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First World War Canadian Operational Research

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ABSTRACT
This article examines the operational research conducted by the Canadian Corps Gas Services and the Canadian Machine Gun Corps during the First World War. It develops the initial inquiry completed by scholars J.S. Finan and W.J. Hurley and finds that the staff officers of these two specialised Corps conducted operational research with varying degrees of rigour. While none of them ever used the term 'operational research' to describe their work, they were undoubtedly its practitioners through their innovation, trials, experimentation, and subsequent dissemination of knowledge. This article offers a new interpretation of their adoption of a new scientific approach to operations and learning within the Canadian Corps during the First World War.

Introduction

Before breaching the Canal du Nord on 27 September 1918, in one of the most audacious operations conducted by the Canadian Corps, the corps commander, Lieutenant-General Sir Arthur Currie, reported, 'A complete programme of harassing fire by Artillery and Machine Guns was also put in force nightly. The Corps Heavy Artillery... carried out wire cutting, counter-battery shoots and gas concentrations daily, in preparation for the eventual operations.'[1] As Currie noted, the Canadian Corps did not only rely on artillery to shape the battlefield. Fire plans also incorporated indirect machine gun fire and gas. Together they provided what one historian has compared to a 'percussion crescendo' that supported the advance of the

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[1]Quoted in Ministry Overseas Military Forces of Canada (OMFC), *Report of the Ministry Overseas Military Forces of Canada, 1918,* (London: His Majesty's Stationery Office, 1919), p. 155.

infantry.[2] While gunners had conducted the technique of indirect artillery fire since the late nineteenth century, armies did not use chemical warfare or indirect machine gun fire on the battlefield until 1915. Canadian Corps machine gun and gas officers used operational research (OR) to incorporate gas and machine gun barrages into the corps' fire plans, enabling the infantry to break into German defensive positions, and to protect its soldiers from the effects of gas on a chemically saturated battlefield.[3] Although these officers never referred to their work as OR, they practiced the methodology as we now understand it, and their scientific studies are examples of OR that predate its formal emergence as a distinct discipline in the 1930s.

OR is defined by the Operational Research Society of the United Kingdom as:

> [T]he application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials, and money in industry, business and defence. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.[4]

The discipline adheres to the scientific method in that hypotheses examined through OR are testable, replicative, and observable. The OR methodology is quantitatively

[2]Shane B. Schreiber, *Shock Army of the British Empire: The Canadian Corps in the Last 100 Days of the Great War,* (St. Catherine's: Vanwell Publishing Limited, 2004), p. 47.

[3]For an assessment of the experience of the Canadian Corps and BEF with machine guns and gas, see Shelford Bidwell and Dominick Graham, *Fire-Power: British Army Weapons and Theories of War, 1904-1945,* (Barnsley: Pen & Sword Military Classics, 1982); Tim Cook, *No Place to Run: The Canadian Corps and Gas Warfare in the First World War,* (Vancouver and Toronto: UBC Press, 1999); G.S. Grafton, *The Canadian 'Emma Gees:' A History of the Canadian Machine Gun Corps,* (London: Hunter Printing Company, 1938); Paddy Griffith, *Battle Tactics of the Western Front: The British Army's Art of Attack, 1916-18,* (New Haven and London: Yale University Press, 1994); Albert Palazzo, *Seeking Victory on the Western Front: The British Army and Chemical Warfare in World War I,* (Lincoln and London: University of Nebraska Press, 2000); Bill Rawling, *Surviving Trench Warfare: Technology and the Canadian Corps, 1914-1918,* (Toronto, Buffalo, and London: University of Toronto Press, 1992); Donald Richter, *Chemical Soldiers: British Gas Warfare in World War I,* (Lawrence: University Press of Kansas, 1992); and Tim Travers, *The Killing Ground: The British Army, the Western Front and the Emergence of Modern Warfare, 1900-1918,* (Barnsley: Pen & Sword Military Classics, 2003).

[4]Maurice W. Kirby, *Operational Research in War and Peace: The British Experience from the 1930s to 1970,* (London: Imperial College Press, 2003), p. 3.

based; however, the discipline of OR does not necessarily involve complicated mathematics. In a military context OR provides commanders and staffs with a method to measure performance and effectiveness. OR informs them if they are doing the right things and doing the right things well. Commanders seek to employ their forces as efficiently and effectively as possible, and OR provides commanders and their staffs quantitative tools to measure how well they are using their forces and how well their forces are performing.

The experience of the British Expeditionary Force (BEF) during the Battle of the Somme between 1 July and 18 November 1916 marked a watershed moment for innovation on the Western Front. Pertinent to this examination, it had resulted in the addition of machine gun and gas staffs to the corps headquarters, such as: the then Lieutenant-Colonel Andrew McNaughton; the staff of the counter-battery staff office; the staff officers of the Canadian Machine Gun Corps (CMGC); and the Canadian Corps Gas Services who together innovated, trialled, experimented, and disseminated their findings as best practices.[5] Many staff officers leveraged their prewar scientific backgrounds while also benefitting from the innovations and practices of other formations in the BEF. Curiously, despite the importance of gas and machine guns to the Canadian Corps, neither arm had a robust staff structure comparable to the artillery. Nor did they have a prestigious office like the artillery counter-battery staff office with access to the corps commander. Insufficient staffing to manage both operations and OR imposed limitations on the scientific work that these staff officers could conduct, and the nature of the two weapon systems complicated data collection. Whereas the effects of artillery on the battlefield (cratering or damage from shrapnel) could be measured, the effects of gas or bullets fired during a machine gun barrage could not be so easily gauged. Personalities and inter-arm rivalries negatively affected the OR done by gas and machine gun officers as well. Despite these challenges, there is much evidence of OR indicators such as innovation, trials, experimentation, and the dissemination of findings, however imperfectly they may have been done.

Armies had fielded variants of the machine gun since the American Civil War; however, the stature of the machine gun rose dramatically on the Western Front. In the BEF, the machine gun eventually emerged as a distinct arm. In 1914, each infantry battalion in the Canadian Expeditionary Force had just two machine guns.[6] As the

[5]For an assessment of the OR conducted by McNaughton and the staff of the counter-battery staff office, see J.S. Finan and W.J. Hurley, 'McNaughton and Canadian Operational Research at Vimy,' *The Journal of the Operational Research Society*, Vol. 48, No. 1 (January 1997): pp. 10-14.

[6]G.W.L. Nicholson, *Official History of the Canadian Army in the First World War: Canadian Expeditionary Force, 1914-1919,* (Ottawa: Queen's Printer and Controller of Stationery, 1962), p. 25.

number of machine guns in the Canadian Corps increased between 1915 and 1918, the corps first grouped all the medium Vickers machine guns into companies that were affiliated with brigades. OR practitioners must be critical thinkers, and the CMGC was fortunate it could select its OR staff from the machine gun units that already comprised the 'best and brainiest men' from the infantry battalions.[7] The formation of the CMGC as a distinct arm from the infantry followed on 15 January 1917.[8] The last major reorganisation occurred in May 1918 when the Canadian Corps reorganised the brigade machine gun companies into divisional machine gun battalions, each with ninety-six guns. Two motorised machine gun brigades, with forty guns, augmented machine gun barrages for corps operations. These reorganisations largely followed those implemented by the British Army, except in 1918, a Canadian division had ninety-six machine guns to a British division's sixty-four.[9] Combined, the Canadian Corps had nearly the same firepower as a small British army. Not only quantitative differences existed between the CMGC and the British Machine Gun Corps. The commander of the CMGC also had greater control over these weapons, since General Headquarters (GHQ) did not uniformly implement this control for the corps machine gun commander across the BEF until November 1918.[10] Not only did Brigadier-General Raymond Brutinel, commander of the CMGC, have more machine guns at his disposal, but he also had the command and staff structure to use them more efficiently than the British could until GHQ clarified matters in November 1918 .[11]

Towards the end of 1916, the CMGC Vickers machine guns were in use to fire indirect barrages. Machine gunners had some knowledge of indirect fire before the war, but, like the artillery, most understood their primary role to be the use of a direct fire weapon.[12] Indirect fire, however, enabled the engagement of targets situated in

[7]H.T. Logan and M.R. Levey, *History of the Canadian Machine Gun Corps, C.E.F.,* (Bonn, London, and Ottawa: Canadian War Narratives Section, 1919), p. 100. The author is grateful to Dwight Mercer for provision of this reference.
[8]Library and Archives Canada (LAC), RG9-III-D-3, Vol. 4981, File 598, War Diary (WD) – Corps Machine Gun Officer, Canadian Corps, November 1916 – June 1917, Appendix M, Canadian Corps General Staff, G. 669 61/21, 'Memorandum to Form Canadian Machine Gun Corps,' 15 January 1917.
[9]Nicholson, *Official History of the Canadian Army in the First World War*, p. 383.
[10]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 150.
[11]On Brutinel as a commander and innovator, see Cameron Pulsifer, 'Canada's First Armoured Unit: Raymond Brutinel and the Canadian Motor Machine Gun Brigades of the First World War,' *Canadian Military History* Vol. 10, No. 1 (2001): pp. 44-57; and Yves Tremblay, 'Brutinel: A Unique Kind of Leadership,' in *Warrior Chiefs: Perspectives on Senior Canadian Military Leaders*, eds., Bernd Horn and Stephen Harris, (Toronto and Oxford: Dundurn Press, 2001), pp. 57-70.
[12]R.V.K. Applin, *Machine-Gun Tactics,* (London: Hugh Rees Ltd., 1910), pp. 46-54.

defilade. It also enabled the machine guns to fire over the heads of advancing infantry to augment the artillery fire plan. The actual procedure for indirect machine gun fire mirrored the procedures used by the artillery. To fire indirect, the machine gunner needed to determine the following: the exact position of his weapon, the direction to the target, the distance between the gun and target, as well as the angle of sight between the gun and target.[13] When firing over friendly troops, machine gunners also needed to account for the distance from the gun position to friendly troops and the height of friendly troops above the gun position. The gunner determined direction and range with a compass and map, and then used a spirit level, elevating dial, or clinometer, an instrument that measures the angle of elevation of the barrel from the ground, to set the elevation of his gun. Machine gun barrages adhered to the same principles of artillery barrages, but officers gave more consideration to siting the machine guns in enfilade to maximise the beaten zone of the weapon over the target during the barrage.[14]

The Canadian Corps incorporated machine guns into the wider fire plan prepared by the artillery. Captain George Lindsay, a British infantry officer in charge of machine gun training for the BEF's New Army divisions, had pioneered the use of machine gun barrages.[15] Lindsay's ideas shaped experimentation with this technique on the battlefield and began in 1915, although the first instance of a machine gun barrage is difficult to determine. The British official history states that the machine guns of the British 2 and 47 Divisions, fired the first indirect machine gun barrage during the Battle of Loos between 25 September and 8 October 1915.[16] However, historian Paddy Griffith writes, 'the true father of the machine gun barrage turns out to have been the equally energetic and forceful Brigadier E. [*sic*] Brutinel, the machine gun officer to the Canadian Corps.'[17] Griffith credits Brutinel with firing the first barrage on 2 September 1915. In neither case, however, was the machine gun fire incorporated into the wider artillery fire plan. Through OR, the machine gunners developed the tactical acumen to integrate their weapons into the fire plans that supported the later operations of the Canadian Corps.

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[13]J. Bostock, *The Machine Gunners' Handbook: Including the Vickers and Lewis Automatic Machine Guns, Eleventh Edition,* (London, W.H. Smith & Son, 1917), pp. 197-198.

[14]General Staff, General Headquarters, *Notes and Rules for Barrage Fire with Machine Guns,* (Machine Gun School, Machine Gun Training Centre, May 1917). The beaten zone refers to the elliptical shape formed when the rounds fired from the machine gun strike the ground or target.

[15]Griffith, *Battle Tactics of the Western Front*, pp. 123-124.

[16]James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1915, Volume II, Battles of Aubers Ridge, Festubert, and Loos,* (London: His Majesty's Stationery Office, 1936), pp. 188, 254.

[17]Griffith, *Battle Tactics of the Western Front*, p. 124.

The now mostly discredited myth of the superiority of Dominion forces over their British counterparts extended to the use of indirect machine gun fire.[18] Historian Pierre Berton claims, 'The British thought of the machine gun as a kind of super rifle. It took the Canadians to demonstrate at Vimy that it could be employed as light artillery.'[19] Shelford Bidwell and Dominick Graham argue that the Canadian Corps pioneered machine gun tactics because its officers did not hold prejudices against employing the weapon in an indirect fire role, as the British Army did.[20] These arguments are unfounded. The BEF first incorporated a machine gun barrage into the artillery plan during the attack made on the Thiepval Ridge between 26 and 27 September 1916.[21] Incidentally, the Canadian Corps played a prominent role in that attack. The attack did not result in complete success, but the machine gun barrage fired by 1 Canadian Motor Machine Gun Brigade worked. '[I]t is reported that during the 1st hour of firing that [the machine gun] Battery completely wiped out [the] German counter attack directed against the flank held by the 14th Batt[alion].'[22] Nevertheless, machine gun barrages were not particularly efficient, and a machine gun company could fire well over one million rounds in a single day, and yet only produce more of a morale effect than a physical one.[23] Making machine gun barrages more effective and more efficient required OR.

Brutinel played an instrumental role in the innovations of machine gun tactics and methods. An engineer by training, and a French soldier when the war began, Brutinel enlisted in the Canadian Expeditionary Force at the request of Sir Clifford Sifton, the former Canadian Minister of the Interior, to help form the 1 Canadian Motor Machine Gun Brigade.[24] Brutinel assisted in raising funds for its equipment, arranged for the design and purchase of their armoured cars, and purchased their first Colt machine

[18]For a recent examination of how the British Army innovated and learned on the Western Front, see Aimée Fox, *Learning to Fight: Military Innovation and Change in the British Army, 1914-1918,* (Cambridge: Cambridge University Press, 2018).
[19]Pierre Berton, *Vimy,* (Toronto: McClelland and Stewart, 1986), p. 170.
[20]Bidwell and Graham, *Fire-Power*, p. 123.
[21]Martin Farndale, *History of the Royal Regiment of Artillery: Western Front, 1914-18,* (Woolwich: The Royal Artillery Institution, 1986), p. 154.
[22]LAC, RG9-III-D-3 Vol. 4986, File 626, WD – 1st Canadian Motor Machine Gun Brigade, September 1916, Appendix 137, Lieutenant-Colonel Raymond Brutinel, 'Report on Operation 26-27 September 1916,' n.d.
[23]Griffith, *Battle Tactics of the Western Front*, p. 124.
[24]LAC, RG150, Accession 1992-93/166, Box 1212-39, Raymond Brutinel Personnel File; and Canadian War Museum, George Metcalf Archival Collection, 20020045-1525, The Raymond Brutinel Tapes, Tape 1, p. 2, 18 October 1962. The author is grateful to Dwight Mercer for provision of this reference.

guns.[25] He also promoted a culture of learning within the machine gun unit. In one early experiment, Brutinel instructed his staff to make a terrain model and plot the trajectories of the machine guns. [26] From this model, he determined that machine guns could fire indirectly 500 yards into the enemy's rear area, at a place where several German artillery officers congregated at predictable times. After engaging and scattering these officers several times, the German artillery retaliated against the machine guns. Brutinel used their retaliation as proof that his indirect machine gun fire methods worked. While this experiment lacked the rigour of later tests, it was a start.

While Brutinel possessed a keen and analytical mind, he was also an egotistical self-promoter. During the war, he disagreed or clashed with Lindsay, Secretary of State for War Lord Kitchener, Lieutenant-General E.A.H. Alderson, then commander of 1 Canadian Division, Brigadier-General C. Bonham-Carter, Brigadier-General Staff (Training) at GHQ, and the staff of the GHQ Machine Gun School.[27] Generally, his disagreements with these people stemmed from his belief that they did not understand how machine guns ought to be employed. His tendency to take credit for almost all innovations in machine gun tactics and techniques makes substantiating his claims difficult. For instance, he claimed that the French Army sought him out to instruct French officers on the machine gun methods he had used at Vimy between 9 and 12 April 1917. Brutinel did lecture French machine gun officers; however, his claim that General Émile Fayolle, commander of *Groupe d'armées du Centre*, watched Brutinel's demonstration, converted to his methods, and then ordered a commander to attack with only a machine gun barrage supporting the advance seems unlikely.[28] The French official history makes no mention of Brutinel drastically revising French doctrine, and Fayolle had established a reputation for meticulous artillery preparations before his attacks.[29] During the summer of 1917, the French Army was in a state of near mutiny after the failed Nivelle offensive, so it seems unlikely that any commander would have ordered an attack without artillery support.

While the Canadian Militia had limited experience with machine guns prior to the First World War, it had none with chemical warfare. The Canadian Expeditionary Force had its debut with gas during the Second Battle of Ypres between 22 April and 25 May

[25]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 16.
[26]The Raymond Brutinel Tapes, Tape 11, p. 2.
[27]Ibid., Tape 7, pp. 1-2; and Tape 21, pp. 1-2.
[28]Ibid., Tape 20, p. 3.
[29]Ministère de la guerre, état-major de l'armée – service historique*, Les Armées Françaises dans la Grande Guerre, Tome V, Volume 2: Les offensives à objectifs limités, 15 mai – 1 novembre 1917,* (Paris: Imprimerie Nationale, 1937), p. 340; and Robert A. Doughty, *Pyrrhic Victory: French Strategy and Operations in the Great War,* (Cambridge and London: Harvard University Press, 2005), pp. 291-292.

1915, when the German Army used chlorine gas against the soldiers of 1 Canadian Division as well as the French *45 Division d'infanterie* and *87 Division d'infanterie territoriale*. Neither the Canadians nor the French had protection against the new weapon. Innovation was needed to shield their forces from the effects of poison gas. Much like early flash-spotting and sound-ranging innovations for counter-battery fire, serving officers with a scientific background identified the problem and proposed solutions almost immediately. The ammonia in urine partially neutralised chlorine, so when the German unleashed gas against the Canadian division on 24 April 1915, several officers ordered their soldiers to urinate into their handkerchiefs and then cover their faces with the wet cloths.[30] Better solutions followed. Both the gas and the medical services of the BEF began developing masks and respirators to protect their soldiers from the physical effects of gas and enable them to fight in a chemical environment. The War Office experimented with several gas mask designs before adopting the small box respirator in August 1916.[31] This gas mask remained in service for the remainder of the war. Even with this mask, though, the Canadian Corps Gas Services and Canadian Army Medical Corps had to continually revise training and techniques to mitigate against newer, deadlier gases delivered through increasingly effective means. The fight against gas never ceased.

Like all weapons, gas also has psychological as well as physical effects, and the morale effect of it is amplified when used against undisciplined or ill-trained soldiers. Soldiers needed to know that their respirators worked and how to use them. Gas training became as necessary as rifle shooting and grenade throwing. Historian C.R.M.F. Cruttwell, who served as an officer with 1/4 Battalion, Royal Berkshire Regiment, described the soldiers' predicament.

> In the face of gas, without protection, individuality was annihilated; the soldier in the trench became a mere passive recipient of torture and death…. [N]early every soldier is or becomes a fatalist on active service; it quietens his nerves to believe that his chance will be favourable or the reverse. But his fatalism depends upon the belief that he has a chance. If the very air which he breathes is poison, his chance is gone: he is merely a destined victim for the slaughter. Later on, when gas-masks became increasingly efficient, this type of warfare was regarded as an unpleasant incident, for suffering became contingent on carelessness or surprise.[32]

[30]Cook, *No Place to Run*, pp. 6-7.
[31]Nicholson, *Official History of the Canadian Army in the First World War*, p. 71.
[32]C.R.M.F. Cruttwell, *A History of the Great War, 1914-1918,* (Oxford: Clarendon Press, 1934), pp. 153-154.

Historian Tim Cook expanded upon this concept of *faith* in equipment, 'The creation of the faith in both respirators and anti-gas training was the most important legacy of the Canadian Corps Gas Services.'[33] Measuring faith is impossible, and faith is rarely rooted in provable fact. Yet in the case of chemical warfare, faith still needed science.

Trials completed during training in France were vital to this process. After witnessing one such gas mask trial in May 1915, a soldier wrote, 'We were at first rather skeptical as to their efficiency, but the *test* proved this to us and gave us a great deal of confidence.'[34] Not all gas training proved as beneficial, and some formations went to the frontline inadequately prepared for the chemical environment.[35] The process of protecting soldiers from this new weapon was hardly perfect. However, gas training reinforced to soldiers the importance of gas discipline and gave them confidence in their protective equipment. Gunner G.H. Jackson described the gas training that he underwent in France. '[T]he gas … turned my brass buttons black, destroyed the illuminated dial on my watch and turned my khaki uniform a reddish brown. Say! what [*sic*] would it do to your lungs without protection?'[36] No training could ever fully prepare a soldier for combat. However, any training is better than none, and gas staffs used OR – especially trialling – to develop protective equipment and training to protect BEF soldiers from the effects of chemical warfare.

The BEF not only developed countermeasures to gas; it actively sought to use gas offensively. In June 1915, the War Office formed two Special Companies of Royal Engineers that comprised soldiers and officers with chemistry backgrounds and appointed a Royal Engineer officer, Major C.H. Foulkes, to conduct and coordinate chemical warfare in the BEF.[37] Eventually, this force expanded into the Special Brigade, Royal Engineers. The Special Brigade used a variety of delivery systems to attack the Germans with gas. It was the only force in the BEF that used gas offensively until the artillery received large quantities of gas shells in 1917. The British first used gas on a large scale at Loos in 1915. In planning the attack, General Sir Douglas Haig, then commander of First Army, opted to use dispensed chlorine gas to compensate for an insufficient quantity of guns and shells.[38] Despite some successes, the gas failed to

[33]Cook, *No Place to Run*, p. 233.
[34]Quoted in Richter, *Chemical Soldiers*, p. 13. Emphasis added by the author.
[35]Cook, *No Place to Run*, p. 81, pp. 90-94.
[36]Charles Lyons Foster and William Smith Duthie, eds., *Letters from the Front: Being a Record of the Part Played by Officers of the Bank in the Great War, 1914-1918, Volume I,* (Toronto and Montreal: Southam Press Limited, 1920), p. 149.
[37]Palazzo, *Seeking Victory on the Western Front*, p. 44; and Richter, *Chemical Soldiers*, p. 16.
[38]Edmonds, *History of the Great War: Military Operations, France and Belgium, 1915, Volume II*, p. 153.

subdue the German defenders, and the attack resulted in minimal gains with heavy casualties. After the battle, Foulkes ordered his officers to submit notes on the results of the chemical attacks, assessing the effectiveness of the gas in their sectors. He also compiled reports from captured German documents and prisoners.[39]

By analysing these notes and reports, Foulkes quantified the effects of gas and developed procedures for the proper use of gas. This problem solving is what OR does, by finding shortcomings in the system and addressing them to improve effectiveness and efficiency. But the gas officers still needed to integrate gas into the overall offensive system. Arguments proposed by historians like James Edmonds, the British official historian of the Great War, that 'Gas achieved but local success, nothing decisive; it made war uncomfortable, to no purpose' miss the mark.[40] Donald Richter's assertion that chemical warfare was 'occasionally effective, never decisive' is probably more balanced.[41] Like aircraft, machine guns, and quick-firing artillery, it could never win the war on its own, but when combined with artillery and machine guns, it did help achieve neutralisation and suppression effects.

As the employment of gas and machine guns required increasingly specialised skills, the staff establishment responsible for their use grew. A First Army order to the Canadian Corps in the spring of 1916 appointed a gas officer (DGO) in each divisional headquarters and effectively created the Canadian Corps Gas Services (CCGS).[42] And the formation of the CCGS helped ensure uniformity of anti-gas training across the divisions of the corps.[43] It also facilitated the dissemination of lessons learned within the Canadian Corps and to other British formations. By October 1916, battalions, brigades, and divisions all had gas officers, who were responsible for anti-gas training and adherence to regulations. Only the headquarters of armies and corps lacked a gas officer. Like the artillery, the gas services operated within a wider imperial structure, and these innovations to the Canadian chemical warfare establishment largely resulted from the British direction. The British had grouped their offensive and defensive

[39]Richter, *Chemical Soldiers*, p. 92.
[40]James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1918, Volume V, 26 September-11 November: The Advance to Victory,* (London: His Majesty's Stationery Office, 1947), p. 606n2
[41]Richter, *Chemical Soldiers*, p. 147.
[42]William G. Macpherson, *History of the Great War: Medical Services, Diseases of the War, Volume II, Including the Medical Aspects of Aviation and Gas Warfare, and Gas Poisoning in Tanks and Mines,* (London: His Majesty's Stationery Office, 1923), pp. 328-334.
[43]Cook, *No Place to Run*, pp. 6-7.

chemical warfare specialists under the Gas Services on 25 January 1916.[44] This directorate coordinated both offensive and defensive aspects of chemical warfare. Efforts to create Canadian Engineer 'Special Companies,' responsible for the offensive use of gas during the winter of 1917-1918, did not materialise.[45] Thus the CCGS played the largest role in the development of anti-gas techniques and advised on the offensive use of gas.

The emergence of the CMGC as a distinct arm from the infantry or artillery facilitated the conduct of OR by machine gun officers. Like McNaughton, Brutinel enjoyed the support of the senior commanders in the Canadian Corps and the BEF for his work. Haig was even enthusiastic about the technique.[46] Brutinel's forceful personality may have brought him into conflict with others, but it also ensured that the CMGC could maintain the corporate knowledge of indirect fire.[47] Otherwise, its officers would lose the necessary skillsets for this technical work. Brutinel recalled:

> To maintain the fluidity of this great fire power, intense training was essential, implying tactical appraisal of the task at hand, the Machine Gun Officer becoming ipso facto the Technical Adviser of the Infantry Commander, or if preferred, his Consulting Engineer. The Administrative organization of the Canadian Machine Gun Battalion met these essentials.[48]

The machine gunners adopted a unique organisation structure in much the same way the artillery did. Not only did this unified structure improve standardisation in the training and use of machine guns, but it also facilitated the control of corps level machine gun barrages and the dissemination of new ideas and innovations from the machine gun units to the headquarters of the Canadian Corps.

The General Officer Commanding (GOC) CMGC had a modest staff that included a brigade major for operations, a staff captain for administration and transport, a reconnaissance officer, and seven other ranks (see Figure 1). The brigade major, Major W.B. Forster, had worked as an accountant before the war and attested into 27

[44]James E. Edmonds, *History of the Great War: Military Operations, France and Belgium, 1916, Volume I, Sir Douglas Haig's Command to the 1st July: Battle of the Somme,* (London: His Majesty's Stationery Office, 1932), p. 78.
[45]Cook, *No Place to Run*, p. 143.
[46]Gary Sheffield, *The Chief: Douglas Haig and the British Army,* (London: Aurum, 2011), p. 151.
[47]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 45.
[48]The Raymond Brutinel Tapes, Tape 9, p. 2.

Canadian Infantry Battalion.[49] The officer responsible for administration, Captain J.K. Lawson, had a prewar administrative career.[50] The reconnaissance officer, Lieutenant W.T. Trench, and his replacement from 24 April 1918, Lieutenant P.M. Humme, had both worked as surveyors.[51] Captain M.R. Levey, another pre-war surveyor and the officer who collected most of the data from Brutinel's early trials, joined the staff as a staff learner during the summer of 1918.[52] The combined mathematical and administrative abilities of the staff were well suited the conduct of OR. Each infantry division commander retained authority over the machine gun battalion affiliated with their division. However, the GOC CMGC assumed control to coordinate machine gun plans for corps level battles. Planning these barrages required much staff effort, and they conducted most of their research during operational lulls. While the formation of gas and machine gun staffs helped the Canadian Corps better use these weapons, neither the CCGS nor the CMGC had a large staff complement that could manage operations and conduct operation research like the counter-battery staff office could do. The corps headquarters did not permanently allocate staff supporting the corps machine gun officer until 19 March 1918.[53]

[49]LAC, RG150, Accession 1992-93/166, Box 3212-14, William Burton Foster Personnel File.

[50]LAC, RG150, Accession 1992-93/166, Box 5471-20, John Kilburn Lawson Personnel File.

[51]LAC, RG150, Accession 1992-93/166, Box 9777-69, Waldo Talbot Trench Personnel File; and LAC, RG150, Accession 1992-93/166, Box 4609-48, Powell Mat Humme Personnel File.

[52]LAC, RG150, Accession 1992-93/166, Box 5611-79, Mark Robert Levey Personnel File. On the staff learner system in the Canadian Corps, see Douglas E. Delaney, 'Mentoring the Canadian Corps: Imperial Officers and the Canadian Expeditionary Force, 1914-1918,' *The Journal of Military History* Vol. 77, No. 3 (July 2013): pp. 942-943.

[53]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 65.

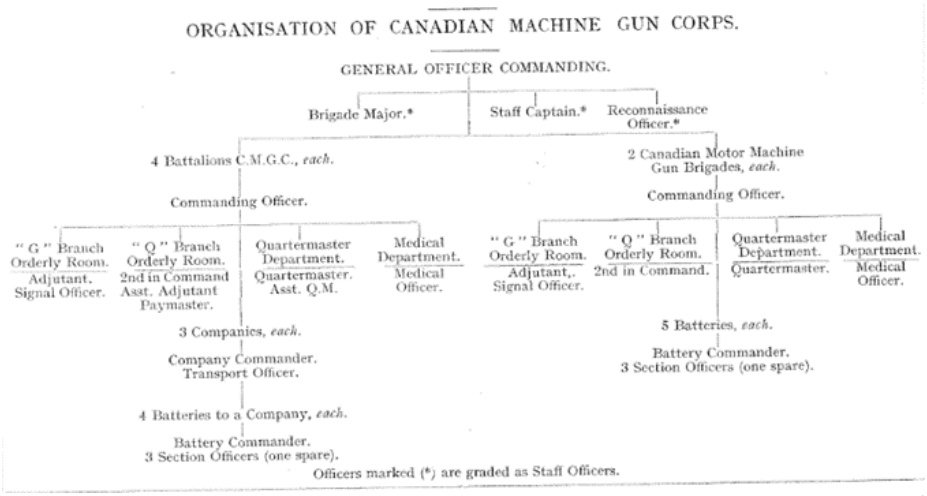

Figure 1 Organisation & Staff Structure of the Canadian Machine Gun Corps, 1918.[54]

The formation of a staff to manage chemical warfare at the corps level did not occur until 1917, and the gas services staff continued to lack sufficient personnel to manage its myriad responsibilities, including the conduct of OR. On 26 March 1917, the Canadian Corps appointed Captain W. Eric Harris as the chemical advisor in the corps headquarters.[55] The chemical advisor position fell under the purview of the 'G' or operations staff. However, his close liaison with the Canadian Army Medical Corps, training establishments, and logistics organisations meant he also had close links with the corps 'A' (personnel) and 'Q' (logistics) staff. The small staff that comprised the CCGS included a clerk, corporal, batman, and driver.[56] As the corps chemical advisor, Harris leveraged the DGOs as well as the brigade and battalion gas officers for data for analysis that he integrated into his OR reports (see Figure 2). However, he only had coordination authority with these officers. This limited command arrangement denied Harris the flexibility to modify the structure and manning of the corps gas staff based on operational experience, something McNaughton never had to worry about with the counter-battery staff office. Furthermore, Harris did not have the same authority over the DGOs that McNaughton had over the guns of the heavy artillery,

[54]OMFC, *Report of the Ministry Overseas Military Forces of Canada, 1918,* (London: His Majesty's Stationery Office, 1919), p. 290.
[55]LAC, RG150, Accession 1992-93/166, Box 4097-44, Walter Eric Harris Personnel File.
[56]LAC, RG9-III-D-3, Vol. 5048, File 923, WD – Chemical Advisor, Canadian Corps, April 1917, Appendix II, First Army Headquarters, Establishment of the Gas Services,12 February 1917.

despite the neat organisational diagram at Figure 2. Harris could only do so much work with his tiny staff, and he even had difficulty maintaining the CCGS war diary.[57]

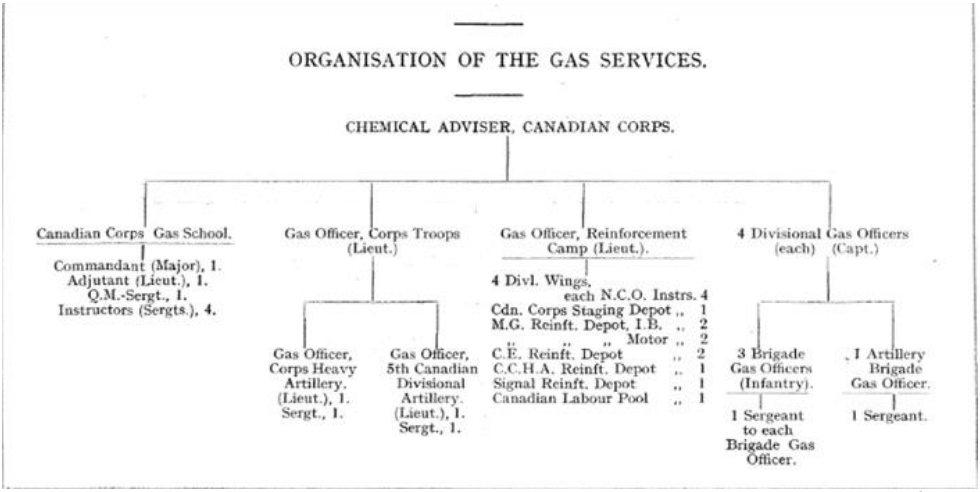

Figure 2 Organisation and Staff Structure of the Canadian Corps Gas Services, 1918.[58]

Since armies only began using chemical weapons on a large scale during the First World War, the War Office had to look beyond formal military training to find suitable officers for service on the chemical warfare staff. These gas officers had a long list of responsibilities, and the army attempted to match their relevant qualifications and skills from their prewar civilian careers to their new military duties. Principally, Harris was responsible for the coordination and training of the DGOs as well as the standardisation of the corps anti-gas policy.[59] Other important tasks included liaison with the artillery for the use of gas shells, collation of information on German chemical warfare tactics from prisoner of war interrogations, and collection of samples of new chemical agents used by the Germans for the British Gas Services to analyse. His prewar career as a science teacher helped with these tasks.[60] Harris had joined the Canadian Expeditionary Force as an artillery officer but mostly served as a gas officer, first with the 2 Canadian Division and later as the assistant chemical advisor at First

[57]Ibid., August 1917, Canadian Section GHQ, 'Note to Canadian Corps Chemical Advisor,' 28 September 1917.
[58]OMFC, *Report of the Ministry Overseas Military Forces of Canada, 1918,* (London: His Majesty's Stationery Office, 1919), p. 283.
[59]WD – Chemical Advisor, Canadian Corps, April 1917, Appendix I, First Army Headquarters, No. G.S. 528 'Duties of the Chemical Advisor,' 11 March 1917.
[60]Harris Personnel File.

Army. All the DGOs in the Canadian Corps in April 1917 had scientific, teaching, and administrative backgrounds. Lieutenant A.A. McQueen, 1 Canadian Division DGO, worked as an electrical engineer before he enlisted into the artillery.[61] Lieutenant A.B. Campbell, 2 Canadian Division DGO, an infantry officer, had been a clerk.[62] The DGO of 3 and 4 Canadian Divisions, Lieutenants N.C. Qua and H. Beaumont, worked in education and mining, respectively.[63] The staff of the CCGS understood the components of systems, as well as the importance of learning and administration. Innovation, trials, experimenting, and disseminating – the hallmarks of OR – required these skill sets.

The findings of the OR performed by Harris and his staff percolated through the army headquarters to GHQ and were finally encapsulated in doctrine, such as *SS534 Defence Against Gas*.[64] In cooperation with the Canadian Army Medical Corps, the CCGS conducted a rigorous programme of OR to defend against poison gas. For instance, in September 1917, the CCGS examined no fewer than six areas of concern, including countermeasures for new German gas shells, testing sites to determine the efficacy of gas masks, and an increase in casualties suffering temporary blindness from exposure to mustard gas.[65] Following an enemy gas shell bombardment against the battery positions of 2 Canadian Divisional Artillery on 6 September 1917, the gas officer investigated the types of ammunition fired, recorded the prevailing meteorological conditions, interviewed the casualties, and noted the state of the gas-proof dugouts.[66] He found that the Germans fired a mixture of high-explosive and gas shells to damage the gas-proof dugouts to target exposed soldiers with both splinters and gas. The batteries had taken additional precautions prior to the shelling owing to the favourable conditions for a gas bombardment. The Canadian gunners sustained two serious casualties, one caused by a splinter from high explosive and the second from the force of the gas shell bursting on top of the gun pit. No serious casualties were attributed to the gas itself. The gas officer attributed the lack of casualties to the effectiveness of

[61]LAC, RG150, Accession 1992-93/166, Box 7193-9, Allan Alderson McQueen Personnel File.
[62]LAC, RG150, Accession 1992-93/166, Box 1419-28, Alexander Bruce Campbell Personnel File.
[63]LAC, RG150, Accession 1992-93/166, Box 8039-3, Norman Charlton Qua Personnel File; and LAC, RG150, Accession 1992-93/166, Box 563-32, Henry Vincent Leeming Beaumont Personnel File.
[64]General Staff (GS), General Headquarters (GHQ), *SS534 Defence Against Gas,* (March 1918).
[65]WD – Chemical Advisor, Canadian Corps, 1, 8, 10, 24, 25, and 27 September 1917.
[66]Ibid., Appendix I, Lieutenant H.H. Wallace, Artillery Gas Officer, 2nd Canadian Divisional Artillery 'Report on Gas Shell Bombardment 2nd Canadian Divisional Artillery Battery Positions on September 6th, 1917,' n.d.

the gas-proof dugouts and the small box respirator. He made minor recommendations for additional procedures, such as increased vigilance during weather conditions favourable to a gas bombardment and limiting the frequency that personnel moved in and out of the gas-proof dugouts during a bombardment, and he presented his findings in a report submitted to Harris on 10 September. Harris discussed the report at a conference with the DGOs on 15 September and forwarded it to the chemical advisor at First Army headquarters.[67] While the report went up the chain of command, Harris issued a new directive on 1 October for defensive measures against gas for artillery units in the Canadian Corps.[68] The directive addressed all of the recommendations from the 6 September bombardment.[69] The CCGS sent copies of these reports and directives to the chemical advisor at the First Army headquarters, which compiled the reports from its corps and sent a consolidated report to GHQ. The British Gas Services at GHQ analysed these reports and eventually published pamphlets like *SS534*.[70] These publications spurred further OR to verify the effectiveness of new methods, and the cycle of OR began again.

While the CCGS did not have a monopoly on conducting trials, it was the only organisation in the Canadian Corps that committed the findings of its trials to paper and then disseminated them. The infantry conducted some creative trials with chemical defence, but tests conducted outside of the formal structure could never amount to much

> The other day we dug a deep trench and filled it with the brand of gas the Germans use; some of our boys put on a new style of [gas] helmet we have and walked through it. The test was highly satisfactory, so we have not much to fear.[71]

While this test may have made the infantrymen confident in their respirators, these informal experiments lacked the rigorous data collection that typified reports prepared by the CCGS. The gas staff structured their reports on infantry casualties in the manner of No. 2 Operational Research Section, an OR staff serving within the headquarters of the 21 Army Group, during the Normandy campaign of 1944.[72]

[67]Ibid., Appendix II, Minutes of Meeting of D.G.O.'s at C.A.'s Office Canadian Corps 15 September, 1917, p. 2, n.d.
[68]Ibid., October 1917, Appendix I, 'Defensive Measures Against Gas for Artillery Units,' n.d.
[69]Ibid., 10, 13, and 17 September 1917.
[70]GS, GHQ, *SS534*.
[71]Foster and Duthie, eds., *Letters from the Front*, p. 50.
[72]WD – Chemical Advisor, Canadian Corps, March 1918, Appendix 15, Major W.E. Harris, Report on Recent Cases of Gas Casualties, 16 March 1918; and Report No.

Through these efforts, the Canadian Corps disseminated its findings to other BEF formations and achieved high standards of gas discipline and training, which resulted in fewer gas casualties. General Sir Henry Horne, commander of First Army, sent a congratulatory letter to the Canadian Corps after it sustained less than forty casualties after a forty-eight-hour chemical bombardment attack in February 1918.[73] His letter noted how the effectiveness of the gas training and discipline in the corps contributed to this low figure of casualties. Achieving this high standard was not an accident. It was the result of analysis and much deliberate work.

While being responsible for gas training allowed the staff of the CCGS to trial new masks and anti-gas drills, it also proved a distraction from OR. As the chemical advisor to the Canadian Corps, Harris had control over all anti-gas training that corps schools conducted in France. However, his authority did not extend to the anti-gas training given to Canadian recruits across the Channel in Britain. Furthermore, unlike Brutinel, Harris lacked the clout to make substantive changes to the Canadian Expeditionary Force chemical warfare organisation, which would have improved training. Following his appointment as commander of Canadian forces in the United Kingdom in December 1916, Lieutenant-General Sir Richard Turner improved the overall quality of training for Canadian soldiers in England; however the chemical defence training that recruits underwent there remained deficient.[74] Harris travelled to Britain in December 1917 to standardise the anti-gas training conducted there with that done in France, and also form a chemical warfare training organisation subordinate to the CCGS.[75] Harris struck out, and for the remainder of the war, gas training in England remained inadequate.[76] Navigating the relationship between the Canadian Corps and the Canadian forces in the United Kingdom remained a distraction for the CCGS. Harris and his staff spent an inordinate amount of time and effort sorting out training deficiencies of the replacements arriving from England instead of conducting research.

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19 Infantry Officer Casualties, in Terry Copp, ed., *Montgomery' Scientists: Operational Research in Northwest Europe – The Work of No. 2 Operational Research Section with 21 Army Group, June 1944 to July 1945,* (Waterloo: Laurier Centre for Military Strategic and Disarmament Studies, 2000), pp. 425-430.

[73]WD – Chemical Advisor, Canadian Corps, February 1917, Appendix 12, First Army Headquarters, No. G.S. 1035, Letter of Appreciation of the High Standard of Discipline and Gas Training in the Canadian Corps, 19 February 1918.

[74]William F. Stewart, *The Embattled General: Sir Richard Turner and the First World War,* (Montreal, Kingston, London, and Chicago: McGill-Queen's University Press, 2015), pp. 171-206; and Cook, *No Place to Run*, p. 117.

[75]WD – Chemical Advisor, Canadian Corps, 22 December 1917.

[76]Harris subsequently had to leave France and return to England to supervise training on at least one other occasion. WD – Chemical Advisor, Canadian Corps, 10 June 1918.

Harris and his gas officers did not have a monopoly on chemical warfare innovations in the BEF, and neither did Brutinel and his staff for improving indirect machine gun fire. However, their innovations and trials resulted in the incorporation of machine gun barrages into every corps fire plan after the Somme. The CMGC developed ballistic shooting cards by arcing the machine gun fire on hard-packed sand beaches at low tide.[77] One of Brutinel's officers, Levey, measured the accuracy and precision of the bursts and cross-indexed the findings with their clinometers.[78] Trials like this one enabled the CMGC to accurately fire hundreds of thousands of bullets into pre-determined kill zones on order. This type of fire denied the Germans the opportunity to repair damaged obstacles and defensive positions at night and proved useful for cutting off German forces attempting to withdraw.[79] Much like the informal sharing of reports between artillery staffs, the machine gun officers disseminated the results of this trial with other formations. It took many trials like this one, but eventually, training institutions adopted these methods and ensured standardisation across the BEF. The involvement of Brutinel in these technical machine gun innovations stands in marked contrast to Major-General E.W.B. Morrison, commander of the Canadian Corps artillery, and the development of the artillery. The latter preferred to let his talented subordinates like then Major Alan F. Brooke and McNaughton do most of the work.

After the Somme in 1916, the Canadian Corps incorporated machine gun barrages into all its major attacks. From these operations, Brutinel and his staff conducted much OR to improve the effectiveness of their technique. The machine gun barrage was an important component of the fire plan for the assault on Vimy Ridge in 1917, and Brutinel's guns fired nearly five million rounds during the barrage.[80] It prevented the Germans from maintaining their defensive positions, and it augmented the suppression provided by the artillery barrage. Indirect machine gun fire also prevented defenders from withdrawing or reinforcing their positions.[81] The report prepared after Vimy Ridge by the CMGC is interesting for how it contrasts with the one prepared by

[77]The Raymond Brutinel Tapes, Tape 9, pp. 2-3.
[78]Levey Personnel File.
[79]GS, GHQ, *SS201 Tactical Summary of Machine Gun Operations No. 1,* (France: Army Printing and Stationery Services, October 1917), p. 2; and GS, GHQ, *SS192 The Employment of Machine Guns: Part I, Tactical,* (France: Army Printing and Stationery Services, January 1918), p. 17.
[80]LAC, RG9-III-D-3, Vol. 4957, File 503, WD – GOC RA, Canadian Corps, April 1917, Appendix I, BGGS Canadian Corps, G.3. S.156/31/2., Artillery Instructions for the Capture of Vimy Ridge, p. 3, 28 March 1917; and Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 169.
[81]The Raymond Brutinel Tapes, Tape 19, p. 2.

McNaughton and the staff of the counter-battery staff office for the same battle.[82] These artillery officers conducted post-battle reconnaissance of the German battery positions to verify the accuracy of the intelligence and collect data on the effect of the counter-battery programme for statistical analysis. The CMGC staff relied largely on anecdotal evidence from machine gun companies, infantry formation staffs, and prisoner interrogations - not quite the same quantitative rigour. Even so, the report still yielded several lessons learned.[83] Based on the evidence gathered, the morale effect of indirect machine gun fire was more significant than the number of casualties inflicted on the Germans. That is what prisoners of war said, and the disrepair of obstacles and defensive positions, because German soldiers dared not enter them for the machine gun bullets raining down, corroborated it. So did the capture of trench mortar positions that had not been resupplied with ammunition. The report also recommended observation of fire, when possible, more clinometers (one per two machine guns), and an increase in the strength of the machine gun companies to help carry the vast quantities of ammunition required to fire these barrages. The CMGC widely disseminated the report throughout the BEF and the French Army, and *SS192*, *SS201*, and *Notes and Rules for Barrage Fire with Machine Guns* reflect several of its recommendations.[84] The staff also published a document on the employment of mobile forces based on the experiences of Brutinel's motorised machine gun forces at Amiens (8-11 August 1918) and Arras (26 August - 3 September 1918).[85] This broad dissemination of knowledge acquired through OR across the Western Front could be further trialled and experimented within operations. Officers then collected new data, and the process would begin again.

The machine gun barrage supporting the attack on Valenciennes (28 October – 2 November 1918) demonstrates that the CMGC adopted many of these findings. In addition to the overwhelming artillery preparations planned by McNaughton, forty-seven machine guns supported the attack of the 10 Canadian Infantry Brigade on Mont Houy alone.[86] The machine guns fired the barrage with enfilading fire, and machine gun officers were supposed to observe the fire and make modifications to the fire plan if

[82]WD – Corps Machine Gun Officer, Canadian Corps, November 1916 – June 1917, Appendix K, Notes on the Employment of Machine Guns in the Canadian Corps during the Operations Leading to the Capture of Vimy Ridge, n.d.
[83]Ibid., pp. 2, 8-9.
[84]GS, GHQ, *SS201*; GS, GHQ, *SS192*.
[85]LAC, RG9-III-D-3, Vol. 4817, File 19, WD – Canadian Corps – General Staff, September 1918, Appendix II. Canadian Corps General Staff, G.528/3-53, *Employment of Corps Mobile Troops*, p. 2, 19 September 1918.
[86]LAC, RG9-III-D-3, Vol. 4986, File 624, WD – 4th Canadian Machine Gun Battalion, October 1918, Appendix Y, General Staff 4th Canadian Division, G. 29/2910-559, 'Valenciennes Instructions No. 2,' p. 4, 31 October 1918.

necessary. Poor visibility and mist made observation impossible, so the machine guns fired the barrage in accordance with the scheduled timings.[87] Brutinel praised the work of his machine gunners, and the history of the CMGC notes the 'abundant evidence of the effectiveness of our Machine Gun Barrage.'[88] However, with thousands of shrapnel, high explosive, and gas shells also being fired at the Germans, quantitatively assessing the effectiveness of machine gun bursts was almost impossible. McNaughton, for instance, argued, 'There is no evidence to show that the machine gun barrage was very effective. We must not distort history to carry forward wrong conclusions as to the proper use of this important weapon.'[89] Like Vimy, after-action assessments of the machine gun barrage relied on anecdotal evidence, not statistics.[90] Only so much OR could be conducted without data to substantiate or disprove the hypothesis that machine gun barrages were effective.

The staff of the CMGC thought long and hard about improving machine gun tactics, as did Harris when he had to develop offensive gas procedures for the Canadian Corps. Before the widespread introduction of gas shells, only the Special Brigade, which was controlled by GHQ, had the equipment to disperse gas.[91] However, an increased supply of gas shells in 1917 meant that artillery played an increasingly important role in targeting the Germans with gas.[92] Earlier operations supported by gas had yielded mixed results. 4 Canadian Division launched a four battalion raid against a portion of Vimy Ridge on 1 March 1917.[93] The canister dispensed gas completely failed to subdue the German defenders, and the raid ended in disaster. The BEF had hard learned this lesson at Loos, but there is no evidence that the DGO, Lieutenant H. Beaumont, objected to a plan that completely relied on gas. The Canadian Corps appointed Harris to the headquarters later that month, and the corps never again launched attacks that depended on canister dispensed gas to support the infantry.

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[87]Ibid., November 1918, Appendix G, Commanding Officer 4th Canadian Machine Gun Battalion, 4th Battalion Canadian Machine Gun Corps Report on Operations, 14 October to 6 November 1918, p. 1, n.d.

[88]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 422.

[89]Quoted in John Swettenham, *McNaughton: Volume 1, 1887-1939,* (Toronto: The Ryerson Press, 1968), p. 153n1.

[90]Logan and Levey, *History of the Canadian Machine Gun Corps*, p. 422.

[91]Palazzo, *Seeking Victory on the Western Front*, pp. 78-79.

[92]Ibid., pp. 164-164.

[93]LAC, RG9-III-D-3, Vol. 4859, File 159, WD – 4th Canadian Division – General Staff, March 1917, Appendix A, Brigade Major 12th Canadian Infantry Brigade, S.G. 4/279, Report on Operations Carried out by the 12th Canadian Infantry Brigade (In Conjunction with the 11th Canadian Brigade) on 1 March 1917, 5 March 1917.

Despite the disappointing results of the gas that supported the raid launched by 4 Canadian Division, the Canadian Corps increasingly used gas in its operations but as part of a wider system that included the artillery, and machine guns. Within a fortnight of his appointment as the corps chemical advisor, Harris met with McNaughton to discuss the use of gas shells for the attack against Vimy Ridge.[94] While weather conditions precluded the use of gas as part of the fire plan on 9 April, the CCGS produced a thorough report on the plan for the chemical bombardment and subsequent use of gas shells during the battle.[95] Although weather affected artillery dispensed gas less than it did canister dispensed gas, high wind would still quickly dissipate an artillery dispensed gas cloud. Harris prepared a useful guide to help gunners plan for engaging the enemy with chemical shells.[96] This guidance also stressed the importance of surprise, since the gas had its greatest effect on German gunners before they had the opportunity to don their respirators. The report also identified that enemy gunners did not need to be killed for the neutralisation to be effective.[97] Dousing their battery positions in poison gas and forcing the artillerymen to don their respirators would hinder their ability to serve their guns. This report identified the shortcomings with *SS134 Instructions on the Use of Lethal and Lachrymatory Shell*, and the revised edition published in March 1918, included all the recommendations made by Harris.[98] It made its way to published doctrine within months, which is a good thing. And it may very well have been practice before it appeared in writing.

After Vimy, the Canadian Corps almost exclusively used gas for counter-battery work. Artillery remained the preferred dispersal method of gas and, by 1918, counter-battery was the most important task for the guns. As the OR conducted by the counter-battery staff office revealed, the operational tempo during the Hundred Days campaign of 8 August to 11 November 1918 did not permit detailed intelligence gathering by multiple sensors that had been possible during static warfare. With limited intelligence on the disposition of the hostile batteries, gas, an area weapon, became increasingly useful for neutralising enemy guns. Major-General Morrison directed that '[g]as concentrations will be freely employed—surprise effect will be striven for—the

[94]WD – Chemical Advisor, Canadian Corps, 7 April 1917.
[95]LAC, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, Notes on Artillery preparation and Support of the Attack on Vimy Ridge. April 9th.1917, Captain W.E. Harris, No. 11/58, Report on the Preparation of Gas Shell Bombardments. Canadian Corps – Attack on Vimy Ridge, 9 April 1917, n.d.
[96]WD – Chemical Advisor, Canadian Corps, April 1917, Appendix V, Captain W.E. Harris, Instructions for Firing Gas Shells, 6 April 1917.
[97]Report on the Preparation of Gas Shell Bombardments. Canadian Corps – Attack on Vimy Ridge, 9 April 1917, p. 2.
[98]GS, GHQ, *SS134 Instructions on the Use of Lethal and Lachrymatory Shell,* (France: Army Printing and Stationery Services, March 1918).

best results being obtained by a short and very intense burst of fire.'[99] Harris had made all these recommendations in his operational report on the Vimy battle.

While not all officers in the Canadian Corps embraced gas, the artillery certainly did. During the Hundred Days campaign, the artillery arguably used too much gas. *SS134* advised against engaging areas with gas that friendly troops would occupy, and, generally, the infantry did not penetrate far enough into the enemy's depth to seize the hostile battery positions.[100] The September 1918 introduction of the British mustard gas shell, which was a more persistent agent than other gases, proved particularly useful for engaging static targets, like hostile batteries. The agent continued to harm soldiers even after they put their gas masks on. Due to the persistence of mustard gas, the GOC Royal Artillery retained authority for its use.[101] Generally, the Canadian Corps does not seem to have been overly concerned about its infantry fighting through and consolidating in chemically contaminated areas. Before the assault on Bourlon Wood on 27 September 1918, the artillery saturated the forest with 17,000 gas shells over fifteen days before the attack and another 7,600 after zero hour.[102]

While the CCGS continued to conduct some OR throughout this period, the collection of data for the offensive use of chemical weapons proved difficult. With his limited staff, Harris could not conduct post-battle data collection in the same way that the more numerous counter-battery staff office could do. Nor could his officers determine the effects of gas because its effects did not last. There were no gas craters to analyse. Other than captured German documents or prisoner interrogations, the chemical advisor had to rely on anecdotal evidence about how effective the German defensive fire was to determine how well the gas bombardments worked. Assessing protective measures and anti-gas training was a little easier, however, because Harris and his staff could always monitor Canadian gas casualties reported by the Canadian Army Medical Corps. A spike in the number of casualties could indicate poor gas discipline, ineffective protective equipment, a new German tactic, or a new agent. In any case, further data could be collected, analysed, and mitigation measures implemented. On 3 December 1917, the CCGS disseminated a new directive to the divisions warning them that the Germans would soon likely use gas dispensed by

[99]LAC, MG30-E81, Major-General Sir Edward Whipple Bancroft Morrison Fonds, Vol. 2, Artillery Corps, Orders and Instructions, September – December 1918, GOC RA Canadian Corps, O.907/2 O.2, Canadian Corps Artillery Policy, p. 1, 3 October 1918.
[100]GS, GHQ, *SS134*, p. 11.
[101]Canadian Corps Artillery Policy, p. 1.
[102]Cook, *No Place to Run*, p. 204.

trench mortar.[103] The directive warned that the Germans could form dense clouds of gas with minimal warning and stressed the importance of maintaining discipline and continual anti-gas training. On the night of 8-9 December, the Germans bombarded 2 Canadian Division with a mixture of gas and high explosive shells.[104] The DGO investigated the bombardment and presented his findings in a detailed report similar to the report that 2 Canadian Divisional Artillery gas officer had submitted to Harris in September 1917.[105] The division sustained no gas causalities, and the 'Gas-proof dugouts gave excellent protection.'[106] The new procedures and techniques that Harris had recommended less than a week before had paid off. The CCGS again revisited its procedures after the Germans inflicted several gas casualties on 30 December. An investigation revealed that due to the cold weather the gas casualties had failed to remove their woollen caps before donning their respirators, which resulted in a poor seal.[107] Within one day, Harris circulated a letter throughout the Canadian Corps reinforcing the importance of properly conducting anti-gas drills.[108] This quick observation-hypothesis-action cycle was OR at its best.

Like the CCGS, the staff of the CMGC also had difficulty quantifying the effects of a machine gun barrage. Unlike shellfire, which left craters and damage to equipment, the effects of indirect machine gun fire could not be easily determined or measured. One British machine gun officer noted, 'The general result must be regarded as probably considerable but certainly incalculable.'[109] Furthermore, the CMGC rarely had enough forward observers to adjust fire and provide battle damage assessments. That situation did not improve. It did not help that the artillery, as an institution, did not believe in the efficacy of indirect machine gun fire. McNaughton proved most critical:

> I was all for employing machine-guns to fire indirectly on the appropriate occasion but the trouble was, once you had this art of indirect fire, or at least once you thought you had it, the tendency was to use it when it wasn't apt. The

[103]WD – Chemical Advisor, Canadian Corps, December 1917, Appendix A, Captain W.E. Harris, Chemical Advisor, Canadian Corps, 9/142 Circular regarding use of T.M. Gas shells similar to British projectors by the enemy, 3 December 1917.
[104]Ibid., 9 December 1917.
[105]Ibid., Appendix B, Captain A.B. Campbell, D.G.O., 2nd Canadian Division, Report on Gas shell bombardment area of 2nd Cdn. Divsn. on 8/9-12-17, 10 December 1917.
[106]Ibid.
[107]Ibid., 31 December 1917.
[108]Ibid., Appendix K, Captain W.E. Harris, Chemical Advisor, Canadian Corps, No. 7/149 Letter Regarding adjusting of S.B.R. while wearing woollel [*sic*] caps, 31 December 1917.
[109]R.M. Wright, 'Machine-Gun Tactics and Organization,' *The Army Quarterly* Vol. I (January 1921): p. 294.

> machine-gun, you must never forget, is a weapon of opportunity. If it gets one burst in against a few Germans coming up in a file, or something of that sort, it's paid for itself. But you can fire thousands of rounds in indirect fire and the Germans wouldn't even know they'd been fired at because they're usually scattered over too wide an area and the bullets would merely prick the air. The expectation of a kill is low and, unlike a shell, the danger space is very short.[110]

Even some machine gun soldiers questioned its effectiveness. Despite their use of motor transport to move to different sectors of the front, the machine gunners often had to carry their guns and ammunition forward on mules or their backs. While the engineers built light rail to keep the guns supplied with shells, the five million round fireplan fired by the CMGC at Vimy relied on soldiers moving the ammunition forward on foot. That was a strain.[111] Private Donald Fraser's comment on machine gun indirect fire is telling:

> Tonight I shot away a couple thousand rounds of indirect fire. Indirect firing is not very satisfactory - you cannot see the target and, of course, do not know what damage, if any, is done. Besides, the belts have to be refilled and it is a blistery job forcing shells in with the palm of the hand without a protective covering.[112]

The evidence used to substantiate the effectiveness of machine gun barrages is somewhat sparse. Quantitative assessments of the technique are limited to behind-the-lines studies like the one conducted on the wet beach sand at low tide. After-action studies invariably relied upon anecdotal or at times questionable evidence. Even the metric used to determine that indirect machine gun fire prevented the resupply of German trench mortars at Vimy was questionable. Mortar bombs are not artillery shells. When a mortarman drops a bomb down the tube, there is no empty casing like there are for artillery pieces that would accumulate around the gun. Intelligence officers collected most information from prisoner interrogations. During Passchendaele, 31 July to 10 November 1917, one report noted 'Prisoners of the 76th Fus[ilier]. Reg[imen]t. state that the 111th Div[ision]. which sustained our attack on the 26th Oct. suffered very severely both from our artillery and M.G. barrages, the

[110]LAC, MG30-E133, General Andrew George Latta McNaughton Fonds, Vol. 358, J.A. Swettenham, Transcripts of Tapes of General McNaughton's Recollections of the First World War (Flanders Fields Transcripts), Tape 7, pp. 9-10, 17 January 1963.
[111]Papers of Private Richard William Mercer, 'Randall Hansen Transcript,' October 1970, courtesy of Dwight Mercer. The author is grateful to Dwight Mercer for the provision of this reference.
[112]Reginald H. Roy, ed., *The Journal of Private Fraser, 1914-1918: Canadian Expeditionary Force,* (Victoria: Sono Nis Press, 1985), p. 251.

counter-attacks of the supporting batt[alio]ns being particularly severely handled.'[113] Other reports cast doubt on the effectiveness of the machine gun tactic. After Valenciennes on 1 to 2 November 1918, McNaughton asked the artillery intelligence officer to scrutinise the claims that the GOC CMGC had made about the effectiveness of the machine gun barrage. 'I told our intelligence officer to ask every prisoner of war whether, in marching up to counter-attack, he had come under machine-gun fire. We couldn't get a German prisoner from any of the counter-attacking battalions to say that he even knew he was being fired at.'[114] Reports from Canadian infantrymen are similarly contradictory. To the infantry, fire support is fire support, and it would be impossible to distinguish between effects on the enemy from shellfire or a machine gun barrage with thousands of guns simultaneously firing. The most that these studies concluded about indirect machine gun fire was that it likely had some effect on the enemy, especially when it came to re-entering artillery-damaged areas to do repairs, but that the logistical requirements to sustain the technique made it inefficient compared to the use of artillery.

Conclusion

Despite the OR studies done by the CMGC to develop the machine gun barrage and improve its effectiveness, machine gunners did not conduct indirect fire after the First World War. Brutinel had returned to his residence in southern France and resumed his banking career after the war.[115] Without its forceful patron, the independence of the CMGC became increasingly doubtful, especially considering the British began disbanding their Machine Gun Corps in 1919.[116] In 1936, the Canadian Militia disbanded the CMGC and reassigned some infantry battalions as machine gun battalions.[117] Without practice, the ability to conduct indirect fire waned. Brutinel regretted this deterioration of the skill set and noted: 'It is evident that the doctrine of the Canadian Machine Gun Corps will be also forgotten until the next Blood letting when it may have to be learned again, perhaps at a great cost.'[118] During the Second World War, First Canadian Army retained one machine gun battalion per infantry division; however, these machine gunners no longer fired their weapons as part of a barrage. Nor did they attempt to relearn how to fire machine gun barrages. McNaughton may have been responsible for this loss of capability since he had never really believed in

[113]LAC, RG9-III-D-3, Vol. 4854, File 142, WD 3rd Canadian Division – General Staff, November 1917, Appendix 996, 3rd Canadian Division Summary of Intelligence From 12 noon 1st to 12 noon 2nd November 1917, p. 2.
[114]'Flanders Fields Transcripts,' Tape 9, p. 14, 15 February 1963.
[115]Pulsifer, Canada's First Armoured Unit, p. 56.
[116]Bidwell and Graham, *Fire-Power*, p. 193.
[117]Grafton, *The Canadian Emma Gees,* pp. 216-218.
[118]The Raymond Brutinel Tapes, Tape 17, p. 1.

the effectiveness of the tactic.[119] He served as Chief of the General Staff from 1929 until 1935 and as commander of First Canadian Army until December 1943, so he had the authority to stifle all attempts to revive the technique. The infantry used machine guns only for direct fire during the Second World War. Except for infantry mortar platoons, only the artillery conducted indirect fire.

The CCGS had an even shorter existence than the CMGC. Harris issued his final order telling soldiers to carry their respirators on their person on 20 December 1918, and the gas services were disbanded one month later.[120] Despite the disbandment of the Directorate of Gas Services on 22 May 1919, the British continued to study chemical warfare, and Winston Churchill, then the Secretary of State for the Colonies, even proposed using it against Afghan tribesmen on the Northwest Frontier.[121] While the British did not use gas in their small wars, a July 1919 report stressed the importance of peacetime preparation. 'Ample and generous provision must be made for the continuous study of chemical warfare both as regards offence and defence during peace, in order to ensure the safety of the fighting forces of the Empire.'[122] Several officers in the Canadian Corps had recommended forming gas companies, like the British Special Brigade. However, the Ministry of Overseas Military Forces of Canada never acted on the recommendation, so Canada had no offensive gas capability other than the artillery.[123] Even the defensive expertise of the CCGS lapsed. Despite concerns over the stockpiles of chemical weapons maintained by some countries, the Canadian Militia had no money or staff during the interwar period for chemical warfare OR.[124] Fortunately, combatants did not use chemical weapons against each other during the Second World War. Nevertheless, Canadian soldiers continued to undergo anti-gas training, and the Canadian government established the Chemical Warfare School in Suffield, Alberta, to continue research.[125] The technology and procedures for defence against chemical warfare had advanced little since the Great War.

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[119]Schreiber also arrives at this conclusion. Schreiber, *Shock Army of the British Empire*, p. 82.

[120]WD – Chemical Advisor, Canadian Corps, 20 December 1918.

[121]Richter, *Chemical Soldiers*, p. 214; and Marion Girard, *A Strange and Formidable Weapon: British Responses to World War I Poison Gas,* (Lincoln and London: University of Nebraska Press, 2008), p. 182.

[122]The National Archives, Kew, WO 33/3114, War Office, Report of the Committee on Chemical Warfare Organization, p. 1, 7 July 1919.

[123]Cook, *No Place to Run*, p. 143.

[124]C.P. Stacey, *Arms, Men and Governments: The War Policies of Canada, 1939-1945,* (Ottawa: Queen's Printer, 1970), p. 3.

[125]C.P. Stacey, *Official History of the Canadian Army in the Second World War, Volume I, Six Years of War: The Army in Canada, Britain and the Pacific,* (Ottawa: Queen's Printer and Controller of Stationery, 1955), pp. 136, 240, 246.

During the Second World War 21 Army Group's No. 2 Operational Research Section did not do any OR on indirect machine gun barrages or chemical warfare because the British and Commonwealth armies did not use these methods. Indeed, the only differences between the operational researchers in the Canadian Corps of the First World War and the No. 2 Operational Research Section of the Second World war were those of organisation and nomenclature. No. 2 Operational Research Section existed in the army group headquarters to conduct operational research. That was the only task for its staff. This staff was larger than the combined staffs of the CMGC and the CCGS, which both had primarily to deal with operations. Also, the specialised staffs of the Canadian Corps did not have a specific term that described their methodology. No. 2 Operational Research Section did - operational research.

Like the staff of the Canadian Corps counter-battery staff office, the officers of the CMGC and CCGS conducted OR as we now understand it. This examination is limited to two specialised staffs in the headquarters of the Canadian Corps. Further enquiry covering the entirety of the BEF is warranted to determine how uniformly other corps also conducted OR during the First World War, if at all. Armies had not used gas or machine gun barrages on the battlefield before 1915. However, by 1918, the Canadian Corps had mastered both and incorporated these techniques into its fire plans. In the intervening years, gas officers needed to develop countermeasures to enable Canadian troops to survive on the chemical battlefield and develop doctrine on how gas could be used offensively by the corps. Unlike the case of counter-battery artillery, the experimentation was more ad hoc and relied upon statistical analysis of gas casualties to gauge the effectiveness of countermeasures. Anecdotal evidence provided data for the analysis of the effectiveness of chemical bombardment. Similarly, OR on the use of machine guns firing in an indirect role could have benefited from more numerical analysis. Still, however imperfectly they may have performed OR, the staffs of the CMGC and CCGS adhered to the principles of the discipline and used the OR methodology to collect and analyse data, test solutions, and solve the novel problems that confronted them on the Western Front.