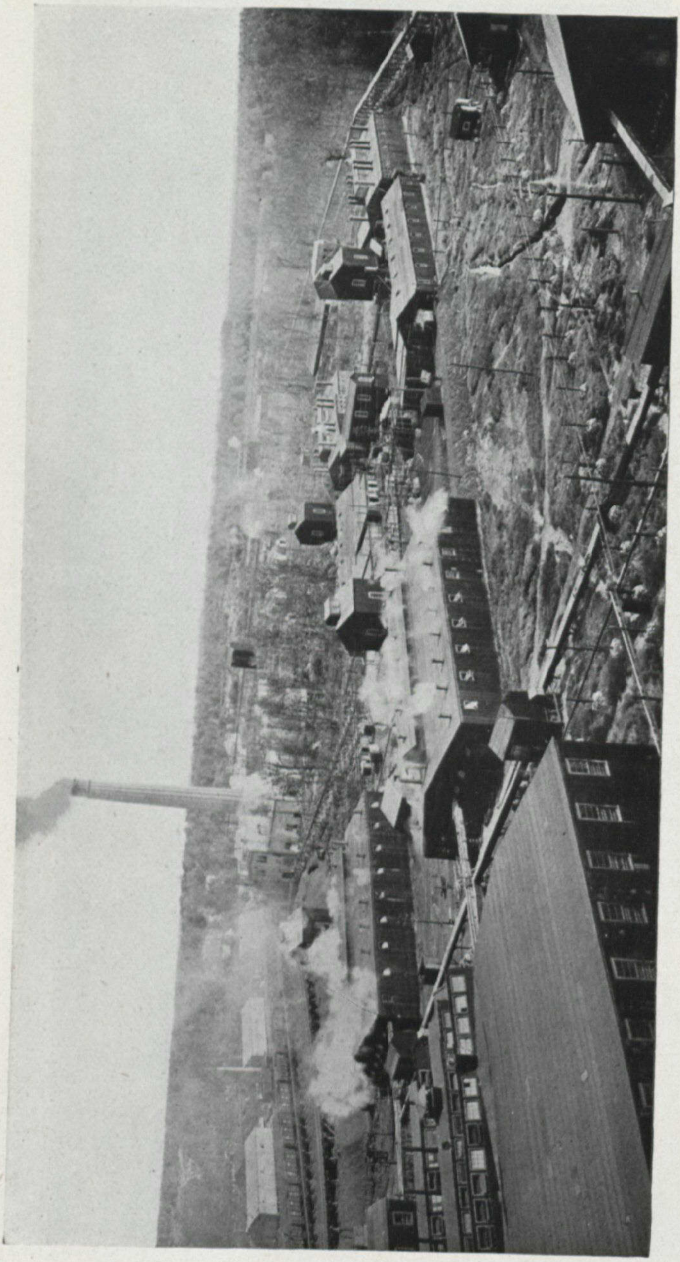


Fig. 99.

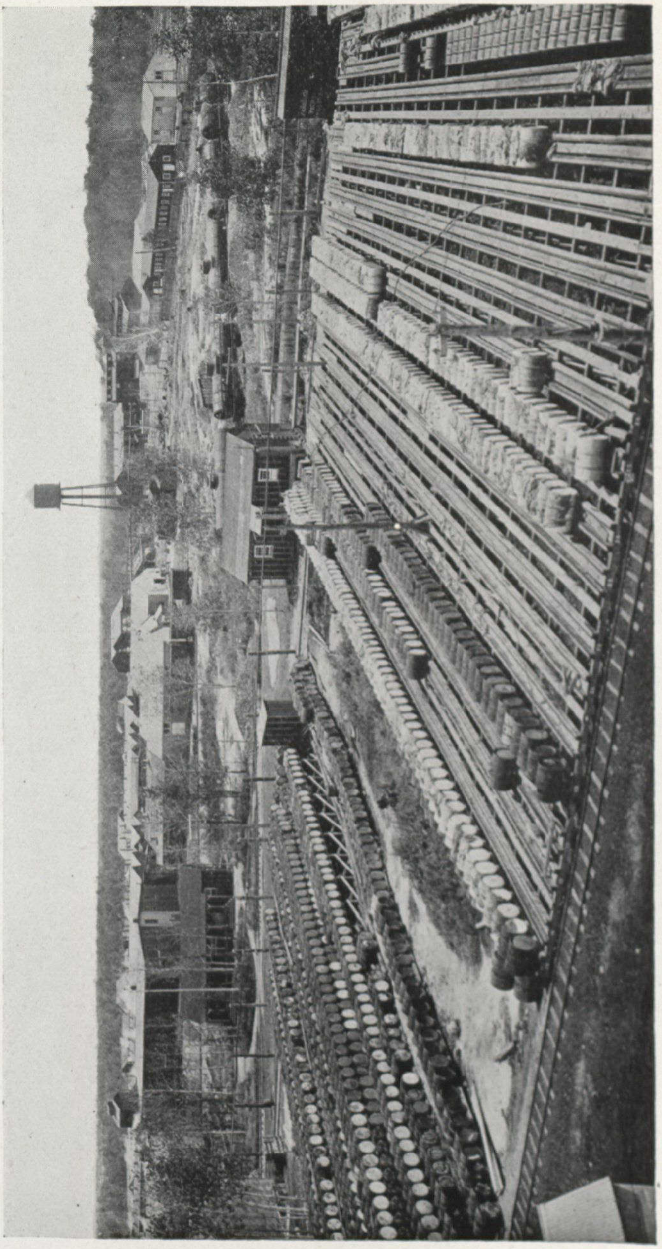


Fig. 100. British Cordite Co.

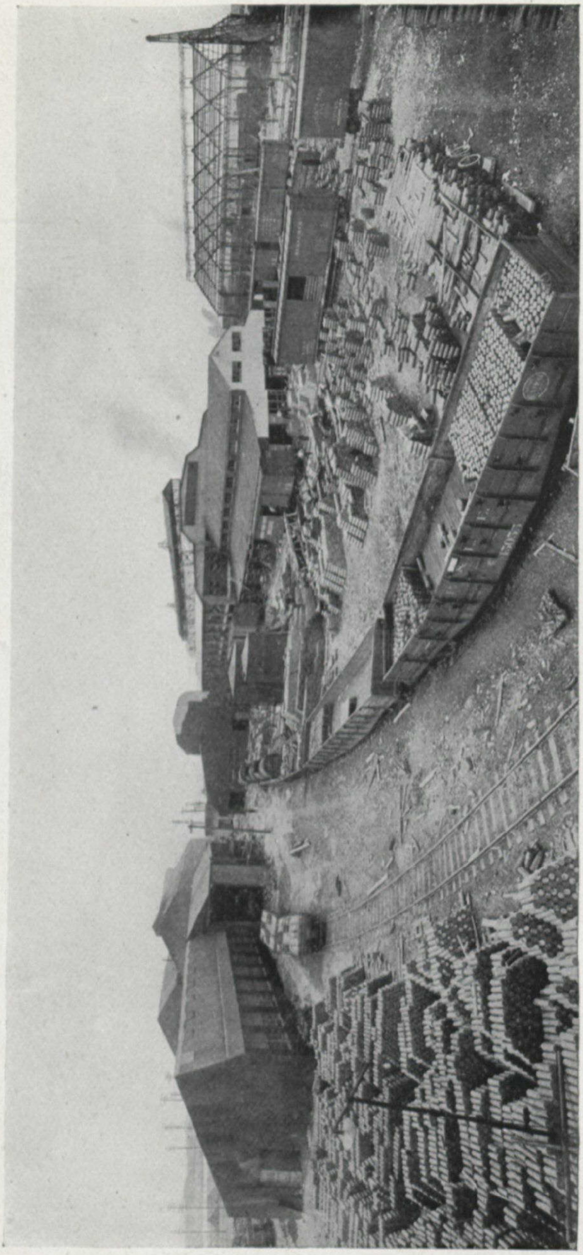


Fig. 103. British Forgings, Toronto.

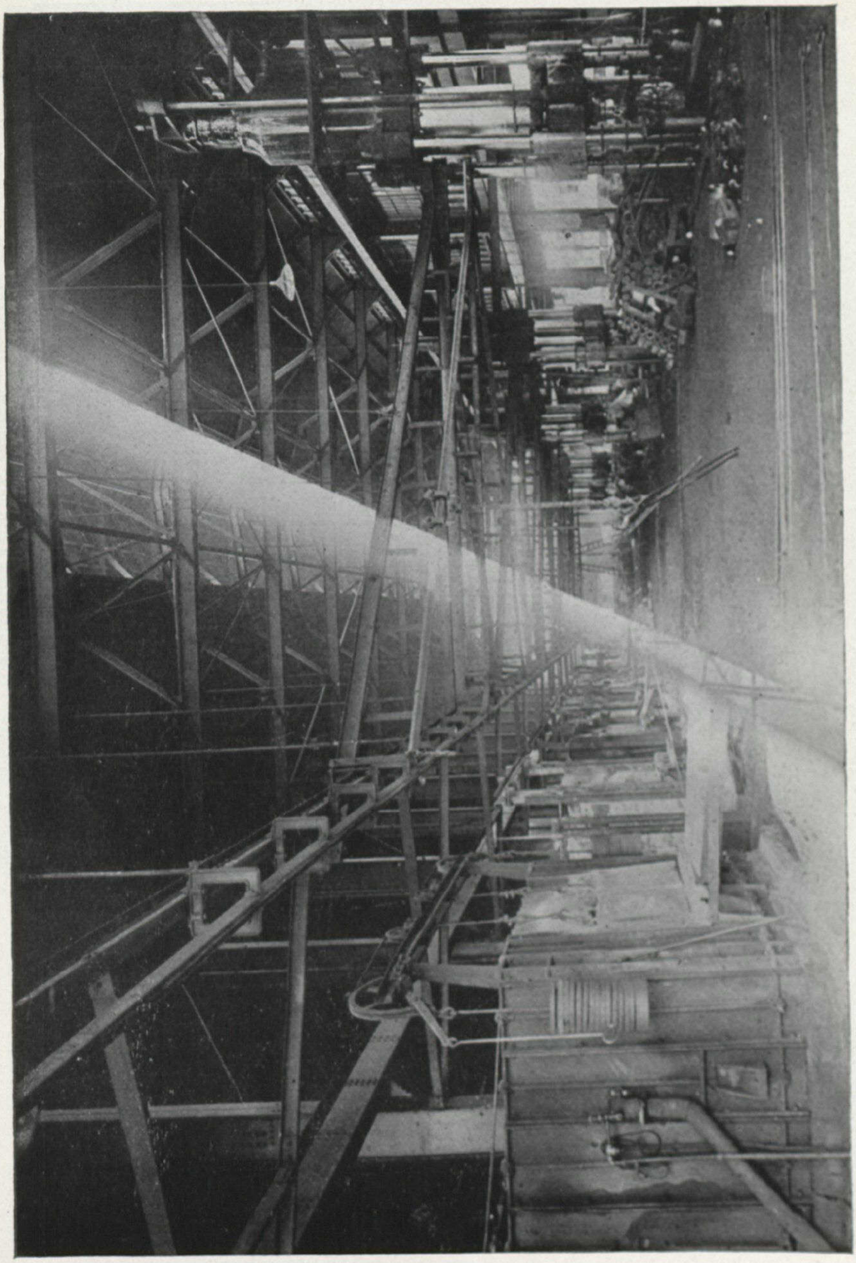


Fig. 104. British Forgings, Furnaces and Presses.

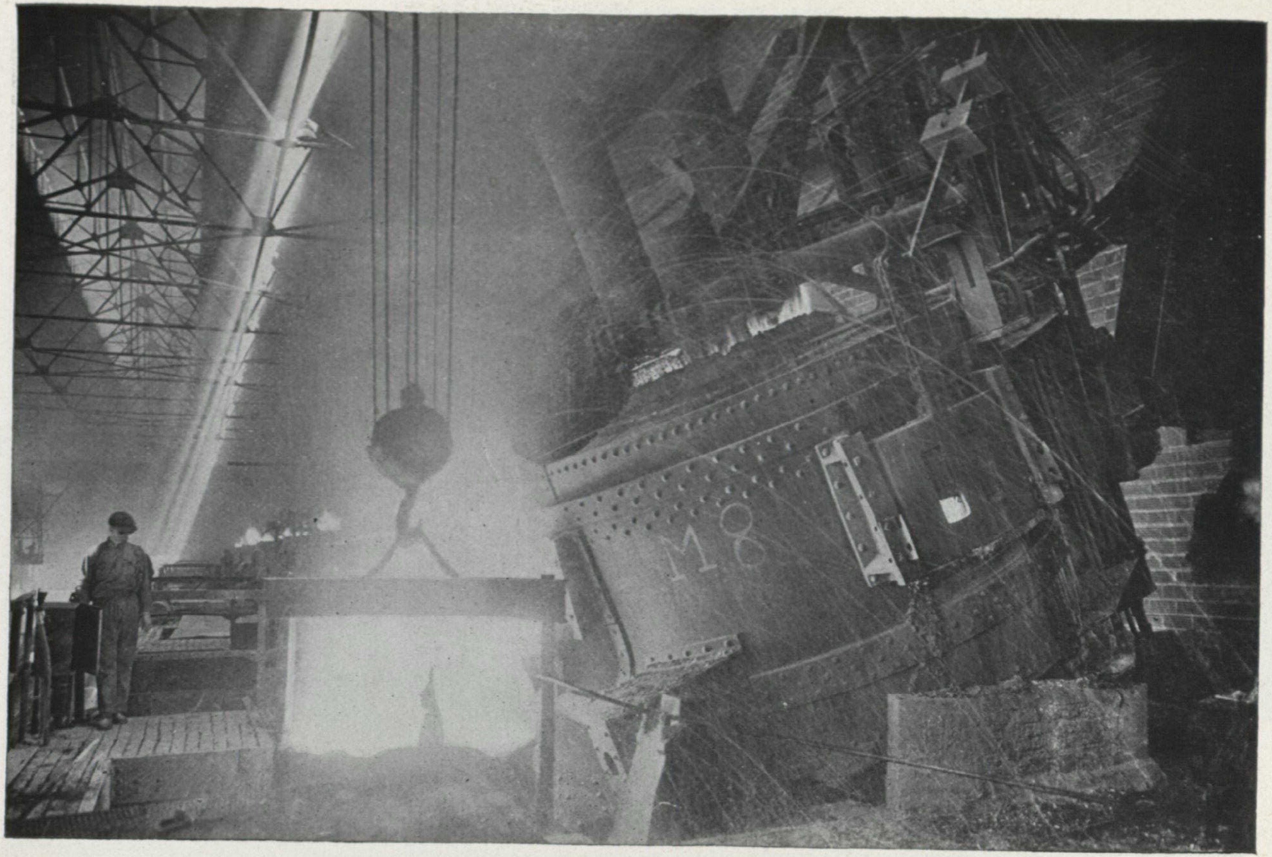


Fig. 105. Electric Furnace, British Forgings, Toronto.

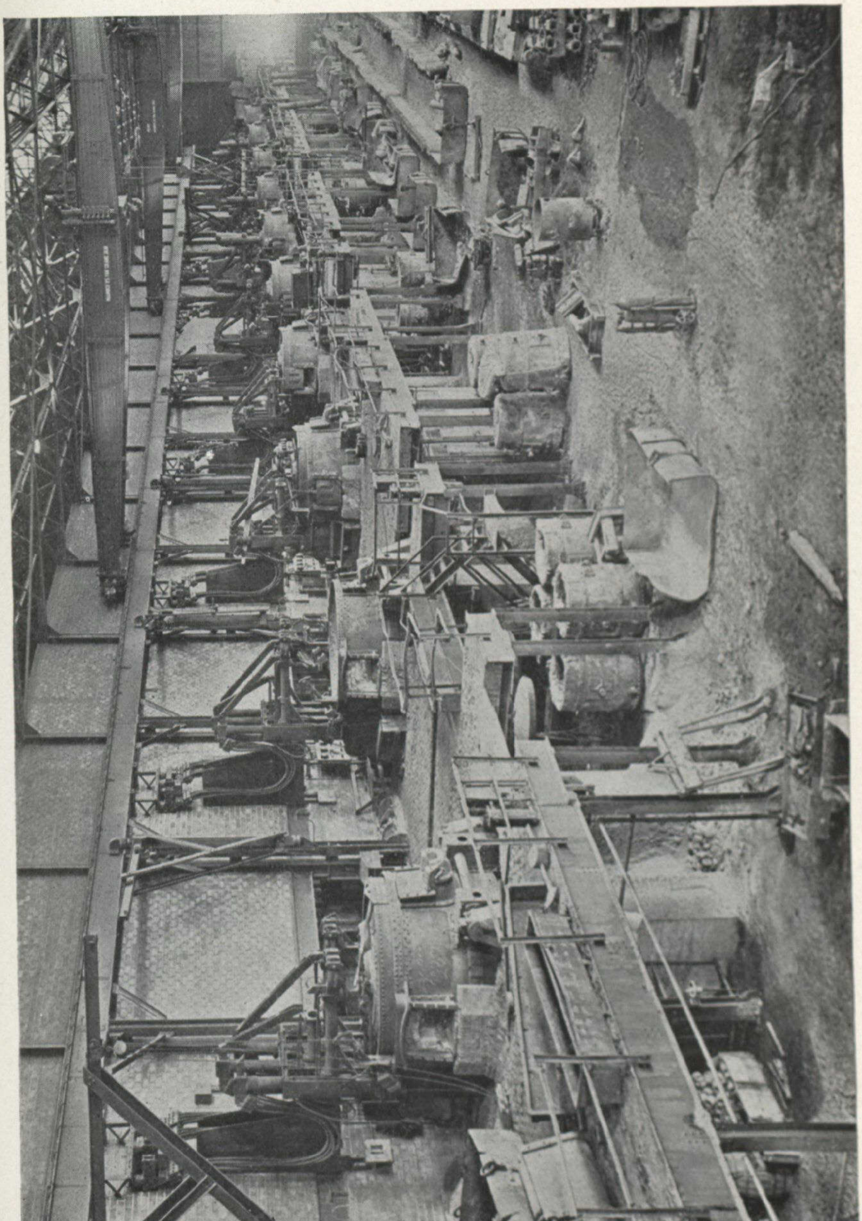


Fig. 106. British Forgings, Toronto. Electric Furnaces.

amounted in the middle of 1917 to as many as 8,072 persons. Of these 130 were senior or directing staff, mainly civil or mechanical engineers, and of the remainder at least 600 were either engineers by profession or highly skilled technical men. The balance included some 550 clerical staff and over 2,000 women examiners, chiefly on fuses and the like.

One of the Inspection Divisions in which we are specially interested was that of Gauges and Standards, organized in 1916, under Captain R. J. Durley, one of our past Councillors. This Division purchased the gauges for the Inspection Department, inspected them, repaired them and, in many cases, manufactured those of special character while their travelling staff assisted the District Gauge Examiners in checking up their standard gauges. They also were responsible for ensuring the correspondence of the gauges used in Canada with those used in England, to avoid any possibility of rejection of work re-inspected there. This necessitated the use and, in many cases, the design and construction of delicate measuring apparatus, as the accuracy of the new gauges is required to be from ten to twenty times that of the piece to be measured and the tolerance allowed does not in certain cases exceed one-ten thousandth of an inch. This Division also designed a large number of the various gauges used, and employed from forty to fifty tool makers on gauge repair and special work Fig. 107. It spent over $3,000,000 in the purchase of inspection gauges and, in 1917, made over 200,000 separate examinations of gauges in use and purchased. It is a good example of one of the ramifications of the munitions industry of which little is known and appreciated.

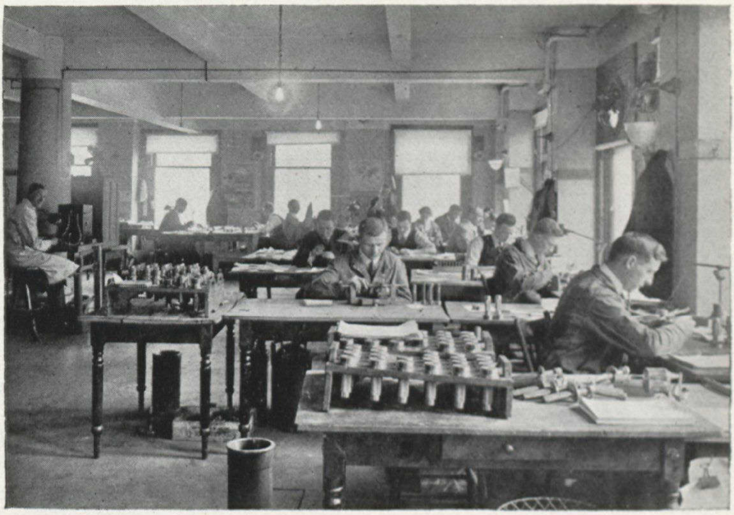


Fig. 107. I.M.B. Gauge Inspection Office, Ottawa.

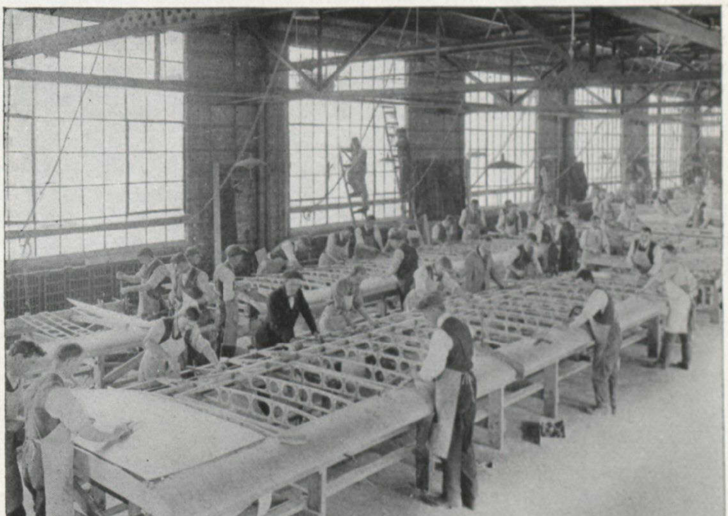


Fig. 108. Can. Aeroplanes Ltd., Wing Making.

While not strictly included under the head of Munition work, I feel that this record would not be complete without a reference to the plant of the Canadian Aeroplanes Limited, which was also constructed under the supervision of the Board at Toronto. This work was placed in charge of Sir Frank Bailie and attained a capacity of 300 machines per month, the total number completed being 2,921 aeroplanes and 30 F-5 flying boats. Practically all parts of the planes are constructed at this plant, with the exception of the engine and, when working to capacity, 2,150 employees are engaged. In addition to this plant, the Board also undertook the work of securing the ground, erecting the buildings and furnishing the equipment for the various flying camps of the Royal Air Force at Camp Borden, Moren Heights, Leaside, Camp Mohawk and Beamsville, at which so many Canadians were trained for air service.

Other activities of the Board not actually connected with munition work were the construction of forty-four steel and forty-six wooden steamships at a total cost of over $68,000,000, the purchase of over 4,000 tons of ferro silica, of 23,000,000 feet of aeroplane spruce and fir and various other requirements of the Imperial Government. Their principal work, however, was the production of munitions and in this the grand result was over 67,000,000 shells at a total cost of 1,200 million dollars, the output of over 450 different firms and 250,000 employees. These shells required two million tons of steel, 18,000 tons of copper, 25,000 tons of spelter and 138,000 tons of lead, to say nothing of the 27 million dollars worth of shell boxes and numerous other materials which it would be wearisome to recapitulate.

The Canadian achievements in munition production may not have approached those of France and England, but in comparison with anything accomplished in our previous history I believe we can justifiably be proud of them as a great piece of work which was well and honorably done. I cannot express this better than by concluding this address with the cables sent to the Chairman of the Imperial Munitions Board by Mr. Lloyd George and Mr. Winston Churchill.

Mr. Lloyd George cabled:—

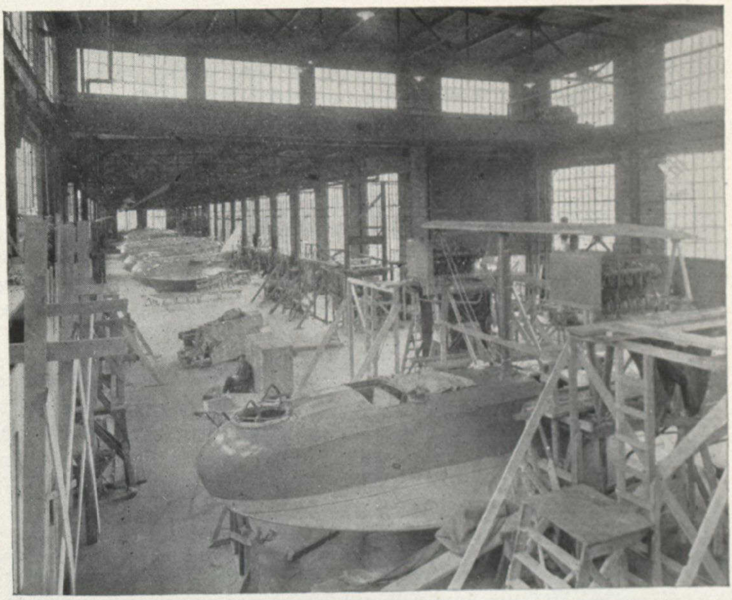


Fig. 109. Can. Aeroplanes Ltd., Flying boats with two Liberty Motors on one in foreground.

Fig. 110. Can. Aeroplanes Ltd., Final Assembly.

"Now that hostilities have ceased, I am anxious to send you, on behalf of myself and my colleagues in the War Cabinet, our congratulations on the great work of the Imperial Munitions Board for three years, which has been of such signal assistance to the British Empire and to the Allied Cause. It is a great and varied achievement for your Board, not only to have produced so great an output of munitions, representing no small proportion of the shells used by the British Armies, but also they have built over three hundred and fifty thousand tons of shipping for the Ministry of Shipping, to have assisted in so great a degree the Royal Air Force in Canada to have developed the great output of aeroplane timber which has been essential for our Air Service.

"As the Board was appointed by me when I was Minister of Munitions, it is particularly pleasurable to me to recognize the success, efficiency and value of its work and to thank you and, through you, your staff, the Canadian manufacturers and the great army of workers who have so splendidly assisted you, for the great service so rendered."

Mr. Winston Churchill cabled:—

"As the Armistice with Germany has now been concluded I wish, as Minister of Munitions, to congratulate you and, through you, all your staff on the splendid work of the Imperial Munitions Board during the last three years.

"You have carried through a work of the greatest magnitude with uniform success and efficiency, and I wish to pay my personal tribute to the great ability, energy and organizing power you, as Chairman, have shown.

"Canada's remarkable output of munitions has played a large part in the munitioning of the British Armies and will remain a testimony to the high value in that great struggle of the work of the Board and of all those, whether manufacturers or work people, who have shared the burden with you."

These cables record in eloquent terms the appreciation by men, who were in a position to know the facts, of the results obtained by Canada in the manufacture of munitions.

Fig. 101. CANADIAN EXPLOSIVE CO., NOBEL PLANT.

Fig. 102. PANORAMIC VIEWS OF BRITISH FORGINGS, TORONTO.