<u>NOTE</u>

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REPORT NO. 73

HISTORICAL SECTION (G.S.)

ARMY HEADQUARTERS

14 Feb 55

A Survey of Army Research and Development 1939-45

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A Survey of Army Research and Development 1939-45

1. The declaration of war in 1939 found the Canadian Army without the establishments or organization necessary to carry out scientific research or technical development. This is readily understandable since up to this time, with a few exceptions*, Canadian commitments had not warranted any independent work along such lines, and the policy had been to depend on Britain, not only for the development of warlike stores, but largely for their production as well. The war changed this and Canada became a contributing partner to the Allied pool of knowledge in war technology.

2. Development requirements materialized faster than did the organizations to cope with them. The Battle of Britain was largely responsible for this. British scientists were too busily engaged in dealing with immediate technical problems to devote much manpower to studying the longer term problems. Furthermore, it was desirable to decentralize some development work from Britain on account of the vulnerability to air attack. It was natural, too, that an increase in development activities should parallel the increase in production which was taking place. As development problems originated they were allotted to whatever organization was considered best equipped to deal with them, whether industrial, universities or Government departments. In some fields coordinating committees were formed to supervise research in their own particular spheres. Where no organized bodies existed to investigate certain types of projects these were formed, as the need arose, wherever possible about an existing nucleus of qualified personnel. A number of research organizations undertook problems independently on their own initiative. As a result of this somewhat haphazard growth of research and development groups a certain amount of confusion developed along with it.

> The number of technical groups and committees was increased with the increased production of weapons, and as a result there was divided responsibility, lack of cohesion and poor liaison between groups and committees (1).

*The exceptions were in the fields of radio, ballistics and chemical warfare. See W. Eggleston, Scientists at War, Toronto, 1950.

Once such confusion existed it was some time before it could be eliminated. As late as November, 1942, no less than four agencies in Ottawa alone were independently working in one specific field of research (2).

3. Within the Army, much of the development and research work became concentrated in the branch of the Master General of the Ordnance, which, in peace time, had held a nominal responsibility for research (3). In this branch by various processes technical directorates gave rise to development directorates. The pre-war Directorate of Mechanization and Artillery split into the Directorate of Technical Research and the Directorate of Ordnance Services (Mechanization). The Directorate of Technical Development in turn gave rise to the Directorate of Chemical Warfare and Smoke (D.C.W.S.), the Directorate of Artillery and the Directorate of Development of Vehicles and Small Arms (D.V.S.A.), all of which were development directorates. A Directorate of Electrical and Communications Development originated in the Directorate of Signals of the General Staff Branch, but eventually came under M.G.O. control. A Directorate of Engineering Development (D.E.D.) came into being in the Q.M.G.'s. Branch where it remained throughout the war. Medical services being under control of the A.G.'s. Branch, medical research likewise came under the same control. Later there were formed a Directorate of Operational Research in the General Staff Branch and a Directorate of Inter-Service Research and Development in the M.G.O. Branch. In addition to development organizations within the Army, research and development on behalf of the Army was carried out, to mention a few, in the Department of Munitions and Supply by the Army Engineering Design Branch, Signals Production Branch, and Military Technical Advisers Staff; by the Inspection Board of the United Kingdom in Canada in its Artillery Proving Establishment; and by the National Research Council in radar and radio especially. It will be readily recognized that by the time all these organizations were in operation the problem of coordinating research and development was quite acute.

4. In certain specific fields means of coordination were established relatively early during the war. A notable lack was in the field of armament development. To remedy this, at General McNaughton's instigation, the Army Technical Development Board (A.T.D.B.) was set up in March 1942 to "promote research, design, experiment and development in connection with all matters and things wherewith the Master General of the Ordnance is now charged" (4). However, those fields in which standing Boards and Committees already were functioning (e.g. Chemical Warfare and Radar) were excluded from its purview (5). In addition A.T.D.B. was not normally interested in the exploratory phases of an investigation (6). Furthermore, although the Board was responsible otherwise for coordinating all army development projects and was responsible for allotment of funds for this purpose, on occasion the Board Secretariat disclaimed financial responsibility for expenditutes incurred in branches other than the

M.G.O. on the basis of the wording of the Privy Council authority (4).

5. These various limitations circumscribed the operations of the Board and sometimes delay rather than expedition resulted. Had its existence predated that of those organizations whose work it was to correlate, its effectiveness might have been considerably greater.

6. The distance between "designer" and "user" with its consequent delay in communication and liaison imposed difficulties, which though they gradually decreased remained to some extent until the end of European hostilities. It augmented, too, those, unfortunately rather frequent, misunderstandings which are prone to arise when each fails to appreciate the problems and limitations forced by circumstances on the other. Many steps were taken to overcome the resulting difficulties. The aim was to reduce the channel of communication on technical matters to a minimum. Since the developments in the tactical situation tended to extend and complicate the channels of communication the earlier measures taken to insure adequate technical liaison became less effective, and so were of necessity subjected to revision. The establishment of a Directorate of Staff Duties (Weapons), (D.S.D.(W)), at Canadian Military Headquarters, London, provided a clearing house in the United Kingdom for the transmission of technical information between the United Kingdom and National Defence Headquarters, Ottawa. Gaps still occurred in technical information received from research and development establishments of the United Kingdom. To eliminate these gaps a technical liaison group of 57 technical officers was established under D.S.D.(W) at Canadian Military Headquarters in January, 1944. (7). Members of this staff were attached to research organizations in the United Kingdom where they were enabled to secure essential technical information at first hand. Experience in Italy demonstrated the existence of an excessive delay in the transmission of user criticism of design detail back to development agencies. It was important to overcome this before the invasion. Consequently, in May 1944, a Canadian Section Weapons Technical Staff and an Armoured Fighting Vehicle Technical Staff were authorized (8), to work respectively at 21 Army Group and Headquarters First Canadian Army. The two technical staffs along with an Operational Research Team, for which provision had been made in March 1944 (9), were combined to form No. 1 Canadian Field Research Section (10). This unit arrived on the continent just prior to VE Day.

7. In order to perform the necessary experimental work certain research establishments were constituted under the administrative direction of the various technical directorates previously mentioned. In August 1941 the Experimental Station at Suffield was established to carry out large scale field investigations in chemical warfare (11); it was jointly operated by the Department of National Defence

and the British Ministry of Supply. At the same time the Research Establishment (Chemical Warfare) was constituted at Ottawa to carry on research primarily into the defensive aspects of chemical warfare (11). The establishment (later designated Chemical Warfare Laboratories) assumed responsibility for the programme of chemical warfare research previously instituted by the National Research Council. These two organizations came under the administrative direction of D.C.W.S. as did also the War Disease Control Station established in December 1942 (12) to carry on research into defensive measures against biological warfare.

8. In armament research a number of separate groups existed which were ultimately incorporated into the Canadian Armament Research and Development Establishment (1). The groups involved were a ballistics group of the Inspection Board, Explosives Pilot Plant financed by the Department of National Defence and constructed by the National Research Council, and a design group of personnel drawn from several sources. To carry out the necessary experimental work required by D.E.D. there was set up in Ottawa in October 1942 an Experimental Establishment, R.C.E. (13).

9. For communications research the Canadian Signals Research and Development Establishment (C.S.R.D.E.), originally designated the Canadian Signals Experimental Establishment, was authorized (14).

10. With the large volume of vehicle production in Canada a Proving Ground Detachment, R.C.O.C. (15), later renamed the Vehicle Proving Establishment, N.D.H.Q. (16), was formed primarily for the purpose of carrying out acceptance tests on new vehicles and accessories. A limited amount of successful development work was carried out by this establishment.

11. The following sections describe some of the specific development work carried out by or for the army during the war.

12. From the date of its inception to the end of the war the Army Technical Development Board recorded upwards of 450 projects, exclusive of research problems relating to radar, chemical warfare, operational research, medical and overseas work. Nor did it include exploratory research (see ref.6). Projects investigated in these other fields brought the total to somewhere in the neighbourhood of 2000, and above this there were those assessment programmes of such establishments as the Vehicle Proving Establishment which carried out over 500 serviceability trials on various items of vehicles development. Of the A.T.D.B. projects mentioned above, 126 were cancelled for various reasons; 208 were completed, of which 35 went on to the production stage and were produced for service use.

13. It is obviously impossible in the space available in an outline sketch such as the

present one to do more than barely touch the highlights of the developments carried out in the years 1939 to 1945.

ARTILLERY EQUIPMENT

The "Sexton" (25 pr S.P. tracked)

14. The Sexton was designed to satisfy a requirement for a self-propelled artillery unit which would have sufficient mobility for use with an armoured division. Requirement specifications were drawn up in March 1942 under the direction of the Director of Technical Research (17), and the Army Engineering Design Branch of the Department of Munitions and Supply were made responsible for the project (18). A pilot model underwent trials at Petawawa in June of the same year (19). Later trials, carried out in England, resulted in the adoption of the equipment by both British and Canadian armies (20). Over 2000 of these guns were produced for service use (21) (22).

15. The unit consists essentially of a 25-pr Field Gun mounted on a tank chassis of the Ram or Sherman II type. The gun is capable of 15° elevation, 9° depression; and 25° left, and 15° right traverse (21)(22), and carries a crew of 6. It is capable of 25 m.p.h. and has a radius of action of 125 to 145 miles.

16. Among the users of Sextons were the 8th and 23rd Field Regiments (S.P.) R.C.A., and the 19th Army Field Regiment (S.P.) R.C.A; in the attack on Arnhem on the 13th of April, 1945, the 8th Field Regiment fired 19,447 rounds from these guns, or over 810 rounds per gun during a twenty-four hour period (23). The guns of the 19th fired nearly a quarter of a million rounds between 19 Sep 44, and VE day, being in action on one occasion for 33 days (Operations "VERITABLE" and "BLOCKBUSTER") which accounted for over 67,000 rounds (24). The diarist of the 23rd Field Regiment wrote on 2 Sep 44:

> After a month of continuous moving our Sextons are beginning to show slight signs of wear and tear. They have shown up splendidly in a campaign very tough on armour and everyone had been delightfully surprised (25).

17. The 8th Field Regiment had reluctantly turned in their Priests (S.P. 105-mm) on leaving Italy in February of 1945 (26) and were issued with Sextons on arrival in Northwest Europe. First firing found "everyone is well pleased with the guns" (27). The 19th exchanged Priests for Sextons in August 1944 (28), and fired the new guns for the first time on 9 Sep (29); "the Air O.P. reported that all guns were shooting together". The diary entry for 20 Sep

44, contains a note of complaint as well as of pride:-

> The Batteries are experiencing quite a bit of trouble with their S.Ps. Idler wheels' bearings are burning out. One or two recuperator systems have caused trouble. Captain Nelson, with the 22nd Armoured Regiment reported "People I am with say "splendid shooting by you this afternoon, one 88 mm gun knocked out"".

Subsequent evidence indicates that the difficulties mentioned were rectified shortly afterwards.

40-mm "Bantam" (Lightened Bofors Gun)

18. This development was undertaken to reduce the weight of the light anti-aircraft gun in order to improve its cross country performance, to enable it to be towed by a jeep, to make it more easily air portable and to permit its use in jungle warfare (30). With this in mind Canadian Military Headquarters suggested, with War Office concurrence, that Canada develop a light weight platform for the weapon (31) (32). A preliminary design was drawn up in the Technical Liaison Group (C.M.H.Q.) and the development undertaken by the Directorate of Artillery with the assistance of a Design Engineer from the National Research Council (33). By August 1944 preliminary studies and general assembly drawings were completed (34), and the production of four pilot models was instituted. A series of trials was carried out in Canada in October and November of the same year, following which the pilot model was sent to England for further trials (35). As a result of the British trials the War Office approved the equipment for introduction into service use (36), and the Ministry of Supply placed an order for 200 equipments (37) which was later increased to 720. Although the requirement for jungle use was eliminated by the cessation of hostilities against Japan the Bantam was adopted as the standard airborne divisional anti-aircraft weapon (38).

Variable Time Fuze*

19. "The [Variable Time] VT type of fuze represents at the present time the greatest advance in fuze design since the introduction of the mechanical type in 1917" (39). The fuze automatically explodes the shell to which it is attached when the shell arrives within lethal distance of a target. It is essentially the target itself which initiates the means of bringing about its own destruction. Fundamentally the fuze consists of both a miniature radio

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*Also known as the Proximity or Radio Proximity Fuze.

transmitter and receiver, which transmits a signal capable of being reflected (slightly changed) from an approaching target; receives the reflected signal, amplifies the difference between the two signals and utilizes this amplified oscillation to trigger an electronic switch which sets off an electric detonator.

20. Such a fuze had been suggested independently by several sources before the war, but no attempt had been made to solve the attendant practical problems. The British took it up early in the war, applying their effort to the development of fuzes for aircraft rockets. In the autumn of 1940 a British scientific mission, the Tizard Mission, visited Canada bringing information on the British work. They considered that the fuze offered a profitable field of effort for Canadian Research (40)(41). The National Research Council accepted the problem and under their sponsorship a team was organized in the Department of Physics of the University of Toronto to work on it (42). The Canadian work was directed to the development of a fuze for the 3.7" anti-aircraft shell and the 4" naval shell, and included the problem of development of rugged miniature radio tubes for use in these fuzes.

21. The attendant difficulties in the development can perhaps best be illustrated by noting that all the parts of the fuze had to be sufficiently strong to withstand the shock of discharge from the gun and the spin of the shell in flight. The former requires that components be capable of supporting 20,000 times their own weight. Spin is at the rate of 475 revolutions per second which imposes a stress in a direction different to that imposed on firing the gun (43).

22. Meanwhile in the United States the National Defence Research Committee had instituted a research programme on proximity fuzes directed primarily towards a fuze for the 5" naval anti-aircraft gun (44), but including also development of fuzes for rockets and bombs (unrotated projectiles) (45). Discussions with the Tizard Mission added stimulus to the United States programme and paved the way for mutual cooperation and interchange of ideas. At an early stage industrial resources were integrated into the United States programme. Such was not the case in Canada.* When the United States development

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*The reason for this is not clear. D.M.G.O.(C) states "in Canada no attempt had been made to integrate development work with manufacturing facilities" (46), whilst a member of the Research team (47) says "progress was initially slow because of lack of industrial facilities for the development of the special radio tubes and batteries". Yet, Baxter (48) reports, in reference to National Defence Research Council contracts negotiated in November 1940, "Further assistance was derived from the Rogers-Majestic Company of Toronto which had developed a larger rugged four-element tube for British use".

of tubes outstripped the Canadian effort the latter was abandoned, the required tubes being made available by the United States to the Canadian team for use in their fuze development. The laboratory aspects of the problem were completed by May 1942 (49). The summer of 1942 saw firing trials of models carried out at Camp Borden, following which the sponsorship of the development passed from National Research Council to the Department of National Defence (50). By spring 1943 satisfactory fuzes had been produced on a pilot scale. Further development work in Canada was discontinued since by now United States work had advanced to a stage where their larger naval fuze had seen successful operational service, and their attention was now focussed on smaller fuzes which represented considerable advance in design over the Canadian model (51).

23. Production of V.T. fuzes for service use until the cessation of hostilities was entirely in the United States where two types were produced for British account. The effect of introducing the fuze into anti aircraft use is strikingly demonstrated by the increase, during the last four weeks of concentrated buzz bomb attacks against England, in the effectiveness of gun-fire in the destruction of the V-1's. Taken by weekly periods, of the targets engaged there were destroyed in the first week, 24%; in the second, 46%; in the third, 67%; and in the final week 79%. "On the last day in which a large quantity of V-1's. were launched against British shores, 104 were detected by early warning radar but only four reached London. Some 16 failed to reached the coast, 14 fell to the Royal Air Force, 2 crashed thanks to barrage balloons, and anti-aircraft accounted for 68" (52).

25-pr Carriage for Upper Register Firing

24. It became increasingly apparent during the Italian campaign that some modification to the 25-pr gun was desirable to enable the gun to be fired at elevations greater than those for which it was originally designed. "Upper Register" implies angles of elevation greater than 45°. The method of achieving these high elevations in the field with existing equipment was to "dig in" the trail, that is to say dig a pit behind the gun so that by lowering the trail below ground level the elevation of the barrel was correspondingly raised. Obviously this digging in consumed time and delayed the deployment of guns when "upper register" was required.

25. To meet the requirement an officer of the Technical Liaison Group at C.M.H.Q. designed a hinged trail for the gun which, it was anticipated would allow an extra 15° of elevation. A prototype of the design was made by No.2 Canadian Base Workshop, England, in May 1944 (53). Trials were carried out during the summer. While these trials on the whole were satisfactory, it appeared that trouble

might be expected in service due to the difficulty in excluding dirt from the hinge. Consequently, the Chief Engineer Armament Design (C.E.A.D, Ministry of Supply, U.K.) was asked to redesign this modification, incorporating improvements to exclude dirt (54). The Ordnance Board expressed the opinion that "the use of upper register firing is insufficient to justify the modification of the equipments", but considered "that this modification should be borne in mind for possible inclusion in new designs of equipment" (55).

26. The redesigned prototype (Carriage, 25-pr, Mk 3) was ready for trials in January 1945. As a result of the trials the Ordnance Board recommended the approval of the design (56), and it was adopted shortly thereafter for use on all future production of short axle 25-pr carriages (57). The finalization of the design came too late for production equipments to see service.

Sabot Projectiles

27. The Sabot Projectile represents one of the numerous ways of achieving high muzzle velocity with a gun to attain the advantages of longer range, increased penetration of armour and shorter time of flight. The idea is not particularly new and has occupied some attention for the past 70 years although development was somewhat perfunctory until the period of the past war. It provides a means of firing a smaller calibre shot in a gun of higher calibre. The advantage of this type of ammunition is that an especially designed gun is not required. The Sabot is a support for the smaller calibre shot which is discarded after the round leaves the muzzle. On discharge the complete shot receives the same amount of energy as a full calibre shot would receive but being lighter in weight the equivalent energy transmitted results in an augmented velocity. The Sabot may be either segmented so as to discard radially, or it may be a pot type which is left behind or discarded axially during the flight of the round.

28. The current interest in Sabot Projectiles was revived by Lt-Gen A.G.L. McNaughton, who in 1942 made a sketch of a type of Sabot on which some trials were carried out by the Ordnance Board (58) (59). His suggestion called for a synthetic resin or light metal Sabot with a small explosive charge to detach the Sabot in flight.

29. The early requirement expressed by General McNaughton was for a projectile for the 25-pr gun in order to improve its effectiveness against armour. Several designs were produced by the staff of the Military Technical Adviser of the Department of Munitions and Supply and by the staff of the Proof and Development Establishment of the Inspection Board. This particular investigation was discontinued on a basis of "no requirement" before a completely satisfactory solution to the problem had been reached (60).

In the meantime attention had been turned to the development of a 6-pr Sabot Projectile for the anti-tank gun with a considerably greater degree of success (61). However, by this time interest had shifted again from the 6-pr to the 17-pr, so that the 6-pr development was not carried on to commercial production. The development did, however, prove the praticability of, and revived interest in the pot type of Sabot. As a result of the work Canada was asked to develop a 17-pr Sabot by the Ordnance Board (62) (63), since the radially discarding Sabot at that time in service did not fill the requirement for accuracy. The development of the 17-pr Sabot began too late for the results to be applied before the termination of hostilities.

30. This project illustrates how while changing requirements might vitiate the specific application of a particular idea, yet the fundamental principles involved in investigating the idea may be applied to subsequent requirements.

20-mm Guns

31. The course of the development of 20-mm guns provides an outstanding example of the confusion which can arise and the expense which can be incurred through a lack of uniform policy and through frequent revisions of requirements. In 1942 General McNaughton expressed an urgent need for 20-mm guns along the lines of the Oerlikon but having a shorter inboard length so that it could be mounted in armoured fighting vehicles. It was required that the gun be capable of a high rate of fire and that it be belt fed (64) (65) (66). The development was taken up under the aegis of the Army Technical Development Board, the Military Technical Design Advisers Staff, and the Engineering Design work was carried out by the John Inglis Company, Toronto. At the same time the Inglis Company undertook the design of several types of mountings for the 20-mm gun (67) (68). Pilot models were shipped to England in 1943 for demonstration (69). On the basis of the demonstration the Inglis gun was accepted as filling the requirements of the Canadian Army overseas (69). Certain modifications were suggested (70). As it stood the gun was designed to fire Hispano ammunition. Pending the finalization of the Inglis gun design an order for 2600 guns and single mountings called for Hispano 20-mm guns which would subsequently be replaced by the Inglis gun (71). However, shortly before completion of these contracts War Office policy underwent a revision. This policy called for exclusive use of Polsten guns on universal mountings within the 21st Army Group (72). Steps were then taken to redesign the Inglis gun to accept Polsten ammunition (73).

32. Consequent upon the new policy C.M.H.Q. advised that they now had no requirement for a single mounting 20-mm gun and it was proposed that the

contract be cancelled (74). An order for 1000 quadruple mount equipments remained in force with the proposal that the mounting be redesigned to accept Polsten guns (75). The Skink (see below, para 67), previously equipped with Hispano, was redesigned to accomodate Polstens (76). The contract for quadruple mountings and accessories involved an expenditure of rather more than twelve and one-half million dollars - which had proceeded too far for cancellation to involve any saving (77).

33. As a result of the unfortunate experiences in the 20-mm development the Chief of the General Staff refused approval for initiation of any other 20-mm development projects in April 1944 (78).

SMALL ARMS

3" Mortar Projects

34. In December 1943 the War Office stated an urgent requirement for a light weight base plate for the 3" mortar, to weigh not more than 40 lbs and to enable a range of 2750 yards to be obtained (79). In order to obtain a comparable range with the standard base plate it had been necessary to strengthen it, resulting in a weight of 52 lbs (80). A design was drawn up in the Directorate of Artillery for a base plate made of stainless steel which was expected to weigh 25 lbs (81). At about this time consideration had been given to the use of magnesium alloys for fabricating certain service equipment, of which the base plate of the 3" mortar was one (82). As a result the Chief of the General Staff asked M.G.O. to undertake the development of such a base plate. This request had been anticipated and a design arrived at by the Directorate of Development of Vehicles and Small Arms (83) (84). Authority was given to proceed with both designs. A number of models of both were produced and firing tests carried out during the early part of 1944. By April it had been decided that the steel base plate satisfied the requirement laid down by the War Office and the design was finalized (85) (86). Samples of this base plate were sent to Australia, United Kingdom and the United States for trial (87) (88).

35. Of the magnesium alloy base plate, following tests at Canadian Small Arms School (Eastern), the following opinion was expressed:-

> "Of several base plates which had been subjected to trials at this School this appears to be unquestionably the most satisfactory" (89).

In July 1944 tests were carried out in England and surprisingly enough the magnesium base plates fractured through after four or five rounds had been fired (90). It later developed that failure was due to the tests having been carried out using a Mk 4 barrel; whereas the plate had been designed to take a Mk 2 barrel, no Mk 4 barrel being available in Canada at the time. The redesign of the base plate to accomodate all types of barrels was therefore undertaken (91). In the same tests the steel base plate showed a certain lack of stability and further redesign was undertaken (92). In August 1944 the whole question of mortar design was reviewed by the Ordnance Board and new designs were divided into immediate, intermediate and ideal categories (93). It was considered in view of the urgencies of the immediate and intermediate requirements that Canada would be unable to contribute to these categories before the end of the year and she should therefore confine research to the longer term policy (94).

36. Meanwhile in April of 1944 the Directorate of Artillery proposed investigations into the entire field of mortar design (95). One phase was the improvement to the barrel in order to increase durability, to decrease the weight and to make it possible to obtain increased ranges (96). Prototypes of a design of tapered barrel were produced for trials. It was indicated that considerable reduction of weight could be obtained without loss of ballistic qualities (97). Following the production of several experimental barrels it was concluded that the advantages of this design over the Mk 5 light weight barrel were approximately 25% reduction in weight, 10% improvement in accuracy and 15% increase in strength (98). Trials carried out on the barrel in Australia indicated that the barrel was more accurate in range and line than the normal barrel (99).

Lightened Rifle

37. Small Arms Limited had been carrying on some experimental work on the design of a lighter rifle than the current issue, i.e., No.4. The project was taken under the surveillance of the Directorate of Development of Vehicles and Small Arms in September 1943 (100). C.E.A.D. of the Ministry of Supply had also designed a lightened form of the No.4 rifle, the adoption of which was being considered by the War Office (101). Since the Canadian design rifle appeared to meet the War Office requirement two samples were sent to the United Kingdom for examination (102). It was found that the samples required restocking and de-nickeling (103) following which they gave satisfactory performance. There were, however, certain features of criticism which were brought out (104). However, as a result of trials at Bisley the British lightened No.4 rifle subsequently called No.5 was adopted by the War Office. In the meantime India had requested 25,000 rifles similar to the Canadian model (105). Small Arms Limited proceeded with the design of a rifle incorporating the best features of both the No.5 and the

previous Canadian model. Since, however, the No.5 had gone into production in the United Kingdom further development of the second Canadian model was not continued, and since no confirmed requirement was forthcoming from C.M.H.Q. (106) the project was cancelled in December 1944. The Australians in the meantime had carried out trials on the first Canadian light model and reported extremely favourably in its accuracy, handling and serviceability but deemed it unacceptable due to excessive flash (107) (108).

Snipers' Equipment

38. Subsequent to a general survey of the situation on snipers equipment (109), a meeting was held in June 1943 to determine how best to meet both immediate and long term requirements (110). A number of comparative firing trials had been carried out on various commercial and service sights which appeared to indicate there was considerable room for improvement (111) (112) (113). For the longer term policy specifications were drawn up for a 5X telescope sight (114) (115) and a 3½X sight (116), and the production of prototypes was instituted (115) (117). The decision to design the lower power model came as a result of a suggestion originating in the United Kingdom (118). The War Office evinced considerable interest in the development of the two sights (119), and by the end of November, 1943, were so actively concerned about the sniper situation that it seemed doubtful if the Canadian prototypes would be completed in time for full consideration to be given to them by the War Office (120). In December an added requirement was introduced into the operational specification (121). This called for sights to be proofed against fungus growth under tropical conditions. Prototype samples of the telescope sights were sent to the United Kingdom in March 1944 (122), and at the same time steps were taken to modify the design in order to make it fungusproof (123) (124). As a result of reports from the United Kingdom, which all indicated preference for the 5X over the 3½X model, an educational order for 100, 5X telescope sights was placed (125) (126) (127) (128) (129) (130). Speaking of the Canadian sights the Assistant Chief of the Imperial General Staff stated "that the Canadian 5X and 3½X telescopes were incomparably better in every way than anything that we or the Germans had so far produced, the 5X being better than the 3½X" (128). It caused no small surprise to learn in July 1944 that the provisional adoption of the 3½X rather than the 5X sight had been recommended (131). This necessitated changing the educational order previously placed (132) (133). Concurrently, at War Office request, the Ministry of Supply initiated inquiries for production information based on a requirement for 4000 3½X instruments (134), but were disappointed to learn that no deliveries could be made before April 1945 (135), whereas they had understood, on a basis of unofficial information (136) given without reference to the proper authorities (137), that deliveries could be completed by April

1945 (135). On account of the length of time required to start production the War Office order was not forthcoming (138). Nevertheless, interest in the sights remained (139), and found expression in a renewed inquiry for delivery estimates in March 1945 (140), although a 21 Army Group Report to the War Office (141) had stated: "there is no particular advantage to be obtained from the adoption of the Canadian Sniper's rifle". Four telescopes, two of each power, had been sent to the Western Theatre of Operations for user trial (142); two of these were "destroyed by enemy action" and a third captured complete with sniper (143).

39. It should be stressed that a telescope sight is not a complete unit in itself, but forms an integral part of the rifle on which it is subsequently mounted, and particular care is taken to match the two to each other. The combination is known as "Equipments, Rifle (T)." Once assembled the assembly normally remains intact.

40. In 1943 Small Arms Limited carried out experimental work on modifications of the No.4 Rifle (the standard issue), and developed two types, referred to respectively as "Scout" and "Section" Sniper Rifle (144) (145). These rifles were provided with telescope mounts and special butts. Four of the Sections Sniper' Rifles were sent to U.K. in March 1944 (146), and one to Australia in June of the same year (147). These were presumably the rifles used in the test under which the telescope sights were reported above. The rifles themselves were well received, the butt especially coming in for favourable comments.

EXPLOSIVES

41. The need for cooperative effort by a number of different groups in order to achieve successful ultimate application is more apparent, perhaps, in the field of explosive research than in most others. Several research projects were instituted by the N.R.C. relatively early in the war. Some of these progressed quite rapidly beyond the laboratory stage of development, and, to further the work, a coordinating committee was set up which later became the Associate Committee on Explosives of the N.R.C. Three sub-committees functioned under the parent committee; these controlled, respectively, research, development and testing (148).

42. The majority of research work was carried out in Universities under N.R.C. grants. Development aspects became increasingly important as research effort met with success. In order to bridge the gap between research and production, plans were instituted early in 1942 for the construction of an explosives pilot plant to be built by the N.R.C. and operated under the aegis of the Explosives Committee (149). Before instituting production it

is essential that all aspects of the serviceability of new explosives be investigated. It was here that the army was able to make its contribution to the integrated effort in explosives work. In addition considerable use was made of the staff and facilities of the Proof and Development Establishment of the Inspection Board of the United Kingdom in Canada for testing the explosives.

43. As a result of the Canadian effort two outstanding contributions were made to explosives technology. The better known of these was connected with the explosive RDX. This material has an explosive power about 50% greater than TNT, which for long had been the standard explosive in use. RDX had been known since 1899, but never adopted for use on account of the high cost of manufacture and its great sensitivity. Both these disadvantages had been more recently overcome to some extent by the "Woolwich" process. In 1940 another process was discovered in McGill University under the sponsorship of the N.R.C. Shortly thereafter American scientists discovered that a combination of the two processes resulted in further considerable reduction in cost. From April 1941 developments were carried on under the supervision of a Joint U.K.—U.S.—Canadian RDX Committee. By this time the explosive had been adopted by the British and was adopted by the U.S. Navy later in 1941. In one plant alone production eventually climbed to 340 tons per day (150).

44. A second Canadian discovery found application in flashless propellants. The one chiefly in use by British services, Cordite N, was not looked upon with favour by the U.S. Navy since as plasticiser it contained nitroglycerine, which conferred certain disadvantages under American conditions of storage and use. In 1942 the U.S. Navy expressed an urgent requirement for a flashless propellant which contained no nitroglycerine. The United States National Defence Research Committee attacked the problem by testing various compounds as replacements for the nitroglycerine in Cordite N. The most promising of these compounds turned out to be one which had been discovered a year or so previously by the explosives research team of the University of Toronto and given the name DINA. The new propellant in which DINA was used as plasticizer was called Albanite (151). In March 1944 the production of 10 tons of DINA was undertaken in Canada for U.K., U.S., and Canadian experiments (152). The success of the experimental work led the U.S. to construct a pilot plant which at April 1945 was making sufficient DINA for the production of one ton per day of Albanite (153). Just before the end of the war the U.S. services awarded a contract for the production of 2000 tons per month (154).

45. Experimental work relating to service application of explosive may be necessary for various reasons; to determine the value of, and to adapt, new

explosives to old uses; to improve upon methods of using service explosives; to adapt service explosives to new purposes, or to develop new explosives for new purposes.

46. It was recommended at the first meeting of the R.C.E. User Committee, 8 Feb 43, that developments to improve military demolition stores be undertaken in Canada. Eight specific requirements were outlined. The work was undertaken under the Director of Engineer Development in conjunction with the Research & Development Sub-Committee of the Associate Committee on Explosives, and a working Committee -- The Committee on Improvement to Military Demolition stores--was set up (155). A series of field trials were carried out in August and November 1943 (156) (157); and March and July 1944 (155) (158). The series of field experiments included trials of new adhesives developed for attaching demolition charges, new Canadian-developed explosives to determine their suitability for demolition task, a Canadian-designed delay action demolition fuze which later formed the basis for a British design (159), as well as comparative trials on modifications and variants of existing demolition stores.

47. An interesting explosives problem arose in connection with the clearance of anti-tank minefields. One method of clearance under investigation was the use of a "Snake" which is really an extremely long (several hundred feet) and flexible Bangalore torpedo, the idea being to project the empty snake across the minefield, and pump it full of liquid explosive which is then detonated with the intention of exploding mines along the path of the snake. Unfortunately, liquid explosives are notoriously dangerous to handle and transport. In order to overcome this danger the War Office requested in July 1944 that Canada undertake to develop urgently an explosive which could be mixed on the spot from safe ingredients (160). Some investigations on explosives of this sort had been carried out already (161) (162), and it was soon possible to suggest a satisfactory mixture (163). Certain technical difficulties delayed the prosecution of the project to its conclusion (164), and the requirement subsided before these were cleared (165).

MINEFIELD CLEARANCE

48. Explosive methods were not the only means investigated of clearing minefields. Indeed the clearance of minefields was one of the most persistent and aggravating problems of the war and no single solution which was 100% effective was ever found. The importance of the problem had been emphasized in discussions between A.C.I.G.S., Chief Engineer, British Army; Director General, A.T.C.B., N.D.H.Q.; and D.S.D.(W), C.M.H.Q. in England in the late summer of 1943 (166) (167). On account of its urgency and

complexity a unique method of approach was adopted (166) (168). In effect, the plan was to condult some 20,000 Canadian engineers and scientists; the members of The Engineering Institute of Canada, The Dominion Council of Professional Engineers, the Canadian Institute of Chemistry, The Royal Architectural Institute of Canada, and the members in Canada of the American Society of Mechanical Engineers and The American Institute of Electrical Engineers. This was to be done by the preparation and circulation of a pamphlet outlining the problem and possible lines of attack, and by the holding of lectures at various centres across the country. Resulting suggestions were to funnel through the Engineering Institute to A.T.D.B. for screening by a specially appointed committee, review by a Working Committee, and, if warranted, investigation by D.E.D.

49. As it developed the scheme proved somewhat embarrassing. On the one hand it was considered that too much information had been divulged to be in the best interests of security (169), and on the other a certain amount of resentment was engendered on the part of the civilian engineers consulted because they felt:

> "that inadequate information was given to the engineering personnel to enable them to attack the problem properly;
>
> Other than a mere acknowledgement, they have received no word on their proposal after it had been submitted, and did not know whether it was feasible or impracticable" (169 (a)).

50. Nevertheless, some 2400 suggestions were received (170). Methods suggested covered every conceivable way of dealing with mines, and the manner of presentation ranged from bare outlines to carefully worked out and blueprinted devices including mechanical, electrical, magnetic, explosive, optical, hydraulic, aero, heating, photograp ic and chemical means. Mechanical devices comprised rollers, harrows, ploughs, grapnels, weights thrown or dropped, prodders, tampers, diggers, dozers, sweepers, rakes, hammers, scrapers, scarifiers and bridges; some adopted from standard commercial machinery; some new in conception (171-183). By far the largest number of these suggestions duplicated principles already investigated or under investigation; a few gave rise to new projects.

51. "Altogether, several thousand proposals were received, and although it cannot be said that any entirely new or startlingly successful method of mine detection and destruction has yet been discovered, a large number of proposals are still being investigated, and very material progress has been made in the perfection and adaptation of various devices which are at present in use" (184).

52. One proposal, of interest in the light of subsequent war developments, suggested using the products of nuclear fission, specifically mentioning Uranium 235; the idea was misinterpreted by the Committee (185).

53. Peculiarly enough "the most successful mine destroyer yet put forward" (186) dated back in its conception to 1941 when the idea was rejected, to be resurrected in the spring of 1943 for development. The device became known as the "Canadian Assault Roller." It consisted of a heavy armour plate roller mounted on a swinging arm so that the shock of explosion instead of destroying the roller would toss it over, about the arm as radius, much like an inverted pendulum (187). In February 1944 the Ministry of Supply ordered 100 sets for each of Sherman, Churchill and Cromwell tanks (188).

BRIDGING

54. One of the most important duties of engineers with an advancing army is the construction of bridges, existing ones being almost invariably destroyed by a withdrawing army. Canadian development effort was devoted no less to the construction than to the demolition aspect of engineering activity.

55. In October 1942 an idea was conceived in the Directorate of Engineer Development for an adjustable universal bridge trestle to provide an intermediate support for various bridge spans in military use, with the twofold purpose of increasing the maximum width of gap across which a given type of span could be used and of reducing the weight of the main carrying members. The original design allowed for class 40 loads and provided for independent operation of legs so that the slope across the bridge could be kept to a minimum irrespective of leg settlement (190). The first prototype was completed in February 1943 (191), and following a demonstration in Ottawa (192) some modifications were made (193) and tests were carried out at the U.S. Engineers Experimental Bridging site in May 1943. The tests proved the equipment to be satisfactory for operational use (194). A requirement having now been laid down by the War Office for a heavier trestle (Class 70) capable of use to depths of 35 feet, development to satisfy this specification was instituted (195) (196). In trials the new trestle met with a favourable reception (197) (198) and as a result the War Office and 21 Army Group expressed a requirement for 50 trestles (199), which was later followed by a Ministry of Supply order for an additional 100 sets (200).

56. Early in 1944 Canada, "with its development facilities and its advanced knowledge of the magnesium alloy art", was asked to undertake the design and construction from magnesium, of a light

alloy infantry assault bridge* (202). Preliminary investigations involving the construction of a bridge section to a proposed design indicated that the proposition was feasible (203), and steps were taken to have 250 feet of this bridging constructed, using Canadian material and facilities (204). Keen interest in the development was displayed by U.S. authorities (205) (206) (207). It was considered that it filled a need which had long been unsatisfied. Concern was expressed, however, that the cost might be too great to justify its procurement for Pacific Theatre Operations (208) (209) (210). No production requirement actually materialized, due chiefly to the cessation of hostilities, though the item satisfied the General Staff requirements of both Canada and the United States (211). The outstandingly important feature of the development was that it served to prove "that magnesium, as well as aluminum, has possibilities and should be considered in future development of light bridging" (212). That the potentialities of the bridge had been recognized in other quarters is manifest by an inquiry as to its possible use as a pedestrian crossing for rivers in State Parks (213).

57. Another venture into the development of river crossing equipment led to considerable controversy. It resulted from a suggestion originating in the U.K. that Canada develop a close support Class 12 raft (214) upon which D.E.D. suggested the investigation of a detachable magnesium alloy truck body usable as a raft (215), an idea which found ready support by other interested directorates (216) (217). It was proposed to produce four prototypes (218). C.M.H.Q. did not consider the utility increased by making a truck body usable as a pontoon (219), and War Office, while feeling it desirable to produce a prototype (220) recommended that development be delayed until a firm policy had been decided (221). The United States took an interest in the idea, and after a demonstration, concluded it might have a definite place in service requirements (222). Thereafter, development was aimed at satisfying U.S. requirements (223). U.K. policy turned out to be contrary to the dual role idea (224), while on the cessation of Pacific hostilities the U.S. requirement ceased (225). The project was therefore cancelled (226).

VEHICLES

58. The effort involved in adapting Canadian facilities to initiating production and to building up

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*For a detailed account of this development see "Development of the Canadian Magnesium Alloy Assault Bridge" by Col E.C. Thorne, M.E.I.C., Engineering Journal, Vol 29, pages 712-716, 1946.

to the ultimate productive capacity of approved types of military vehicles during the early years of the war precluded any great attempt at designing new types of vehicles during that period. To reach an output of 200,000 vehicles per year of over 100 various new types within a period of 3 years is no small achievement (227). Nevertheless, some important development work did take place during those early days. The Ram tank is the best known example. This tank was first produced in 1941, the design being based on the U.S. General Lee tank, but with radical changes in the turret, gun mount and armament (228). The Ram provided a prototype for the M4 (Sherman) tank, which was developed shortly afterwards by the U.S. (229).

59. Typical of development work particularly suited to Canadian conditions and resources is the Snowmobile series of low ground pressure vehicles. The development of these vehicles was supervised by the Army Engineering Design Branch (A.E.D.B.) of the Department of Munitions and Supply. A survey of commercial types of snow vehicles was made in the fall and winter of 1941 on the instigation of the U.K. (230). Following the study complete tests were carried out on the most promising one of these types, and a military vehicle was developed therefrom by introducing a number of modifications to improve the performance under service conditions. (231). Some 129 of these "Bombardier" snowmobiles were built, starting in the spring of 1942. Most of the vehicles were shipped to the U.K. At the same time a project was instituted to develop, from the ground up, a vehicle of a similar type (half track with skis at front), but greater capacity. Interest in this vehicle ceased in July 1943 (232). However, a pilot had been built and during tests it became apparent that such a vehicle could better be manoeuvred by means of the tracks than by ski steering. It was decided, therefore, to build an experimental fully tracked snow vehicle. Tests on the new vehicle were carried out in the winter of 1942-43, and their success led to a decision to adopt the full track principle for service snow traversing vehicles (233).

60. In the spring of 1943 the British Ministry of Supply expressed an immediate requirement for an armoured two-man reconnaissance snowmobile. The results of previous experience were devoted therefore to satisfying this requirement, rather than to a plan which had been contemplated of building an unarmoured personnel and cargo carrying vehicle, and a prototype was built of the vehicle which became known as the "Snowmobile, Armoured Canadian, Mark 1." (234). Production started in early spring 1944 and was completed during the following winter, 410 vehicles having been produced.

61. Meanwhile, in January 1944, the Ministry of Supply had requested A.E.D.B. to develop a version of the Snowmobile for hot climate and amphibious operations. As an interim measure the Mark 1

snowmobile was modified for hot climate operation, while concurrently experimental work was instituted which led to the conversion of the snowmobile into the armoured amphibian Mudcat, of which pilot models were made in the spring of 1945 (235). Design of a lightened load-carrying version of the Mudcat, subsequently called "Muskrat" began in October 1944 (236). Pilot models only were produced (237).

62. The final member of the snowmobile family, the Penguin, reverted to the original oversnow function. With operation "Muskox" impending, work was started by D.V.S.A. in October 1945 on building, from the Mark 1 Snowmobile, a mock up of a sedan type vehicle in which equipment and personnel could be transported in reasonable comfort in extreme cold conditions, a requirement which had been established from the experiences of previous winter exercises. Following brief tests 15 Penguins were made for the operation (238).

63. Operational user trials were carried out on several Mark 1 Snowmobiles in Italy in January and February 1945. Performance over all types of soft ground was excellent. They not only travelled, with ease, roads one and a half feet deep in mud but were able to assist bogged wheeled vehicles to firm footing. The mechanical reliability of the vehicles was good. (239).

64. In operation "Muskox" (February to May 1946) which covered 3,100 miles under the most trying conditions of weather and terrain, it was dust which ultimately proved the worst enemy; during the last 200 miles (36 hours) of running six engines were knocked out from this cause (240).

65. Visualizing the expansion of airborne forces and with a view to possible vehicle requirements in the South West Pacific, No.1 Proving Ground began work in 1942 on the development of components for a track laying vehicle of the smallest practicable size (241). The outcome of this was the "Tracked Jeep". Following construction of a mock up by the Proving Ground a tentative General Staff Specification was drawn up and approval given for the construction of a prototype by the Willys-Overland Co., since a large number of the components were Willys' Jeep parts (242). The vehicle was demonstrated to 220 Military Mission in August 1943 and Major General J.S. Lethbridge, commanding the Mission, recognizing the possibilities of the vehicle for jungle or airborne use, requested that 5 prototypes be constructed for trials (243). In December the Ministry of Supply ordered four vehicles plus four amphibious models (244). This order appeared to duplicate in part the previous request. By March 1944 the position was clarified (245). The financial implications of the British order raised difficulties. Lend-Lease provided only for the supply of standard U.S. military equipment, whereas this was an experimental type, while on the other hand Mutual Aid, the Canadian

version of Lend-Lease, had no authority to cover purchases in U.S. funds. The problem was resolved by a decision to purchase the vehicles for Canadian Army account and transfer them to the U.K. as a gift (246). The first pilot model, built as a two-man lightly armoured reconnaissance vehicle, was completed in April 1944, and following tests and minor changes in design it was shipped to England, where it arrived in August. As a result of British tests their order was changed to provide unarmoured amphibious load carriers instead of the armoured tracked jeeps previously requested (247) (248), but, due apparently to some disagreement (249) this order was again changed to a load carrier, not necessarily amphibious and with belly armour if practicable (250). The original contractor was unable to undertake work on this modification (251), but was willing to cooperate and furnish parts to any other contractor undertaking the work (252). A new contractor was found. Shortly thereafter the Ministry of Supply transmitted instructions to discontinue efforts to procure the vehicles (253), a request which was followed a week or so later by advice that the cancellation should be cancelled, having been sent as a result of a misunderstanding (254). Thereupon the contract was placed as planned (255). It was apparent that the tracked jeep had now got into the "post war development" class.

66. In order to improve the performance of wheeled vehicles in soft ground Lt-Col B.D. Irvin of D.V.S.A. designed a "jungle track" in the fall of 1943. The track could be used similarly to tire chains, or as a wrap around track for the rear bogie of a six-wheeler (256). The first pilot model, tested in the summer of 1944, evolved much favourable comment and attracted the interest of both the U.K. and U.S. (257). It was considered there would be a definite requirement for the track in the Pacific as an accessory for six-wheeled vehicles. Additional pilot models were made incorporating improvements in design (258) and several requests were received for sets of tracks for trials (259).

> The C.A.S. Washington, have informed me that the Jungle Track development is of great interest to the U.S. Forces. There is a definite operational requirement for over-all tracks for the Pacific Area and in the U.S. this project is on the highest possible requirement and, consequently, the U.S. are desperately anxious to get trials underway immediately. The staff also say that if trials are successful there will be tremendous production requirement. In addition, it will provide Canada with a splendid contribution to this phase of the war against Japan (260).

Subsequent to VE day interest in jungle tracks intensified; additional requests came from the Ministry of Supply (261), while the patent rights were released to U.S. manufacturers for military purposes (262). The urgency of the requirement closed with the surrender of Japan, but interest in the device continued into the post war period. In tests carried out in the U.S. in August 1945 it appeared to be the best of all such types of equipment tested (263).

67. At a meeting held at C.M.H.Q. in February 1943 requirement specifications were drawn up for an anti-aircraft tank (the Skink), the function of which would be to accompany armoured formations for their protection against low flying aircraft (264). The problem was passed to A.E.D.B. for investigation (265). Due to the difficulty encountered in finding a contractor to undertake the engineering work a mock-up was made in A.E.D.B. workshops (266). The construction of a pilot model was later undertaken by the Waterloo Manufacturing Company (267). The design consisted of an M4 tank chasis mounting a turret carrying four 20-mm Hispano machine guns. In January 1944 a requirement for 265 equipments was established (268). Shortly thereafter it became necessary, due to War Office policy, to redesign the equipment to fire Oerlikon instead of Hispano ammunition (269). The redesigned pilot model was completed in April (270), and production was instituted the following month (271). After three complete vehicles and eight turrets had been produced the strategic requirement for A.A. Tanks lapsed (272), and the production programme was cancelled (273). In operational trials carried out by First Canadian Army on a pilot model in February - March 1945 the Skink was found useful in the engagement of ground targets (274 & 275). The appreciation of the War Office was summed up by the D.C.I.G.S. as follows:-

> I wish, therefore, to express, on behalf of the War Office our appreciation of the speed and efficiency with which the Skink turret was produced to meet what was, at that time, an important requirement.
>
> It is fully realized that the development of this powerful AA weapon, as far as the production stage in the time available, must have required a very considerable design and production effort, for which full credit is due (276).

FLAME THROWERS

68. Canada came into the picture. To the prescience of the Canadian Commander-in-Chief, General McNaughton, the enthusiasm of Colonel Harold Lynn, Royal Canadian Engineers and later of Lt.Colonels Sawyer and Arnason, and the inspiring keenness of Canadian officers and men of all ranks, much of the practical progress from this time onwards in securing the operational adoption of carrier flame-throwers was due.

Thus did Sir Donald Banks (277) pay tribute to the Canadian contribution in the development of the flame thrower, the success of which, in action, engendered in the users an enthusiasm without parallel in any other new weapon. The Canadian work was so closely integrated into the efforts of the Petroleum Warfare Department, (P.W.D., (U.K.)) that it is impossible to divorce the two in telling their story. P.W.D. had come into being in July 1940 for the express purpose of ensuring, in the teeth of a threatened German invasion, not only that the large stock of petroleum products held in the beleaguered island should not fall into enemy hands, but that its possibilities should be exploited to the fullest extent to extend to the invader literally the hottest reception imaginable. Along with such unpleasantries as "barrel flame traps," "beach flame barrages," "witches cauldrons," "Fougasses" and "demigasses" the ingenuity of the P.W.D. staff led them into investigations on mobile petrol sprayers, though without any intention of trespassing on the fields of the Ministry of Supply's Flame Thrower Experimental Establishment. The Bren carrier seemed to be a suitable vehicle on which to mount such a device. On 28 May 41 a demonstration was made of an experimental model which so impressed Lt-Gen A.G.L. McNaughton that he nominated 1st Bn R.C.E. to assist P.W.D. in developing an improved weapon by carrying out whatever user trials were necessary (278). The War Office gave its approval to the development two months later. Lagonda Motors took in hand the design of a flame throwing equipment, subsequently called the Ronson, while the Canadian Unit carried on extensive tests to determine the practicable load limit and load distribution of the carrier (279). Twelve prototypes of the Ronson were completed by the end of October 1941. There followed a series of tests and demonstrations by "C" Coy 1 Bn. R.C.E., in order to develop the tactics of the weapon and to "sell" the idea to senior officers. The Chief of Combined Operations, the C-in-C Home Forces and the G.O.C. 4th Cdn Armd Div were keen supporters of the carrier flame thrower. The War Office rejected the Ronson, though agreeing that it met the requirements previously laid down, and set out new specifications calling for a longer range, at the same time stating a number of objections to the use of flame throwers in infantry carrier platoons (280), and expressing preference for a tank mounted weapon. The Canadian G.O.C. requested 1000 Ronsons be produced in Canada (281). The decision was made fully conscious of the shortcomings of the Ronson and with the firm conviction that a much more satisfactory weapon could be designed ultimately, but on the basis that the Ronson was the only equipment of its type in existence at the time. A bird in hand is ever worth two in a bush. The Canadian manufacturers first pilot was completed in July. (282). By April 1943, 142 Ronsons had been received in the U.K., and additional 388 were at sea en route, while a further 52 had been lost at sea by enemy action (283).

69. In June of 1942 the Canadian group was established as the Canadian Petroleum Warfare

Experimental Unit (C.P.W.E.U.) for the purpose of investigating improvements in flame guns and in fuels (284). Meanwhile Lagonda were working on the Wasp design, while the Canadian group working at Lagonda built the Hornet which incorporated a new principle in flame gun design. It was expected that both of these would achieve the required range of 80 yards. This they did in tests carried out in July and August (285) (286). Both guns were somewhat complicated. In addition, from the Canadian viewpoint, the Wasp (Mk 1) suffered from the disadvantage of having internally stowed fuel tanks which added to maintenance difficulties and interfered with the primary role of the carrier. The War Office would not accept the risk of external fuel tanks, and ordered 1000 of the Wasps, having decided in Sept 1942 that carriers would be better than tanks* for mounting flame throwers. (287).

70. About this time C.P.W.E.U. undertook to simplify flame guns by producing a model in which fuel flow could be controlled entirely by a single pintle valve. An experimental model, the Barracuda, was ready in February 1943. Concurrently the Lagonda people were working on the Wasp 2 in which the Barracuda principle was adopted. (288). At this stage it was decided that C.P.W.E.U. were required for more urgent duties, and all development work on flame throwers was turned over to P.W.D. and to D.E.D. in Canada (289), while in the Canadian Army overseas Flame Warfare became the responsibility of the Chemical Warfare organization (290). For this reason and due to the fact that the Wasp 2 design was reasonably well advanced and had all the facilities of Lagonda behind it the development of the Barracuda was pursued no further (291). The first Wasp 2 was received in October and, following trials, the Canadian Army adopted it to replace the Ronson subject to it being modified from internal to external fuel tanks, a modification which resulted in the Wasp 2c. (292). Five hundred were ordered. The first prototype was received for preliminary trials in February 1944. First Canadian Army demonstrated to 21 Army Group the advantages of the 2c over the 2 with the result that the former was adopted throughout the Group (293).

> The Canadians had always been prepared to accept risks to the fuel container in mounting it outside the armour at the rear of the carrier for the benefit that this gave of preserving the interior of the carrier for normal use. This was fully justified in the event and the Canadian model 2c became standard for the whole Army before the end of operations (294).

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*Tank flame throwers, (Crocodiles), were later adopted as well.

71. Early in the European campaign the Canadian Army felt the desirability of having a heavily armoured flame thrower in addition to the Wasp but without the disadvantages of a fuel trailer such as the Crocodile had, and in August 1944 drew up plans and specifications for mounting Wasp flame guns in Ram Tank chassis as converted into Armoured Personnel Carriers (Kangaroos). The work of installation was carried out in the Canadian Base Workshops in the U.K. By November a few of the equipments, later called Badger, arrived on the continent, and, following a period of training and minor modifications to the equipment, were used in action. The heavier armour of the Badger afforded additional protection to both crew and equipment over the Wasp. Although casualties to Wasp crews were light, there were no casualties whatever to Badger crews in any operations in which they were used. However, on account of their much smaller numbers and later dates of adoption they were not used to anywhere near the same extent as the Wasps (295).

72. So far little mention has been made of the development of flame thrower fuels, though, in fact, this was the greatest factor in enabling the range of carrier borne flame throwers to be increased from 25 to 100 yards, and with a prospect of attaining still greater ranges. A "Mixtures Committee" had been established early in the career of P.W.D. Under their direction fuel mixes were prepared in the Fuel Research Station, Greenwich and field tested by C.F.W.E.U. (296). An early suggestion that rubber or soap be added to stocks of petrol in commercial filling stations to frustrate any attempt at their conversion to enemy use in the event of a German landing was turned to good advantage when it was recognized that the gels resulting from such acts of sabotage might offer an improvement over the oil mixture currently in use in flame throwers. Attention was first centred about the use of rubber. Shortly after success was achieved the rubber supply failed, thanks to the Japanese (297). Thereafter efforts were confined to the use of soaps. In the United States investigation of thickened gasoline for use in incendiary bombs had been undertaken even before Pearl Harbour (298). The researches of both the U.K. and U.S. groups were successful, resulting in two thickening agents, dependent on different raw materials for their manufacture. The British compound, called FRAS, was essentially an aluminum stearate soap. The U.S. material, called Napalm was a mixture of aluminum compounds of naphthenic and coconut oil acids (298). Investigations on aluminum soaps were undertaken later in Canada at the request of C.M.H.Q. (299). FRAS was adopted as flame thrower fuel by the Canadian Army in November 1942 and by the War Office in June 1943 (300).

73. After two false starts the Ronson did achieve limited operational use in the Pacific by U.S. Forces. In November 1942 the War Office had asked C.M.H.Q. if fifty Ronsons could be sent to the Middle

East, a request which was cancelled a month later (301). Two months before the Sicily landing General Eisenhower asked for "16 Ronsons or latest type flame thrower" (302), to which the War Office replied:-

> Regret unable to comply with your request in view G.S. decision taken on security grounds employ flame throwers in large (rpt large) numbers only.
>
> Unlikely Wasp (latest type carrier borne) flame throwers available for allocation in quantity until June (303).

Whereupon the requirement was cancelled "since no flame throwers available until June" (304). In fact, as early as January 1943, Lt-Gen McNaughton and other authorities had agreed that the flame thrower should not be used prematurely and unnecessarily (304a).

74. A number of Ronsons, estimated at 170, were acquired from Canada by the U.S. Navy and Marine Corps. Some of these were mounted on tanks and some on amphibious craft, and saw service in the Marianas campaign in 1944 (305) (306).

75. Wasps 2c became available to the Canadian Army in France in August 1944 (307). They soon gained the confidence of those units which used them. By the end of the hostilities in the case of experienced users flame was used in approximitely 50% of the main battalion attacks, and from the start of operations to clear the Rhine Valley until the end of the war it was used in 75% to 100% of the main battalion attacks. All units report that their flame throwers were over 90% successful in carrying out their flame attacks, and it is estimated that approximately 200,000 gallons of fuel was used operationally. The following two comments of users are of interest:-

> I consider flame to be a most efficient support weapon and would use it on every possible occasion.
>
> This unit is of the opinion that the Wasp flame thrower is one of the best close support weapons the infantry ever have had when within effective range of the target. To achieve this, strong support (fire) was given to them. (308).

The particular value of the Wasp in the type of country encountered in the Netherlands is emphasized in the following:-

> In recent operations over the polder country, where a carrier was often the only vehicle that could be moved, with the enemy occupying positions on one side of a dyke and our own troops on the other, the only

> weapon which effectively winkled out the enemy was the "Wasp". The flame was fired over the dyke, and blobs of ignited fuel set fire to straw and wood covering slit trenches. In almost every case, the enemy was driven out of his positions and was immediately cut down by the fire of supporting infantry or M.Gs. mounted on the carriers themselves (309).

76. A striking, though not typical, Wasp action, took place at Boulogne, when an intrepid flame crew of the Highland Light Infantry of Canada neutralized an enemy fortification located at the end of the south pier. This fortification had proved immune to machine gun and artillery fire. The only approach was by means of the pier itself, a structure some 300 or so yards long and ten feet wide, carrying a narrow gauge railway and under repair at the seaward end. Along this the carrier was driven. After running 100 yards it fired a shot of flame which fell short. Travelling another hundred yards a second shot was fired, then a third, which however, failed to ignite. The flame thrower was "out of gas". The crew had just taken over the weapon, unaware that it had been used previously and not since reserviced. Fortunately the distant sight of flame, and the mere threat of its closer approach had been sufficient to induce the enemy garrison to surrender, and by the time they had summoned up enough courage to emerge the supporting infantry literally were sitting on the fort waiting for them. The result: "no casualties to own troops"; fifty prisoners, a quantity of ammunition, a 75-mm gun and a number of machine guns (one of which covered the pier approach) captured (310). That is the picture time after time. At the Leopold Canal, with the assistance of flame throwers the Canadian Scottish made the assault crossing without casualties (311). Similarly in the crossing of the Senio in Italy on 9 Apr 45 one of the assaulting division, the 2nd New Zealand, lost not a man killed; the total casualties among assaulting troops were 43 killed and 279 wounded (312). Of this exploit Field Marshall Alexander says:-

> This battle saw the greatest use of flame of any in this war and undoubtedly the Crocodiles and Wasps made a most vital contribution to the success gained. I can supplement the account with evidence from the enemy, obtained since capitulation. On 14 April General Von Vietinghoff, the German Army Group Commander, reported to the Supreme Command of the Wehrmacht; "Since 11 April the enemy has been employing a new type of flame-throwing tank which has a range of from three to four hundred metres. These weapons are used to burn out strong-points and isolated pockets of resistance. The range of close combat anti-tank weapons is insufficient to combat them." In the

> absurd exaggeration of the range can be seen a measure of the psychological effect these weapons had on our enemy. (313)

77. The effect on morale is indicated by enemy remarks as well as by user reports. Thus, following his capitulation General Eberding, G.O.C. 64 German Division told the G.O.C. 3rd Canadian Division that "his men feared our flame thrower more than any other weapons at our disposal", while the staff of 30 German Corps named flame throwing tanks and carriers, and smoke as our most effective weapons (314).

78. This extreme phychological effect is a phase which accompanies the successful large scale introduction of any novel weapon. With increased familiarity a more stable mental attitude accrues and the weapon assumes its proper perspective among "conventional" weapons. It is hoped that, for the flame thrower, this statement will never have to be demonstrated. Meanwhile flame throwers

> ...had fulfilled the anticipations of the visionaries. They had fought in over 500 actions, had suffered no higher casualties than the normal carrier crews and had proved themselves invaluable infantry weapons. Many a stout infanteer owes his safe return home to the flaming "Wasps" that struck terror into the hearts of the Nazi hordes (312).

SMOKE

79. Smoke was coupled with mechanized flame throwers in the tribute paid to the effectiveness of our weapons by 30 German Corps staff (see para 77). Although smoke producing devices of Canadian development did not see service use our contribution to the knowledge of the production and use of smoke was in evidence at all stages from the laboratory to the field and especially in the field. Fundamental research was carried on at the universities under extra mural grants from D.C.W.S. (315).

80. Among smoke devices of Canadian origin was the "Comox torpedo". This was a light, self-steering hydrofoil power craft carrying smoke generators (316). The suggestion that such a craft be developed originated in the Navy as an outcome of a large scale smoke demonstration at Courtenay, B.C. in May 1943. The idea was put forward as an alternative means to aircraft for laying smoke screens close in to shore in landing operations (317). Development work was a cooperative effort of several agencies coordinated by A.T.D.B. Trials of prototypes were held at Fort Pierce, Florida, in February 1944. Although the seaworthiness was satisfactory the self-steering was not reliable and considerable difficulty was experienced in launching (318). As time went on it became clear that the problems of steering and launching were not

likely to be solved sufficiently early to be of any great operational value and the project was abandoned.

81. Late in 1942 at the request of C.M.H.Q. the Army Engineering Design Branch of the Department of Munitions and Supply undertook to investigate means of producing smoke screens from vehicle exhausts for the tactical screening of A.F.V. formations (319). Subsequently D.C.W.S. and D.V.S.A. took part in the development. Several models of exhaust smoke emitters for universal carriers were produced independently by various agencies (320). All of them proved mechanically unsuitable for service application (321). A tank version was more successful. Demonstrations of an experimental model on 14 June 1943 indicated that the tentative General Staff requirement could be satisfied and it was decided to have six prototypes constructed for trials (322). The first manufacturer's pilot model was sent to the U.K. in March 1944 (323) and the remaining pilot models were completed and distributed the following month (324). Thereafter the development became a victim of misunderstanding, to which it ultimately succumbed. The misunderstanding arose, perhaps, through lack of emphasis on the intended functions of the emitter coupled with the fact that in tests and demonstrations comparison invariably had been made with the No.25 Rear Smoke Emitter which fired a bank of four No.8 Generators either in pairs or altogether. Whether for this reason or not it came to be assumed that exhaust smoke was put forward as an alternative to the Rear Smoke Emitter. A statement to this effect was made in the report of No.6 (C.W.) Wing, Canadian Training School (325), and the same assumption was reflected in the report of the Chemical Defence Experimental Station (C.D.E.S.) (326) and in the War Office decision rejecting the device (327), though no such suggestion had been made by C.M.H.Q. (328). C.M.H.Q. considered that these two smoke emitters were, in fact, complementary in function (329). The situation was summed up by the M.G.O. as follows (330):

> It was considered that certain statements made in regard to this device both by [Director, Royal Armoured Corps] D.R.A.C. and C.D. Experimental Station shows lack of knowledge of the use and potentialities of the exhaust emitter....Once again we reiterate our statement made in earlier correspondence that this device will not eliminate the tank's individual protective smoke laying devices, (2" bomb thrower or smoke grenades)....As we envisaged it the proper use of the smoke from an exhaust smoke emitter is the laying of a tactical or a collective protective screen.

82. Meanwhile a more urgent smoke requirement had arisen in Europe in connection with the use of carrier flame throwers. What was required was a device to provide immediate self screening to protect flame thrower carriers during the final 1 to 200 yds. of their attack (331). A satisfactory equipment

consisting of an 8-barrelled discharger for No.80 or 81 grenades was developed at C.D.E.S. Porton, England (331). Trials at First Canadian Army (332) resulted in an immediate requirement for 200 of the equipments. In order to make these speedily, Canadian Base Workshops undertook their production. Through the War Office 21 Army Group requested an additional 400 which were also made by C.B.W. (333). This device subsequently replaced the existing rear smoke emitter of tanks (334).

83. Canadian work in the production and control of large tactical smoke screens predated their participation in hostilities by some years. A tactical smoke screen was laid by personnel of the Suffield Station at Bedford Basin, N.S., in August 1942, at the request of the Naval Board (R.C.N.) and which at that time added considerably to the knowledge of area screening, in particular it showed that the harbour could be screened without interfering with sea traffic (335). This marked the beginning of Canadian work which culminated in Northwest Europe in 1944-1945 on a far greater scale.

84. In operations on the continent considerable use was made of oil fog generators as well as of the standard No.24 smoke generators and smoke floats, both of the chemical burning type (336). Oil fog generators were an American development, designed from fundamental physico-chemical data, and embodying the principle, for the first time, of producing a screening smoke by the distillation of high boiling petrolum fractions (337). Several types of generator incorporating this principle were produced.

85. During the period September 1944 to April 1945 the smoke units of the First Canadian Army spent over 70 days in actually putting up tactical smoke screens, exclusive of the time spent in preparation and planning. Over 5,000 tons of smoke producing material were expended in these operations. The largest smoke action, that in support of "VERITABLE" extended from 8 Feb to 12 Mar 45, consuming 3,500 tons of smoke material. Due to changing situations this consisted of a series of screens (rather than a single screen) which had to be changed almost daily. At the completion of "VERITABLE" there was a nearly continuous line of smoke emission points 30,000 yards long paralleling the Rhine.

86. These operations amply demonstrated the value of controlled smoke screens put up by generators.

> The great advantage of using smoke generators (oil and smoke) rather than shell for producing smoke screens is in the economy of effort. It must be remembered that in order to place one pound of smoke agent on the ground about 10 pounds of boxed ammunition is required. Another comparison of effort is the relative tonnages required

to maintain a kilometer smoke screen for an hour in a following wind of average speed (10 mph). With 25 pounder smoke 100 tons of boxed ammunition are required against 1 to 2 tons for smoke generators. Another advantage of use of generator smoke is that it is seldom used at the expense of HE as is usually the case with smoke shell. The use of shell is therefore a very expensive method of putting up a smoke screen but must be accepted when laid in enemy territory. (336)

CHEMICAL WARFARE

87. It might be well at the outset of this section to explain the significance of the term "gas" in the popular expression "Gas Warfare". While to the civilian layman "gas" means hardly anything more than something with which to cook, to the scientist it is a state of matter in which the "molecules are prectically unrestricted by cohesive forces", and has neither definite shape nor volume. Chlorine, the first of modern chemical warfare agents complied with the scientists definition. However, since 1915, which is generally accepted as the year of birth of modern chemical warfare, a number of toxic agents of all three states of matter - solid, liquid and gaseous - have been added to the list of chemical warfare substances so that, to the soldier, the term "gas" has taken on a looser and different connotation, and is applied to "any substance, whether solid, liquid, or vapour, which is used for its poisonous, irritant or blistering effects" (338). It is hoped, therefore, that the present work will not occasion in the strictly scientific reader any mental writhings, when a substance with a boiling point of 217°C. is referred to as a gas.

88. The establishment of the Experimental Station at Suffield (see page 3) made it possible to eliminate from the concepts of the behaviour of chemical warfare agents much of what was either speculation, or, at best, extrapolation from small scale experiments. The station had sufficient territory at its disposal to permit observations to be made of gas releases on a scale commensurate with that likely to be used in operations. Much of its work, especially in the earlier years, consisted in examining by means of large scale experiments those hypotheses which had been developed on gas behaviour on a basis of the dispersion of relatively small amounts of agent. The most significant factors in the release and travel of gas clouds are those several natural phenomena which are collectively called weather. Terrain, which includes the texture and profile of the earth's surface, and the vegetation and buildings upon it, together with the nature of its subsurface, comes a close second. As a result of much meticulous work carried out over many years by

the Chemical Defence Experimental Station in the U.K. it was possible at the beginning of the war to predict with a practicable degree of precision the behaviour of a gas cloud under those variations of weather conditions prevailing at that station. That is to say a satisfactory degree of correlation had been attained between quantity of gas; time, distance and concentration downwind; atmospheric turbulence; wind speed; and air and surface temperatures, within certain limits. Hence the soldier could be taught that under certain weather conditions he was more likely to be subjected to an attack by non-persistent gas than under others. Favourable and unfavourable weather conditions had come to be recognized as concepts in the tactical use of gas. The Suffield work on behaviour of gas clouds was essentially an extension of the previous work to cover experimental conditions well beyond the limits of previous experiments. Without, in any way, discrediting previous work the results did indicate that certain factors, insignificant within the narrower limits became increasingly significant the more certain of those limits were exceeded, and that modification of existing theory was necessary to allow for special conditions. The ultimate effect for practical purposes reduced considerably the significance of favourability and unfavourability in weather conditions (339).

89. In the First Great War, when the use of chemical agents had become a normal feature of battle, and respirators a standard item of personal equipment, the most effective casualty producing "gas" was mustard, a blistering, or vesicant, material resembling an oil, and which produces slow healing chemical burns wherever it comes into contact with the body. Inhaled as a fine spray it usually proves fatal. In the eyes, if not quickly attended to, it causes blindness. Obviously an extremely unpleasant substance with which to be showered. The tremendous development in aircraft between the wars increased the likelihood of just such a contingency to a virtual certainty should gas warfare ever be resorted to. Speculation as to the possible results ranged all the way from the lurid flights of imagination of writers in the sensational press, through the more sober, but sometimes erroneous, calculations of the initiated to the blind pooh-poohings of the ultra-conservative. In any event a tremendous effort was expended in time and material in providing defensive measures. A considerable number of full scale experiments carried out at the Experimental Station on the effectiveness of air sprayed mustard gas enabled conclusions to be drawn based on actual observation instead of conjecture, on fact instead of theory (340).

90. A prominent feature of Suffield work was the assessment, or evaluation of the effectiveness, of various chemical weapons and ammunition under a wide variety of weather conditions, thus eliminating much of the uncertainty as to what might be expected

at temperatures where investigation had hitherto been impossible.

91. The techniques developed and used by, and the special facilities available to, the Experimental Station led them into investigations only remotely related to chemical warfare. Notable among these was work carried out on the emission of D.D.T. solutions from aircraft for large scale control of insect pests. Indeed, the entomological work of the establishment expanded so considerably that it was found necessary to set up, in April 1945, a special section to carry out the volume of work undertaken. Perhaps "remotely" hardly applies here. The eradication of predatory insects by chemical means is but a short step from the eradication of predatory humans. (341).

92. In 1942-43 a series of experiments were carried out in cooperation with the Medical Service on the efficacy of analeptic drugs in the prevention of fatigue in troops. This extended the work in England of Dr. D. Russel Davis, performed early in 1942 with the cooperation of the Officer Commanding, the Regina Rifles (now Gen. C. Foulkes, C.B., C.B.E., D.S.O., C.D., Chairman Chiefs of Staff) and Col. H.M. Brown of the Canadian Medical Service overseas. The conclusions of one test in particular are worth noting. In this test 150 men were involved, a proportion of whom received benzedrine sulphate, exercises lasted 3 days, during which time they marched 50½ hours with a toral rest of only 7½ hours of which it was possible to sleep only 4½. The men were unaware of the period of duration of the test until the actual moment of termination. "The beneficial effects (of benzedrine) were not marked, and the capacity of the drug to alleviate fatigue is not comparable to the influence of good officers on troops" (342).

93. Even if space permitted it would be impossible for security reasons to give a detailed account of all the work of the station. Its share in the United Nations war effort is best summed up in the words of General G. Brunskill, Director of Special Weapons and Vehicles, the War Office:

> For various reasons, the contribution which Canada has made to Chemical Warfare in all its facets has been out of all proportion to the contribution that could rightly have been expected from the Dominion. Suffield has played a large part in this.... (343).

During its wartime operations about 300 Field Experiments, mostly large scale, were carried out, and in the vicinity of 400 technical and scientific reports and memoranda were issued.

94. Less spectacular, but no less essential, was the work of the Chemical Warfare Laboratories,

Ottawa. The primary responsibility of these laboratories was to ensure the adequacy, both in quality and quantity, of the various items of equipment for protection against chemical agents; respirators, fabrics permeable and impermeable, ointments to reduce the effectiveness of blister gases. Needless to say this involved not only considerable routine work; but, in addition, every change in the supply situation of necessary strategic materials, e.g. rubber for respirators; every new item, whether chemical warfare or not, of service equipment adopted for operational use, even such apparently insignificant items as buttons, every new theatre of operations opened, from sub-artic to tropical; every potentially new chemical agent reported raised a defensive problem which had to be investigated. Such investigations provided the establishment with most of its work. A second phase of C.W.L. work was in technological advice and consulting to those manufacturers producing chemical warfare stores whether defensive or offensive. Occasionally supply problems became so urgent that the laboratories were themselves compelled to enter the production field. On these occasions the pilot plant, which formed part of the establishment and which normally was used for the investigation of manufacturing problems, proved invaluable. Thus, when the requirement for D.D.T. by the services was most urgent this pilot plant was the only available source of the material in Canada. Their D.D.T. production, while small by manufacturing standards*, was timely and adequate for immediate needs pending the development of larger production facilities (344).

95. Of considerable importance within the sphere of Chemical Warfare Laboratories activities was the work carried out on physiological aspects of chemical warfare. This covered investigations in prophylactic, immunological and therapeutic means of mitigating the number and severity of chemical casualties. Much effort was aimed at improving the ointments provided for protection against vesicant agents, and with marked success although the objective of producing a single ointment with satisfactory effectiveness against all vesicants, the chief of which are mustard and the nitrogen mustards, was not achieved.

96. Considerable extramural work in chemical warfare was carried on in the universities in both the chemical and physiological aspects of the subject. The extramural effort was more concerned with the longer term problems. This work was integrated into the overall Canadian work by being coordinated in a section set up for the purpose in D.C.W.S. The results of some of these investigations, as of other chemical warfare researches, are now beginning to find their way into the scientific literature (345).

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*The pilot plant produced 7 tons of D.D.T.

97. The Directorate of Chemical Warfare and Smoke was responsible for the administration, and in part, the direction of the work, of the War Disease Control Station, a joint U.S. - Canadian organization. A notable achievement of the scientists of this station was the development of a vaccine against the dread cattle plague Rinderpest (346) (347).

98. It is no secret that none of the belligerents resorted to chemical warfare; one or two incidents reported were minor and may have been purely accidental. When this fact is examined in the light of the almost universal expectation of its use not only before the war but throughout almost its entire course one naturally tends to ask: why? It is not difficult to answer on the part of the Allies; the reason was reiterated at frequent intervals by allied leaders. Gas would be resorted to only if the enemy used it first*. The reason is more difficult to seek on the part of the axis powers. The notorious Nazi disregard for treaties makes it unlikely that the Geneva Convention of 1925 was any deterrent. Besides, Italy had already violated the convention in the Ethiopian War. Both Italy and Ethiopia were party to the Convention. Japan was not a signatory to this agreement and had made some use of gas in the earlier years of the war against China, who was. It is perhaps worthy of note that on both these occasions gas was used against defenceless personnel. The United States was not bound by the Geneva Protocol so that this question does not enter into U.S. - Japanese hostilities. It seems logical, therefore, to discount the Geneva Convention as a factor in preventing the outbreak of chemical warfare. To suggest that humanitarian consideration restrained the axis powers from resorting to gas smacks of the facetious. Rotterdam, Coventry, Buchenwald and a host of others testify otherwise. Lack of confidence in gas as a weapon of war? Germany's extensive preparations as exemplified by Raubkammer belie this suggestion, though the possibility of a disagreement on this score between Government and General Staff exists. The more the question of "why" is considered in conjunction with the Nazi pattern for conducting war the more it seems apparent that they would have resorted to gas had they been convinced that the consequences of its use would react in their favor and provide some advantage which they could not otherwise achieve. The question then resolves itself into determining what factors could have instilled into the Nazi mind the doubts which stayed their chemical hand. The advantages of gas against inadequately protected personnel had been demonstrated on numerous occasions between 1915 and 1935. The extent of chemical defensive measures, of Britain in particular, were well known

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*In the opinion of General McNaughton gas would have been used against German landing in the United Kingdom in 1940.

to the German. The defensive thoroughness, especially in comparison with Germany's own, must have raised doubts as to whether the use of gas would be worth while. In the 1914-18 War gas had been somewhat of a boomerang since the prevailing wind direction in the theatre of operations had been in Allied favour. In 1939-45 the Allies were far better prepared to retaliate, and the enemy believed our retaliatory potentiality even greater than it was. This expectation of receiving severalfold what they were prepared to dispense especially with the loss of air superiority, could have influenced the decision. It seems logical to suppose that our prepardness for chemical warfare, both defensive and offensive, if not the only reason or even the chief reason, was at least a contributing factor to the failure of the Nazis to initiate gas warfare. If this is so then our efforts were not futile, as may appear at first sight, but were, in fact, first class insurance. This belief was expressed by the Comptroller Chemical Defence Department (U.K.):

> Though it may now appear at first sight that since chemical warfare has not been used in the war against Germany our efforts have been largely wasted, this is by no means the case. I have just paid a visit to the German Porton and ammunition dumps and I am certainly surprised at the huge scale on which they have conducted their investigations and the large amount of money they have spent in equipping the place and in providing huge supplies of gas ammunition of all kinds. We have most certainly made them expend a tremendous effort. This they must have done because they knew of our state of preparedness but apparently they were deterred from initiating chemical warfare by the high state of our defence and the retaliation which we should have brought to bear had they initiated this form of warfare. I therefore feel that we have won our chemical war without having to fight it. In other words, we have been an extremely cheap insurance policy, a fact which I hope will not be forgotten in the years of peace when the money bags are a bit tight. (348)

Major General Alden H. Waitt (Chief U.S. Chemical Warfare Service) points out a lesson in preparedness in the non-use of gas by the enemy:-

> It further proves that preparedness pays.... Here is a case where preparedness actually prevented the use of a weapon (349).

There are those who would be prepared to dispute this contention. Without attempting to justify further its validity the fact remains that in this instance preparedness may have worked; in the prevention of war in toto preparedness has never been tried; other methods have, and in vain. There seems to be a good case in favour of giving preparedness a chance. The cost is little compared to that of war.

COMMUNICATIONS

99. The production for service use of army communications equipment running into a value of something like three quarters of a billion dollars is itself a testimony to the efforts of those responsible for the design and development of this equipment. Much of it was of Canadian development. A large proportion of it was due to the work of the Directorate of Electrical and Communications Development and its subsidiary, the Canadian Signals Research and Development Establishment. Originating about a nucleus of technical personnel in the pre-war Directorate of Signals of the General Staff Branch, the group underwent various transformations of function, organization and supervising responsibility, according as the war economy passed through its various earlier phases, until it settled down as a M.G.O. directorate in 1943. At the same time an army radar group which had previously been integral with the signals organization became a section of the Directorate of Artillery. The new D.E.C.D. had well defined terms of reference incorporated into its War Establishment (350).

100. In addition to the normal work of design of signals equipment, the Directorate had, like many other directorates, all those problems to investigate which stem from such things as the failure in supply of a strategic raw material, and the necessity of keeping equipment workable whether in the arctic or the tropics. The loss of rubber supplies necessitated the introduction of synthetic materials as cable insulators, and a wide range of insulated conductors were developed by D.E.C.D. using these substitutes. Perhaps no other single items of equipment are as susceptible to damage due to tropical conditions as are communications sets incorporating, as they do, so many different kinds of materials in their make up. Even under favourable conditions corrosion has to be guarded against. At high temperature and humidities and with the addition of sea salt, and numerous deleterious tropical flora and fauna the danger is increased manifold.

Wireless Set, Canadian, No.9

101. Among the wireless sets widely used early in the war was the Wireless Set, Canadian, No.9, (C.9) which went through several redesign phases to become known, eventually, as the "52 Set". Over $21,500,000 was spent producing more than 2300 C.9 and successor sets for both British and Canadian forces. Based on a pre-war British design the C.9 was a Canadian redesign which gave increased

efficiency and permitted the alternate use of available Canadian tubes. This set was placed in use by the Canadian Army Overseas (C.A.O.) in 1942. It was reported as giving excellent service and made a good impression on the British, giving impetus for the design of No.9 Mk I which came into use by C.A.O., and British Army Overseas in 1943, and in 1944 was used in beach-landing operations in Normandy on D-Day. The Mk I set was designed to double the mileage range on the same frequency. The favourable impression created by this set provided British interest and the impetus for the design of W/S Cdn 52 still higher power and greater frequency coverage. In January 1944 it was agreed that C9 Mk II set be changed in name to Wireless Set, Canadian, No.52 (351).

Wireless Set, Canadian, No.52

102. The C-52, developing from the No.9 Set proved to be very popular in all quarters although it was noted that while performance on medium power was good there was a tendency to overheat on high power. This set was particularly valuable in airborne roles and for command vehicle working. The U.K. alone spent over 14 million dollars purchasing these sets (352).

Wireless Set Canadian No. 19, Mk II and Mk III

103. As with the No.9 set, the C-19 was a redesign of a British model (to accomodate Canadian manufacturing processes). The Mk II of this make replaced the W/S No. 11 in the Valentine Tanks and was standard equipment in the Rams, and saw service in the North African campaign. The C-19 kits were designed to be interchangeable with British designs for general overseas use. In October 1943 the Australian Army, reporting on the conditions of service material under tropical conditions in New Guinea, remarked that "... Canadian No. 19 Sets which were inspected appeared to withstand damp tropical conditions better than other sets." 2 Cdn Armd Bde reported, respecting W/S Cdn No. 19 Mk III"... Sets give excellent service under severe operating conditions." (353).

Wireless Set, Canadian, No. 29

104. In designing a wireless set for operation in the tropics a number of factors which adversely affected radio communication in the jungle had to be considered: heavy rainfall, high humidity, high temperature, tall and dense vegetation, rugged topography and intense electrical storms. As a result a durable wireless set giving better all-round performance and which would also be smaller in size had to be designed and manufactured (354).

105. The Wireless Set, Canadian, No. 29 came into being as a replacement for the Wireless Set

No. 19. An order for 10,000 equipments was placed in Canada on U.K. accounts and production was to commence in July 1945. The "29 Set", besides being simpler to operate than the W/S No. 19, was lighter, had twice the range, and was designed for operation in any theatre of war, from the Arctic to the Tropics. Urgently required by the U.K. for general use in the Far East, production commenced in September 1945 (355).

106. The British requested a design ten times the power of W/S 19 but to the same space limitations. This called for miniature technique hence there was a long period (32 months) of development. The 29 Set was adopted, by the War Office in October 1944 as the standard set for tanks and A.F.Vs. in the war against Japan. There were many improvements in the W/S 29, including increased range, additional frequency channels, elimination of netting procedure and weather-proof construction - to mention but a few. Then, in August 1945, immediately upon cessation of hostilities, the requirement no longer existed. The British order for 10,000 sets was cancelled and a new order subsequently placed for 200 (356).

Other Wireless Sets

107. A number of other wireless sets were developed for specialized work such as the "58" and "88" Sets for infantry use. The W/S No. x88B was designed for radio-telephone communication up to one-and-a-half miles between infantry companies' platoons and for troops supporting Armoured Fighting Vehicles, etc. In some instances the need for a particular wireless set disappeared before it could be brought into production and often after the expenditure of many thousands of dollars in preliminary work (357).

Synthetic Insulant

108. Another important feature of developmental work in communications concerned a synthetic substitute for the rubber insulation on cables. Much design was involved in the search for rubber insulant by industry, N.R.C., and at all test establishments in coordination with the Department of National Defence (358).

109. When the sources of natural rubber were cut off numerous investigations were carried on by the National Research Laboratory in selecting and testing Synthetic Compounds to replace the natural products used in insulating and sheathing cables. The first investigation was in connection with the wiring of tanks and vehicles for the Army and this was carried out for the Army Engineering Design Branch (A.E.D.B.), Department of Munitions and Supply. There followed extensive field tests. The most widely tested synthetic compound at the time was a plasticized polyvinyl chloride (P.V.C.) known variously as Koroseal, Flaminol and Vinylite (359).

110. To most Canadian cable manufacturers this product was new and much of the testing in the first few months was to satisfy Army authorities that the finished product was sound both physically and electrically. Many heat shock tests were made to ascertain that no stresses were present which might result in subsequent splitting and failure in service. Special tests were later carried out with particular attention devoted to low temperature performance leading to the development of new and better plastics. Under low temperature (-40°) it was found that the copper strand in a cable would fail before the plastic insulants (360).

111. Continued tests demonstrated that if good physical properties at low temperatures were required they could be obtained using special plasticizers but by so doing sacrificing the desirable electrical properties. It was necessary to compromise (361).

112. Later when Buna-S type synthetic rubber became available the emphasis was shifted from P.V.C. compounds to this GR-S material and in general the work in the Laboratory was shifted from Army to Navy sponsorship (362).

113. When GR-S was finally given preference over the P.V.C. Compounds it was necessary to determine whether the GR-S produced in Canada (Polymer Corps, Sarnia) was suitable and which manufacturer could produce the best compound in the form of finished cable (363).

114. By comparison the Sarnia product was found to be unsatisfactory since it was a general purpose product built around the needs of the tire industry. Further investigation of the project was not carried on after the cessation of hostilities (364).

RADAR

115. Radar* was one of the "miracles" of World War II for it undoubtedly contributed much toward beating the enemy, particularly Germany. By 1939 British radiolocation devices had been developed to a greater extent than those of the other Great Powers and Britain was thus ready to meet the invader with a new device (365).

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*The British name given to this method of detection was "radiolocation" and "R.D.F." (radio direction-finding). The U.S. Navy coined the word "radar" as an abbreviation of "radio detection and ranging". This term was taken over by the U.S. Army and subsequently adopted by the British Services.

116. Simply stated, Radar consist of a transmitter and receiver located at the same place often with a common antenna. The transmitter sends out energy in pulses. Between pulses the receiver is working and the signals it receives are echoes of the powerful transmitted pulse from nearby objects. The elapsed time between the transmission of the pulse and the reception of its echo measures the distance of the object giving the echo from the place where the radar set is located. The direction of the object is found by providing the radar set with a directional antenna which sends out the pulses in a narrow beam, like a search light (366).

117. Early in the War it was discovered that more trained operators and equipment would be necessary than could be produced by wartime Britain. The War Office therefore requested that Canadian personnel be loaned as Fire Control Operators and that the production of gun laying equipment (G.L. Sets) be undertaken in Canada (367).

G.L. Mk III C Set

118. In the autumn of 1940 the Ministry of Supply requested the National Research Council in Ottawa to develop G.L. Equipment. Work was begun and good progress made. In about ten months time Canada was about ready to go into production, to the amazement of both the U.K. and the U.S. In October 1941 a Canadian G.L. Mk III Set was shortly to be available for shipment to the U.K. After more experimental work, four further sets were produced, one of which was sold to the U.S.A. (368).

119. The G.L. Mk III Set consisted of an Accurate Position Finder (A.P.F.) and a Zone Position Indicator (Z.P.I). Trials of the A.P.F. and Z.P.I. commenced in January 1942 in Surrey, England but unsatisfactory weather caused the trials to be prolonged until June. The successful trials of the Canadian prototype were enthusiastically noted by the British experts. It appeared that Canada could produce the G.L. Sets before Britain and an order was placed for 200 G.L. Mk III C equipments to augment those being received from British production (369).

120. During November 1942 the War Office accepted the L.W. Set for "early warning" employment by L.A.A. Regiments in preference to the Z.P.I. Set since the former could be carried in a 15 cwt truck whereas the latter required the services of a 4 ton lorry and a 6 ton trailer. The provision of Canadian Z.P.I. Sets for Canadian L.A.A. regiments was cancelled and orders were placed during February 1943 for two L.W. sets per regiment although delivery would be slow (370).

121. In the British view there were sound reasons why the Canadian G.L. Mark III Sets should not be used in a mobile role. There was a shortage of

modification and spare parts and there was a lack of proper identification equipment. During 1943, however, suitable identification of friend or foe equipment (I.F.F.) was developed at the National Research Council and placed under trials. Another obstacle to adopting the Canadian G.L. Set was that certain defects were encountered in the first models due to substandard manufacture. In addition the manufacturer, Research Enterprises Limited, was unable to meet production schedules due to shortages of tools and skilled workmen. British manufacturing caught up with Canadian and it would not have been possible to maintain two different equipments for the same purpose. Lastly the Canadian equipment was too bulky and cumbersome, necessitating as it did a three-ton lorry, a four-ton tractor drawing a ten-ton APF trailer and a six-ton Z.P.I. or early warning trailer (371).

122. These factors prompted the War Office to inform C.M.H.Q. in July 1943 that their policy would be not to issue G.L. Mk III C Sets to units of the Field Force but Canadian sets could be used on A.D.G.B. (372).

123. During 1944 an increasing number of Canadian G.L. Sets came to be used on A.D.G.B. sites and the closest liaison was maintained by technical personnel of both the Canadian Army and National Research Council with A.O.R.G. and A.D.R.D.E. of the Ministry of Supply and Anti-Aircraft Command to make improvements in this set's employment. A number of sets were shipped also to France and Russia. A large number had been retained in Canada for purposes of coast defence and internal security whilst other had been made available to Australia for employment in the South-West Pacific (373).

124. Meantime there was the problem of training personnel. In November 1940 the War Office requested C.M.H.Q. for a loan of personnel for a six-month period to be trained and used as operators fire control. Even more urgent was the need for trained maintenance personnel. General McNaughton concurred in the request and training was begun under British auspices. For the most part, technicians and operators trained in Canada were employed in manning radar equipment on Coastal defence and with all anti-aircraft batteries in Canada. Overseas, Canadians were picked for training as fire control Operators at British schools. As operators completed their courses they were attached to British units in A.D.G.B. and further candidates were sent to British anti-aircraft schools. (374).

125. Under General McNaughton's direction, plans were made to organize a Canadian radio location unit. Personnel who had been attached to British units were recalled to form a nucleus and in March 1942, 231 reinforcements arrived from Canada (375).

126. By the end of summer 1942 No. 1 Canadian Radio Location Unit was concentrated at Colchester. With the arrival of the pre-production models of the G.L. Mk III C Set it was possible to intensify training of both maintenance personnel and operators, fire control. The training of Canadian personnel was now well in hand. It was the loan of a considerable number of them to the British which enabled them to place many sets in operation. The end of 1942 found personnel of No. 1 C.R.L.U. serving with British batteries on the South Coast. These gun-sites were visited periodically by Canadian officers. A decision was reached in February 1943 to disband this unit in order to make the Canadian radar organization conform to that of the British Army and to eliminate one of the extra calls on the "man-power ceiling" (376).

OPERATIONAL RESEARCH

> The work of "Operational Research" is to observe, to study and to calculate on what goes on during training and in operations ... (377).

127. The term "Operational Research" was first used in the early days of the war by Coastal Command, Royal Air Force. In the Army, the term was first applied to the mathematical treatment of the employment of radar and other new equipment in air defence. It was found necessary to include in the scope of "Operational Research" such associated matters as the training of personnel and the design of equipment. In other fields the rapid development of new weapons and equipment created new problems of manipulation and of training. The solution to these and other problems called for a combination of the research methods of the physical and biological sciences together with the application of considerable service experience. Many of the problems were beyond the scope of existing development and research establishments, and a number of variously-named research bodies, includin the "Army Operational Research Group," were created from time to time in Great Britain to deal with them (378).

128. Experience of the British Army showed the necessity of an organized body on investigators, equipped and able to furnish the General Staff with an open-minded assesment of the value of equipments, procedures and training methods, in so far as such an assessment could be based on scientific investigation. British operational research sections were formed in 1943 for Army Groups in the field. Doubt existed as to the potential value of these sections and as to their organization and function. Some considered that the unit should operate as a detachment from the Army Operational Research Group, (A.O.R.G.), returning when its study was completed. The system actually adopted

by the British Army was to place the operational research section completely at the disposal of the formation commander as part of his staff working for him on problems arising within his command, and reporting to him only. This section was allowed to exchange liaison letters direct with the Supervisor Operational Research Group (S.O.R.G.) on purely scientific matters. Under the British system several directorates were responsible for army operational research. In practice the British drew no clear lines between the functions of related directorates but, in general, there were three groupings of operational research activity:

(a) performance of weapons and equipment in operation,

(b) behaviour of men using equipment,

(c) tactical employment in conjunction with D.M.T. and D.M.O.

These tasks were supervised respectively by the Deputy Director of Science reporting to the Scientific Adviser to the Army Council, (S.A.A.C.); the Director of Research reporting to the Deputy Chief of General Staff (D.C.G.S.), and the Director of Biological Research reporting to the Director General of Army Medical Services, (D.G.A.M.S.) (379).

129. The experience of the British showed the necessity for organized operational research. Hence, in 1943, at the instance of the Director of Staff Duties (Weapons) at N.D.H.Q., Dr. D.C. Rose of the National Research Council and Lt-Col C. Sandford were sent to England to examine the Operational Research and similar systems in the British Service, and to recommend what organization should be set up for Operational Research in Canada (380).

130. In August 1943, having investigated the British system, Rose and Sanford conferred with Lt-Gen A.G.L. McNaughton concerning operational research, a subject which already had been under active consideration for some time by the Canadian Army Overseas. It was agreed that any operational research section in the C.A.O. should be a British section although Canadian personnel should be included in the group. General McNaughton felt that the organization of an operational research group in Canada would be very valuable for the analysis of physical functions in respect of equipment. Lt-Col Sanford stated that the chairman of N.R.C., Dean Mackenzie, agreed with the establishment of an operational research group especially since it might better survive post-war retrenchment in the military development field. Such an organization would be engaged in psychological as well as physical research. Rose and Sanford opposed any direct connection between the section with the First Canadian Army and any army research organization in Canada.

They suggested that the function of the research organization in Canada should be: "to advise the C.G.S. in any matter, susceptible of scientific study, on which he requests advice." It was noted that because existing military research establishments were working to time and concerned with actual supply and production problems there was a need for an organized body of investigators equipped to undertake scientific study of value of equipments, procedures, training methods and furnish C.G.S. with completely open-minded assessment and (if required) recommendation. In drafting the terms of reference and details of organization for Canada the main factors considered were:

(a) The prior existence in Canada, as in Great Britain, of a number of development and research bodies not covering the whole field of necessary research.

(b) The operational research system must fit in and cooperate ith these existing establishments and must fill the need that they do not fill.

(c) The many differences between conditions in Canada and those in Great Britain which tended to create in Canada a set of problems very different from those presented in Great Britain. (381)

131. The Rose-Sanford report recommended that the Canadian operational research system should be comprised of the following:

(a) <u>The Scientific Adviser to the Chief of General Staff</u>

The S.A./C.G.S., preferably a civilian, had to be in good standing as a research scientist with an entrée to the heads of civilian research bodies. A soldier would tend at times to allow service traditions and seniority to affect the advice he might give to senior army officers. This appointee was required to direct the research work of the Canadian Army Operational Research Group (C.A.O.R.G.). Dr. Rose, the first holder of this office, vacated the post in April 1945 and it remained vacant until after the end of the war.

(b) <u>The Canadian Army Operational Research Group</u>

A member of the C.A.O.R.G. was required to be a well-qualified research man with considerable service experience.

Because of the difficulty in finding such men it was decided to insist only on the research qualification - research experience in a particular field was not required. Where specialist knowledge was required one man had to help another.

Originally overlooked, a technicians' pool was set up in the spring of 1945. Personnel of this group served mainly in connection with recording and processing of data on meteorology work.

(c) The Directorate of Operational Research

This directorate was, firstly, to provide the liaison and the service knowledge and experience necessary to directing the research work along the lines most profitable to the army; and secondly, to relieve the S.A./C.G.S. and C.A.O.R.G. of as much detail as possible. Within the Directorate the functional organization provided sections for:

(i) routine and administration, and

(ii) technical liaison

The tasks in the latter section uncluded liaison with the General Staff technical directorates, training centres, units, operational research in other services, library, and collection and control of progress reports. (382).

132. The proposed research organization was designed to assist existing establishments by making available the results of scientific investigation on the application of their work to actual problems of operations and training. Rose and Sanford believed that there was a useful function to be performed in advising the General Staff on coordination of all research work in the Army and in organizing interchange of information. Included in operational research was operational analysis; that is numerical studies made on the battlefield of such subjects as the killing power and the effect of various weapons, the recording of damage done by barrages and bombings, and the protection afforded to men by their equipment and their shelters (383).

133. In the earlier stages of development of the system, investigators went to work in suitably constituted sections at Ottawa, using the resources of the National Research Council, and at training establishment where there were suitable facilities. It was recommended that for the time being the provision

of research sections for operational formations (other than the First Canadian Army) be deferred. As far as operational research with the Canadian Army in the field was concerned it was suggested that the research section for First Canadian Army be organized on British lines, bearing the same relation to the army commander and to the head of the O.R.G. as did the sections with other formations in the 21st Army Group. This section was to be manned by either British or Canadian military personnel. Also, it was considered inadvisable to establish any direct channel of inter-communication or control between the section and the organization in Canada (384).

134. After further consideration the proposals were approved by the Chief of General Staff and the Minister of National Defence. Initially the Research Group was to be organized in sections stationed as required in Canada. It was anticipated that research sections for field operations might be formed as required for attachment to formation headquarters in the field. In October 1943 the C.G.S. wrote: "It is not practicable to organize the several parts of the operational research system immediately at their full eventual strength. The system must be... allowed to grow as research problems arise and as ... personnel become available... it is proposed that the Scientific Adviser and the Director of Operational Research be appointed as early as possible and proceed with the organization of the system ... interim establishments shall not be filled immediately but only as the system progressively undertakes its responsibilities." (385).

135. The organization of Canadian operational research was authorized in November 1943. An interim war establishment for the Directorate of Operational Research remained in force until 16 May 44, when a revised H.W.E. was approved. Col J.T. Wilson was appointed director in December 1943. The positions of S.A./C.G.S. and of Deputy S.A. also were established by order-in-council in December. The war establishment for C.A.O.R.G. was approved in March 1944 effective 1 Nov 43. The staffs of the Directorate and of C.A.O.R.G. were gradually increased and on 15 Apr 44 consisted of 16 scientists. However the question of a Canadian Operational Research Field Section was still not settled, for on 17 Feb 45 S.A./C.G.S. wrote to D.C.G.S.(C) proposing the formation of such a Section (386).

136. An important feature of Canadian Operational Research was the necessity of carrying out liaison. It was essential that there be an exchange of information with related civil and military research bodies in the United Kingdom, the United States, Australia, India, and, of course with domestic Canadian groups. Initial liaison with the U.K. was established by S.A./C.G.S. (Dr. Rose) and Lt-Col Sanford. Liaison was further developed in May 1944 when Professor Ellis, S.A.A.C., Brigadier Kennedy D.D. Sc., and Dr Nabarro of A.O.R.G. visited

Canada and the U.S.A. Projects were discussed which could be best investigated in Canada because of climatic conditions. Some of the projects undertaken as a result were large scale smoke trials, cold weather troop trials and visibility development. Liaison was developed, too, with Operational Research Sections in Australia, India and various establishments in the U.S.A. In Canada close contact was maintained with many groups, both civilian and governmental in nature - N.R.C., N.D.H.Q. directorates, universities, training centres, etc (387).

137. The relationship of operational research to various portions of the army is of interest. S.A./C.G.S. was authorized to report direct to the C.G.S. if necessary and had the power to decide upon the suitability of projects for investigation. Existing development and research bodies were at first critical of the operational research proposals, especially since the work might have been handled by other directorates. Many projects fell to Operational Research because Operational Research had suitable investigators who were ready to undertake the main responsibilities for the work in collaboration with other directorates. Once the need for this particular type of research was established cooperation was forthcoming (388).

138. The C.A.O.R.G. formed detachments at the Armoured and Signal Corps training centres. These detachments were formed to cope with certain training problems and in this respect the system proved its worth. At first the methods used were met with some suspicions by instructors, reluctant to try a new approach to their problems. Such was the contribution of the operational research detachments that the staffs of both centres wanted detachments permanently attached to their establishments (389).

139. Canadian Operational Research began late in World War II hence an account of Canadian wartime achievements in this field covers only a relatively brief period of time. By August 1945 operational research was well under way and the main job remaining was to ensure that research was adequately provided for in the army in the future (390).

140. A complete investigation of the development of Canadian Operational Research is not practicable in this narrative. However a brief account will indicate the type of research which was involved.

141. In December 1944 the C.G.S. issued a memorandum in which a rough classification of operational research projects was outlined. It was pointed out that operational research included operational analysis: numerical studies of the killing power and effect of various weapons, recording damage done by barrages and bombings, and the protection afforded to men by their equipment and their shelters. The projects fall, roughly, into four groups.

Large scale tactical trials and related problems

142. These were trials designed to establish military doctrine in regard to the use of improvements in technology or fighting under unusual conditions. Examples of these trials were the winter exercises, (Exercises Lemming, Polar Bear, etc.) four of which had been conducted by May 1946. Such tests stemmed, at least in part, from the theory that Canadians would be fighting the Japanese under conditions similar to those obtaining in Canada. The winter exercises provided tests of men, equipment and techniques under specialized conditions - a type of training not pursued among western allies. The conclusion of the exercises was that it was possible to conduct joint army-airforce operations in any part of Canada in any season. It was felt, too, that winter exercises should be encouraged as they provided a good test of men with attendant advantages in discipline and morale (391).

Effect of weapons and equipment

143. Quantitative studies were made of the lethality effects of weapons and analysis of battle results in cooperation with British A.O.R.G. Mine clearance by explosives was investigated as was the effectiveness of H.E. and C.W. Weapons under various conditions. Trials were held to investigate the technical and tactical problems of producing a smoke blanket and fighting in it. Results showed that the preliminary training of troops needed improvement and tanks were found to be very vulnerable to infantry in smoke (392).

Training and selection problems

144. Detachments were established at some training centres to investigate methods of pre-selection, scientific measurements on methods of application of training equipment and of results obtained. The results of research detachments' work at R.C.A.C. and R.C.C.S. training centres became incorporated into training manuals (393).

145. A large portion of the story of Canadian Operational Research goes beyond the period here dealt with and does not properly belong to an account of Canadian wartime technical development. In fact Canadian Operational Research, conceived of in the minds of a few men in 1943, really had begun to function only towards the end of the war. However, as at least one person clearly foresaw, there was a need to establish operational research so that it would be carried on in the post-war days of anticipated military retrenchment. Any such period of retrenchment which may have existed has now been passed and operational research still continues, long after the end of World War II.

146. The major part of this report was drafted by Dr. E.E. Massey during the period 1947-52. The final paragraphs, 101-145, were prepared by Lt. C.A. Larson in 1953. The report was mimeographed in February 1955.

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