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# The Most Dangerous Factory in Britain: First World War Gas Warfare and H. M. Cylinder Depot, Stoke-on-Trent, UK

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ABSTRACT
*During the First World War, Stoke-on-Trent hosted the Ministry of Munitions' H.M. Cylinder Depot. By 1916 it was storing some 70,000 defective, dud and partially-discharged poison gas cylinders salvaged from the Western Front. With desperate gas shortages, cylinders were emptied, repaired and sent on to regional manufacturers to be refilled. The factory operated on a 24/7 basis. This was highly dangerous work with 2,000+ accidents reported for the 300-strong workforce. So many accidents occurred that pioneering high-oxygen medical treatment wards were developed in the nearby North Staffordshire Infirmary Hospital, forming the UK's first respiratory centre. Over 650,000 poison gas cylinders had been handled onsite by the end of the war.*

## Introduction

By late 1914, trench warfare became the norm on the Western Front, and in successive years assumed complex proportions. With the growing complexity of trench construction and the defensive power of artillery and machine guns, repeated unsuccessful attempts to 'break through' opposition lines by frontal assault led to large

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loss of life and ever more elaborate attempts to breach enemy defences, that deployed a range of innovations, from artillery to mining, to tanks, to gas.[1]

It was the first use of lethal gas by the Germans at Ypres in 1915 that 'opened the cylinders' to the widespread use of gas as a weapon of war, despite it being specifically precluded under the Hague Conventions of 1899 and 1907.[2] This first use of poison gas as a breakthrough weapon in the trench war, had, as Fritz Haber has stated, 'no precursors' in practical terms.[3] Nevertheless, it was the case that though all protagonists had considered the use of chemical lachrymatory agents such as tear gas early on, these were not taken seriously until, in 1915, they were superseded by more powerful agents such as the non-lethal ethyl iodoacetate (SK) and chloropicrin (PS), and ultimately the lethal gases chlorine and phosgene, either used alone or in

[1]For an overview of these techniques, see Paddy Griffith, *Battle Tactics of the Western Front. The British Army's Art of Attack 1916-18*, (New Haven: Yale University Press, 1994); Anthony Saunders, *Raiding on the Western Front*, (Barnsley: Pen & Sword, 2012); Bull, *Trench*, p. 95 *et seq*. and Peter Doyle, *Disputed Earth. Geology and Trench Warfare on the Western Front, 1914-18*, (London: Uniform, 2017), p. 178 *et seq*. For mining, see for example Peter Barton, Peter Doyle, Johan Vandewalle, *Beneath Flanders Fields: The Tunnellers' War 1914–1918,* (Staplehurst: Spellmount, 2004); Iain Banks, 'Digging in the Dark: The Underground War on The Western Front in WW1', *Journal of Conflict Archaeology*, 9, 3 (December 2014), pp. 156- 176 https://doi.org/10.1179/157407731 4Z.00000000038; Simon Jones, *Underground Warfare*, (Barnsley: Pen & Sword, 2015) and Kristopher D. Wisniewski, Peter Doyle, Robert J.S. Hunter, Jamie K. Pringle, Ian G. Stimpson, Dane Wright, Kirsty Squires, Zoe Sutherland, John P. Cassella, Fiona Graham, and Paul Ottey, 'A Multidisciplinary Scientific Investigation of the 1916 Hawthorn Mine Crater, Beaumont Hamel, Northern France', *Journal of Conflict Archaeology*, 18, 3-4 (2024), pp. 125-126 http://doi.org/10.1080/15740773.2023.2297202. For the use of gas, see Ludwig F. Haber, *The Poisonous Cloud. Chemical Warfare in the First World War,* (Oxford: Clarendon Press, 1986); Donald Richter, *Chemical Soldiers. British Gas Warfare in World War One*, (London: Leo Cooper, 1986); and Simon Jones, *World War I Gas Warfare Tactics and Equipment*, (Oxford: Osprey, 2007).

[2]James E. Edmonds, G C. Wynne, *Official History of the War. Military Operations, France & Belgium, 1915. Volume ,* (London: Macmillan, 1927)., Charles H. Foulkes, *"GAS!" The Story of the Special Brigade*, (Edinburgh and London: William Blackwood & Sones, 1934); Edward M. Spiers, *Chemical Warfare.* (London: Macmillan Press, 1986); Marion Girard, 'Political Decisions and Britain's Chemical Warfare Challenge in World War I; Descend to Atrocities?', *Defence Studies*, 8, (2008), pp. 105-132 https://doi.org/10.1080/14702430701812019

[3]Haber, *The Poisonous Cloud*, p. 15.

combination.[4] The use of chemical weapons in this way is widely condemned and is rightly proscribed by the United Nations, which continues to prohibit their use under the 1925 Geneva Protocol.[5]

To date, most work on the use of chemical weapons in the First World War has naturally focused on: the development and deployment of gas as a battlefield weapon; the mobilisation of chemists and the chemical industry; the impact of that deployment; the means of countering that deployment by protagonists; and the medical implications of the use of chemical weapons.[6] However, the historiography has focussed less on the workers and the industrial complex producing the gas, which as Marion Girard has indicated, was born out of the pre-existing chemical industry with extra layers of control added in wartime conditions.[7] To add to this scant attention, this study considers an even lesser-known aspect of the deployment of poison gas in the First World War; the development of factories under the Ministry of Munitions in the manufacture, repairing and refilling of pressurised cylinders used to deliver the weapon on the battlefield.

The production of chemicals in the United Kingdom during the First World War was controlled by the Ministry of Munitions, with the UK Government establishing national

[4]Ministry of Munitions, *Official History of the Ministry of Munitions. Vol. XI: The Supply of Munitions: Part II Chemical Warfare Supplies*, (Great Britain: H.M Stationary Office, 1922).

[5]United Nations, 'Chemical Weapons', https://disarmament.unoda.org/wmd/chemical/ Accessed 17 June 2025.

[6]Richter, *Chemical Soldiers*, p. 6 *et seq*., Haber, *The Poisonous Cloud,* p. 22 *et seq;* Albert Palazzo, *Seeking Victory on the Western Front. The British Army & Chemical Warfare in World War 1*, (Lincoln & London: University of Nebraska Press, 2000); Roy Macleod, 'The Chemists go to War: The Mobilization of Civilian Chemists and the British War Effort,1914-1918.' *Annals of Science*, 50, 5 (1993), pp. 455-481; Edgar Jones, 'Terror Weapons: The British Experience of Gas and Its Treatment in the First World War', *War in History*, 21, 3 (2014) https://doi.org/10.1177/0968344513510248; Susan R. Grayzel, 'Defence Against the Indefensible: The Gas Mask, the State and British Culture During and After the First World War', *Twentieth Century British History*, 25, 3 (2014), pp. 418-434 https://doi.org/10.1093/tcbh/hwu035., Thomas Mayer-MaGuire and Brian Baker, *British Military Respirators and Anti-Gas Equipment of the Two World Wars* (Marlborough: Crowood, 2015); Jones, *Terror Weapons*, pp. 6-8; Shirley D. Tuorinsky (ed), *Medical Aspects of Chemical Warfare*, (Washington: Office of The Surgeon General at TMM Publications, 2008)., Jones, *Terror Weapons*, pp. 9-13.

[7]Marion Girard, *A Strange and Formidable Weapon: British Responses to World War I Poison Gas* (Lincoln: University of Nebraska Press, 2008), pp.103-106.

factories to ensure that the increasing chemical wartime demands could be met.[8] Increased demands for battlefield gas weapons produced an industrial environment where it was difficult both to retain employees, and protect them from the noxious materials that took a toll of their health through associated illnesses and/or accidents.[9]

This study examines the operations at H.M. Cylinder Depot at Stoke-on-Trent, Staffordshire, a facility created in 1917 to store, sort and recycle used poison gas cylinders salvaged from the battlefields of the Western Front. As will be demonstrated, it is a site that can reasonably be called the 'most dangerous factory in Britain' due to the number of accidents that affected the workers there. The study objectives were: firstly to document operations at H.M. Cylinder Depot in Stoke-on-Trent and workers' accidents therein; and secondly to evidence the innovative medical advancement developed by North Staffordshire Infirmary to treat both workers and in due course gassed Western Front soldiers.

**Gas and Gas Cylinders**

The first use of gas by the Germans at Ypres on 22 April 1915 saw 170 tonnes of pressurised chlorine gas deployed by the German Fourth Army. It was released from some 6,000 modified commercial liquid cylinders against the northern flank of the trench salient protecting Ypres.[10]

Liquid chlorine was commonly referred to as 'Red Star', from the identifying markers on the cylinders. Acute chlorine gas poisoning led to inflammation of the eyes and the respiratory tract, causing organs to shut down over time and making them susceptible to infections, particularly tuberculosis at that time, and with chlorine being heavier than air it would settle within trenches and dugouts, requiring simple measures such as 'gas curtains' to keep the poison gas out.[11] Later, phosgene was also used. Whilst slower acting than chlorine, it caused similar symptoms, and was more difficult to detect as it was invisible and only the smell of mouldy hay made it noticeable.[12] Phosgene was often used in conjunction with 'Red Star' chlorine, a combination of liquid chlorine and phosgene, carbonyl dichloride ($COCl_2$), a highly lethal pulmonary irritant, referred to as 'White Star', again due to the symbols marked on shells. The

[8]Ministry of Munitions, *Chemical Warfare Supplies,* Appendix IX, p. 102; Peter Reed, 'Making War Work for Industry: The United Alkali Company's Central Laboratory During World War One', *Ambix*, 62 (2015), pp. 72-93 https://doi.org/10.1179/1745823414Y.0000000009.

[9]Girard, *A Strange and Formidable Weapon*, p. 117.

[10]Haber, *The Poisonous Cloud*, pp. 22-40.

[11]James E. Edmonds, G C. Wynne, *Official History of the War*, p.177; Haber, *The Poisonous Cloud*, p. 34.

[12]Haber, *The Poisonous Cloud,* p. 83 *et seq*.

combined gases allowed a better spread before separation, with the chlorine gas layer effectively sealing the underlying denser-than-air phosgene gas that settled into trenches and dugouts. This allowed it to last longer before dispersal and so become more effective.[13]

Added to this arsenal of gas, from July 1917, was bis(2-chloroethyl) sulphide ($S(CH_2CH_2Cl)_2$), known as 'mustard gas' due to its yellow colour and smell, and also known as 'Yellow Cross' by the Germans and 'Yperite' to the French.[14] A dark oily liquid, the 'gas' was delivered in artillery rounds of various sorts. On the night of the 12-13 July 1917 some 50,000 mustard gas shells were fired by the Germans into the Ypres Salient, causing extensive blistering of biological tissue, rather than just extreme lung irritation, together with extreme conjunctivitis.[15] Initial exposure was symptomless until it was too late to take preventative measures. It often pooled in soil and craters for weeks after use, and was visible as an oily yellow liquid. Mustard gas was persistent and penetrated clothing to produce extensive blistering of the skin that could incapacitate a soldier for months.

For the workers in the factories that manufactured the gas, and who pressurised them in cylinders for eventual release, there was considerable danger. The pressure to respond to the first use of gas on the battlefield meant that there was precious little time to develop safety protocols.[16] Notes on conditions made by Miss F.M.G. Micklethwait in June 1915 described the atmosphere in which workers operated, where they 'cheerfully faced each day an atmosphere impregnated with sulphur gases'.[17] Nevertheless, some impacts on the worker population should have been known, especially as chlorine was a common enough chemical in production prior to the war.[18]

On the battlefield, the effectiveness of poison gas as a weapon was heavily dependent upon its means of delivery. In 1915, pressurised cylinders were the only effective means of carrying the gas to the front and deploying it as a weapon (see Figure 1); a method of deployment that would become increasingly outdated as the war proceeded, and as the chemical make-up of the gas became more complex. The first

[13]Jones, *World War I Gas Warfare Tactics and Equipment.*
[14]James E. Edmonds, *Official History of the War. Military Operations, France & Belgium, 1917. Volume 2.* (London: HMSO, 1948), p. 119
[15]Haber, *The Poisonous Cloud,* p. 255
[16]Girard, *A Strange and Formidable Weapon*, p. 117
[17]F.M.G. Micklethwait, 'Note on the Evolution in Chemical Warfare July to August 1915,' 1–2, TNA MUN 5/197/1650/1; quoted in Girard, *A Strange and Formidable Weapon*, p. 118
[18]Girard, *A Strange and Formidable Weapon*, p. 118

use of chlorine gas by the British, released from cylinders, was at the opening of the Battle of Loos on 25 September 1915; it delivered mixed results.[19]



**Figure 1: View of a First World War Gas Attack on the Western Front.[20]**

For the British, five Royal Engineers (RE) 'Special Companies' were formed into a Special Brigade created to deliver the gas at Loos in 1915 and to handle and emplace the gas cylinders in the front lines (Figure 2), often by men who had been chemists or plumbers in civilian life.[21] The British used modified commercial gas cylinders, 8-inches in diameter and 5-feet 6-inches long, though with early shortages these were sourced from a number of different suppliers, including from the United States. The cylinders were placed below the trench parapet, and once in place had to be placed under guard. Foulkes, commanding the Special Brigade in France, also devised a scheme in 1917 for the use of lighter and smaller cylinders that could be carried by one man and therefore deployed on a local basis. [22]

[19]James E. Edmonds, *Official History of the War. Military Operations, France & Belgium, 1915. Volume 2.* (London: Macmillan, 1928)., Richter, *Chemical Soldiers, p. 38 et seq.;* Palazzo, *Seeking Victory on the Western Front,* p.53 *et seq*.; Peter Doyle, *Battle Story: Loos 1915*, (Stroud: Spellmount, 2012).

[20]Francis J. Reynolds, *Colliers New Photographic History of the World's War*. New York: P.F. Collier & Son, 1919

[21]Foulkes, "GAS!", p. 49 et seq.; Institution of Royal Engineers, *History of the Royal Engineers. Volume V. The Home Front, France, Flanders and Italy in the First World War* (Chatham: The Institution of Royal Engineers, 1952), p. 52; Richter, *Chemical Soldiers*, p. 108 *et seq.*

[22]Foulkes, "GAS!", p. 196



**Figure 2: Gas Cylinders in practice and in place in front line trenches.**[23]

The gas was released through a valve fitted with a syphon tube that reached the bottom of the cylinder to allow rapid gas discharge without ice forming at the nozzle to block release. Leaks were obviously to be avoided. The ideal tubes were to be semi-flexible copper or lead, though iron pipes were also used if necessary.[24] The variation in pipes and fittings meant that there were difficulties in standardisation, as famously described by Robert Graves, who witnessed the gas attack at Loos in September 1915, and the frantic search for appropriate spanners to release the gas.[25] A great deal of care was required in fitting these pipes, as illustrated by the manuscript diary of Pioneer Richard Hughes of 'O' Special Company, RE which sees him unloading the cylinders, referred to using the code name for cylinders: which was 'rogers', testing the piping on 3 July 1916, testing and fitting the piping in workshops in France for the next three days, before finally connecting them 'in the trenches' and preparing for a gas attack on 8 July.[26] The initial lead discharge pipes were replaced after the attack at Loos by improvised garden rubber hoses as the original lead pipes were prone to

[23]Photographs by C.R. Alderson, from Foulkes 1936
[24]Foulkes, "GAS!", p. 56
[25]Robert Graves *Good-bye to All That. An Autobiography*, (London: Jonathan Cape, 1929), p. 198
[26]Pioneer Richard S. Hughes, 'O' Special Company, Royal Engineers (Unpublished manuscript trench diary for 1916, Peter Doyle archive)

split.[27] By September 1915 some 6,000 gas cylinders had been transported to France in time for the Loos offensive, which contained 180 tons of mostly chlorine gas, and by July 1916, 91,200 gas cylinders had been delivered, and between June 1916 and March 1917 some 42,559 gas cylinders were discharged.[28] Later, cylinders were largely supplanted by other means which delivered the gas to specific locations. These included the electrically-fired Livens Projectors, a form of mortar, and batteries of which delivered gas projectiles – as did Stokes Mortars and artillery shells which were used commonly from mid-1917 onwards.[29] This made gas attacks more accurate and less affected by atmospheric effects, including wind.

Though gas was a dramatic addition to the battlefield in 1915, by 1918, much of its significance had been countered by the introduction of effective anti-gas measures.[30] For the British Expeditionary Force (BEF) in France and Flanders for the period 1915–1918 records indicate that of the 185,706 gas cases admitted to military hospitals, some 5,899 were ultimately fatal, amounting to 1 in 31 overall.[31] Nevertheless, gas remained a much-feared weapon.[32]

**Gas Cylinders and H.M. Cylinder Depot site, Stoke-on-Trent**

The cylinders required for poison gas discharge were not only expensive to produce, but their manufacture also competed with the production of other cylinders vital for the war effort, such as compressed gasses used in the welding industry, and cylinders for the storage of hydrogen for lighter than air observation and weather balloons which were extensively used by the Army and Navy. This made it necessary to attempt the recycling of gas cylinders after release of the gas.[33] On the Western Front gas cylinders were salvaged from the battlefield and then transported to the UK by boat and train, initially to be stored, then sorted by size and type (see Table 1 below for the symbols used to distinguish the type of agent), before being sent to their respective gas manufacturers to be cleaned, tested and refilled. That work was mostly undertaken by chemical factories in Runcorn and elsewhere in North Cheshire.[34]

[27]The UK National Archive (hereinafter TNA) MUN 5/383/1600/14, L-Col O.F. Brothers, *The Development of Weapons used in Trench Warfare 1914-1918.*
[28]Ministry of Munitions, *Official History of the Ministry of Munitions. Vol. XI: The Supply of Munitions: Part I Trench Warfare Supplies*, (Great Britain: H.M Stationery Office, 1922), pp. 95-96.
[29]Foulkes, "GAS!", pp. 168-173; Richter, *Chemical Soldiers*, p. 159 *et seq.*
[30]Jones, *Terror Weapons*, p. 8 *et seq*.
[31]T J. Mitchell and G M. Smith, *Official History of the War. Medical Services. Casualties and Medical Statistics*, (London: HMSO, 1931), pp. 111-113.
[32]Haber, *The Poisonous Cloud,* p. 195; Jones, *Terror Weapons*, pp. 5-6.
[33]TNA MUN 5/383/1600/14
[34]TNA MUN 5/383/1600/14.



**Figure 3: H. M. Cylinder Depot, Stoke-on-Trent, Staffordshire in 1917.**[35]

In Figure 3 note, from left to right, the General Store, Valve Shed, and the Vacuum Test and Washing Building in the background. Some seventy thousand salvaged cylinders can be seen in this photograph.

By September 1916, cylinder storage was based at the premises of a contractor at Bucknall Sawmills, near Hanley in Stoke-on-Trent in Staffordshire – where specialist facilities were set up to clean and test the returned cylinders. Hanley had good railway links, both to the south of England for transport back from the Western Front, and to the northwest for refilling where many chemical manufacturers were located. The Ministry had financed a railway spur for this specific purpose. By the end of 1916, 70,000 gas cylinders were being stored there, and this was recognised as a problem. In July 1917 the site was nationalised and became His Majesty's Cylinder Depot under the control of the Ministry of Munitions. The Ministry decided to resolve the cylinder backlog by handling the sorting onsite, but this was relatively basic and lacked professional engineering input and infrastructure.

By the end of the war, more than 650,000 poison gas cylinders had been sorted, repaired, and emptied at the depot. The work was done entirely by munitions workers drawn from across 'The Potteries' in Staffordshire – the region most associated with the ceramics industry – including women workers who handled at least 360,000 of the cylinders on site.[36] By the end of 1917 the number of accidents suffered by the workforce were so large that the depot had become known as the most dangerous

[35]From Day (1919)
[36]Ministry of Munitions, *Trench Warfare Supplies,* p.95

factory in Britain. After this time the need for recycling gas cylinders was superseded by the change to the use of artillery shells and Livens Projector drums for the delivery of gas on the battlefield.




**Figure 4: Historical maps of the H.M. Cylinder Depot Site.**[37]

[37]Images supplied by Ordnance Survey/EDINA service. © Crown Copyright Database 2023. (a) County Series 1:2,500 1st edition 1880, (b) County Series 1:2,500 1st revision 1900, (c) County Series 1:2,500 2nd revision 1924 and (d) VectorMap Local 1:25,000 2023 in Hanley, Stoke-on-Trent, UK

In the mid-nineteenth century the site for His Majesty's Cylinder Depot had been a part of Finney Gardens as shown in Figure 4. This had been a plant nursery covering about 6.5 hectares on both sides of the Biddulph branch of the North Staffordshire Railway line. This opened to mineral traffic in 1859, just to the north of Bucknall Station.[38] The railway was opened to passenger traffic in 1859 and Theophilius Cartlidge, who owned Finney Gardens, sold plants and shrubs from the station and developed the area to the east of the railway with assorted picnic areas, pleasure grounds and sporting venues.[39] The depot site west of the railway was given up to provide a wharf area at the terminus of a mineral tramway connecting the Northwood Colliery to the mainline railway – see Figure 4. The colliery developed a large timber yard onsite trading as Bucknall Saw Mills Company Ltd which provided pit props for the mines.

In 1916 the Ministry of Munitions awarded the company a contract to use their site as a sorting depot for empty gas cylinders, brought in by rail, to be sorted and returned to their respective regional chemical factories in northwest England for cleaning and refilling. A 1924 site map in Figure 4 shows the full extent of the H.M. Cylinder Depot at Hanley, with three cranes to offload and load the gas cylinders from the railway.

An historical record of H.M. Cylinder Depot, written by George Day, a medical officer, survives in The National Archives at Kew, and is very instructive in terms of the working conditions at the site, and this section is largely drawn from this account.[40] The six common gas cylinder types at the H.M. Cylinder Depot site are listed in Table 1. However, by the end of 1916, the number of non-refurbished cylinders being stored at the Depot had reached 70,000, and an adjacent field was rented to store them. The stored cylinders either had no symbol marked on them or were classed as defective, meaning they still contained a quantity of gas, or were known as duds which were cylinders with defects or damage, such as broken spindles and valves, or if the cylinder itself was cracked and in need of repair.

[38]Potteries, Biddulph and Congleton Railway https://www.heritagegateway.org.uk/Gateway/Results_Single.aspx?uid=76088&resourceID=19191. Accessed 8 July 2025.
[39]Steve Birks, 2011. Limekiln junction, Finney Gardens. https://www.thepotteries.org/photo_wk/153.htm. Accessed 8 July 2025.
[40]TNA WO142/253, Historical Record of H.M. Cylinder Depot (1919).

| No. | Chemical Gases | Chemical formulae(s) | Military symbol / colloquial name |
|---|---|---|---|
| 1 | Chlorine | $Cl_2$ | Red Star |
| 2 | Hydrogen sulphide and carbon disulphide mixture | $H_2S$ & $CS_2$ | Two Red Star |
| 3 | Mixture of phosgene & chlorine | $COCl_2$ & $Cl_2$ | White Star / Cross |
| 4 | Mixture of sulphur dichloride & chlorine | $SCl_2$ & $Cl_2$ | Blue Star |
| 5 | Mixture of chloropicrin and chlorine | $CCl_3NO_2$ & $Cl_2$ | Yellow Star / Cross |
| 6 | Mixture of chloropicrin and hydrogen sulphide | $CCl_3NO_2$ & $H_2S$ | Green Star |

**Table 1: Medical Officer George Day's Record 1918**[41]

By the beginning of 1917 The Ministry of Munitions had resolved the stored gas cylinder problem by building additional plant and requiring both Red and White Star marked cylinders to be sorted at the rate of 2,000 per week.[44]

Clamped at a rate of 20 at a time, the partly-filled gas cylinders were initially placed in 50°C water-filled troughs heated by coke and then connected to valves and tubes which extracted the gas via tubes as shown in Figure 5 with 'the fumes being carried away by ducting by the means of a 30 inch 'Sirocco' fan'. [44] The gas cylinders were weighed before this process and weighed again after to ensure that they were empty. When full, the gas cylinders weighed 140 lb (63.5 kg). Two scrubber towers were built onsite, which fed the extracted gas through cream of lime, a mixture of calcium hydroxide and water, in the first tower and then through a second tower before being vented, but this was still a basic process that lacked professional engineering input and infrastructure.[42]

The now empty gas cylinders were then washed and hydraulically tested to ensure there were no cylinder cracks, which were repaired as necessary, the cylinders dipped in paint, sorted and separately stacked for moving on to their respective gas factories to be refilled. A separate machine shop was also erected for testing the cylinder valves and for general cylinder repairs. [44]

[41]Ibid, p.14 (TNA WO142/253), summarised the six chemical gases commonly dealt with by factory Nos 1-3 at H.M. Cylinder Depot, Stoke-on-Trent, Staffordshire.
[42]Ibid, p.18

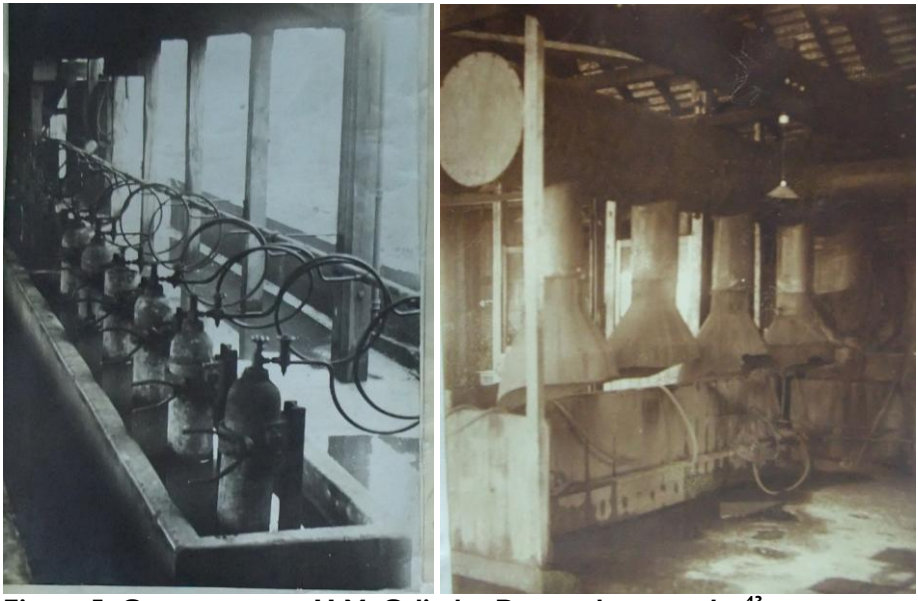


**Figure 5: Contemporary H.M. Cylinder Depot photographs.[43]**

On the left are the water troughs and clamped gas cylinders having any remaining poison gas evacuated via tubes, and on the right the scrubbers and washing plant to clean the emptied gas cylinders. Both processes were extremely dangerous.

**Factory Workers and Accidents**

Whilst initially handling 2,000 cylinders a week, the Depot output increased to 5,000 a week. The all-female workers were supervised by foremen, and worked three shifts of up to 8 hours as noted on time clock cards, and with no extra pay for work on the night shifts. However, there was no shortage of workers as pay at the Depot was typically three- to four-times higher than skilled and experienced female workers could earn in the local 'potbank' or ceramics factories. Others worked in the rail sidings, unloading, stacking and re-loading the gas cylinders which, if full, weighed 63 kg and 20-25 kg if empty, on a two 8-hour shift basis.[44]

Upon arriving at work, workers changed into overalls and regularly washed their hands, including before and after lunch in the depot's mess, overcrowding being strictly prohibited in the event of a gas accident, and washed again at the end of a shift, with

[43]TNA WO142/253
[44]Ibid, p.*44*

the daily disinfection also of all offices, lavatories and wash houses. Workers were forbidden to bring in food and were not permitted to eat while in the factory, since food-handling with contaminated hands was a well-known hazard. Workers were also issued with respirators that they had to carry at all times and which were always worn before going into and during work in the gas shed. A dedicated ambulance room onsite was equipped with beds and oxygen cylinders and was staffed at all times by a nurse and matron, with a local GP retained on a fee to treat accidents.[45]

Despite having a manager with chemical knowledge and the preventative measures employed, the initial gas cylinder extraction and cleaning procedure was very dangerous for the factory workers, with exposure to the gases causing acute ill health, both immediately and long term. This included the irritation and inflammation of the respiratory tract, interference with circulation, acute oedema of the lungs, rapid nervous and cardiac system collapse, and lung symptoms developing more slowly, vomiting, bronchitis, conjunctivitis, lung failure, and even heart failure in one fatal case. Damaged bronchial mucous membrane also made exposed workers more susceptible to tuberculosis which was prevalent and incurable at that time.

The average number of workers employed in 1918 was 284 but they suffered over 2,255 factory accidents at a rate of 794% or almost eight accidents per worker on average as shown in Table 2. For the nine serious cases that resulted in 100% incapacity, they were awarded compensation and a pension.[46]

| Depot accident type | Depot Workers affected | |
|---|---|---|
| | Number | % |
| Slight accidents | 1,114 | 392% |
| Eye cases | 184 | 65% |
| Skin cases | 72 | 25% |
| Gassing cases (slight) | 898 | 316% |
| Gassing cases (serious) | 2 | 0.7% |
| Gassing cases (fatal) | 1 | 0.4% |
| Hernia cases | 2 | 0.7% |
| Total | 2255 | 794% |

**Table 2. Summary of H.M. Cylinder Depot Factory Accidents in 1918.[47]**

Methods of treating exposed workers varied, initially comprising simple bed rest and keeping recovery rooms warm and well-ventilated to maximise recovery efforts. An

[45]Ibid, p.20
[46]Ibid, p.21
[47]TNA WO142/253 from medical officer George Day's 1919 Report.

injection of morphine was also recommended for cases of 'restlessness and excitement'. Some cases were more alarming; for example, if workers developed conjunctivitis from gas exposure, the recommended medical treatment was administration of atropine and cocaine.

Successful trials of patients continuously inhaling oxygen were conducted in Cambridge in 1917. By 1918, due to the serious gas exposure experienced by H.M. Depot workers and others in the north of England, the nearby North Staffordshire Infirmary, shown in Figure 6, installed two oxygen wards with an adjoining corridor, each containing four beds. Although over 100 patients had been admitted to the wards by the end of 1920, over 50% were gassed soldiers from the Western Front.




**Figure 6: Aerial photograph taken of the North Staffordshire Infirmary.**[48]

As reported by Frank Shufflebotham in 1920, the Infirmary's first floor hyperbaric oxygen wards comprised internal steel frames within the building structure, on which were affixed sheet steel, the ward floors being jointless, laid on the existing building

[48]Author owned. Photograph taken in 1930.

floor, and walls and ceilings being plastered.[49] A mezzanine floor carried the 'gas bag' with oxygen cylinders kept on the ground floor piped up to the wards. Air-tight double-framed glass windows were also installed, with double vestibule access and separate double food doors that reduced the egress of oxygen into the wider building. In the ward corridor were scrubbers absorbing carbon-dioxide, moisture and respiration impurities with a Haldane apparatus used to measure oxygen and carbon-dioxide levels and a tank cooler to regulate ward temperature. Electricity was used for lighting and corridor heating by radiators with both an obvious fire hazard. Finally, a rotary pump ensured circulation of air and constituents. Unfortunately, no plans or photographs of those facilities have survived.

Patients were admitted for five to six days with four hours of exercise allowed outside the wards each day. Patients were examined prior to treatment, with notes made of health diagnosis, a chest x-ray, blood examination and response to effort. Emphysema was present in 40% of cases.

Very positive ward results were reported by G.H. Sowry in 1920.[50] Out of 70 cases, 23 were very much improved, 30 much improved, 10 improved and 6 not improved, although the latter may be due to patients' reluctance to acknowledge any improvement until their pensions were settled. Depot workers who were 'unable to work on account of chronic gas-poisoning and other conditions such as asthma or heart and lung problems improved so much in health that they could return to light labour and in many cases they have been able to go back to their former employment'.[51] Finally, a double basal pneumonia severe case soldier made a very rapid and complete recovery which the doctor had never seen such remarkable progress in 27 years of clinical experience.

Keeping the oxygen wards operational at forty percent oxygen levels was estimated to cost of £1 3s. 6d per patient per day due to a production monopoly which was reported to be 'as almost a scandal that the amount of human suffering which may be alleviated by such treatment should be handicapped because of an oxygen monopoly'.[52]

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[49]Frank Shufflebottom, 'Discussion On The Therapeutic Uses of Oxygen', *Proceedings of the Royal Society of Medicine*, Volume 13 (1920), Therapeutic Pharmacology, pp 84-88
https://doi.org/10.1177/003591572001302229

[50]G. H. Sowry, 'Discussion on the Therapeutic Uses of Oxygen', *Proceedings of the Royal Society of Medicine*, 13 (1920), Therapeutic Pharmacology, pp 88-95 https://doi.org/10.1177/003591572001302230

[51]Shufflebottom, 'Discussion on the Therapeutic Uses of Oxygen, p. 88

[52]Ibid, p. 88.

## Closure and demolition

After the 1918 Armistice depot staff were employed to process the remaining stored cylinders until 1919 when the factory was closed, and the site cleared. Despite this, the railway yard remained operational up to the 1970s as shown in Figure 7, when the railway was removed and the site redeveloped as an industrial estate, which today houses car showrooms.

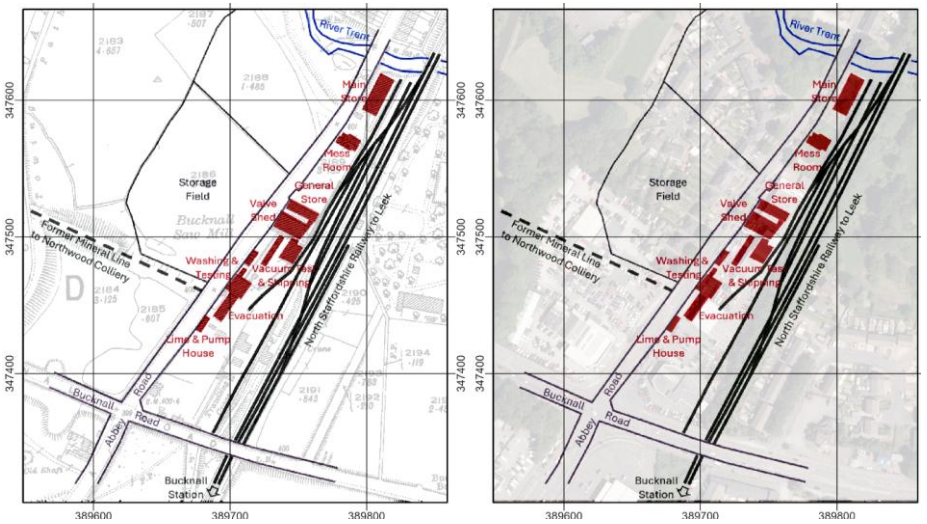



**Figure 7: Sketch map of H.M. Cylinder Depot.**[53]

## Discussion

Poison gas turned out to be a weapon that would not 'break the siege', but from 1917 onwards, was a part of an effective array of weapons directed at enemy infantrymen by the targeted delivery of gas by batteries of electrically-fired Livens Projectors. The demand for suitable gas cylinders made it crucial to recycle spent cylinders from the Western Front, initially by Royal Engineers engaged in salvaging them before they made their way back to the specialist storage and processing site at Stoke-on-Trent that is the subject of this paper. However, limited funding was provided by the Ministry of Munitions' Trench Warfare Supply Department which meant that a full depot and specialised factory could not be built, and crucially, the resulting human cost suffered by the H.M. Cylinder Depot workers was extremely high, with an average rate of over eight accidents per worker in 1917-18. Comparing this with a 1941 commissioned report that found overall accident rates in manufacturing industries in Britain, for the

[53] Depot as listed by the Ministry of Munitions superimposed on modern © Getmapping Ltd. site image of Hanley, Stoke-on-Trent, Midlands, UK.

dates 1901, 1904 and 1938, were *only* up to two per worker.[54] Notwithstanding the wartime and site constraints, it is this accident rate that made this facility the most dangerous factory in wartime Britain; and greater than other contemporary munition factory site disasters as detailed in Table 3 that are more well known for single mass casualty events. While no single disaster at the H.M. Cylinder Depot resulted in mass casualties in the same way – it is the pernicious effects of the numerous cumulative accidents that highlight the hazardous nature danger of this site.

| Date | Location | Manufacturing type | Deaths / Injuries (est.) |
|---|---|---|---|
| 27.05.1915 | Sheerness, Kent | 300 naval mines (est. 150 Tns) in HMS Princess Irene | 352 / 1 |
| 02.04.1916 | Faversham, Kent | Munitions (200 Tn TNT & ammonium nitrate) | 108 |
| 19.01.2017 | Silvertown, Essex | Munitions (50 Tn TNT) | 73 / 400+ |
| 01.07.2018 | Chillwell, Notts. | Munitions (8 Tns TNT) | 134 / 250+ |

**Table 3: First World War Fatal Munitions Factory Disasters.[55]**

This was not the only factory dealing with poison gas in the Potteries area during the First World War. At the nearby, and long-demolished, Sneyd Bycars Gas factory, 80-90 tons of the poison gas chloropicrin was being manufactured each week in 1918, it was used to fill 4-inch mortar shells at the impressive manufacturing rate of 400/hr. These were then sent to the Western Front via the same railway system used for the return of salvaged gas cylinders.[56] The Sneyd Bycars production was also hazardous with 117 reported accidents and 1 fatality in 1918 experienced by the 280 factory workers, approximately one event for every two workers. Other recorded health issues included cardiac conditions, anaemia, conjunctivitis, digestive system and skin issues, and even vertigo. Two explosions with accompanying fires also occurred there in late 1918, causing one fatality and several workers suffering serious burns due to picric acid leakage and ignition. Whilst numbers were comparatively small compared to munition factories accidents as shown in Table 3 these were still of concern.

[54] Duncan Wilson, 'Factory Inspection: A Thirty-Five Years Retrospect', *Journal of the Royal Statistical Society*, 104, 3 (1941), pp. 209-234 https://doi.org/10.2307/2980049.
[55] https://historicengland.org.uk/research/current/discover-and-understand/military/first-world-war-home-front/land/first-world-war-accidental-explosions/ Accessed 19 December 2025
[56] George Williams, Medical report for Sneyd Bycars Factory, Burslem, Ministry of Munitions – X Group WE15, 717-979.

However, like other scientific breakthroughs necessitated in wartime, the North Staffordshire Infirmary hyperbaric oxygen wards initially developed for the gassed workers, made amazingly rapid medical progress in the treatment of other patients with various pulmonary and lung disorders. The benefits accrued were not only for those exposed and injured at H.M. Cylinder Depot and other local poison gas factories but for returning soldiers gassed on the Western Front, and subsequently too for the wider local population suffering from a range of health issues, such as asthma attacks, pernicious anaemia, broncho-pneumonia and other respiratory difficulties from work in the local coal mines and potteries industries.[57] Previous nasal administration of oxygen was found to be satisfactory at 40-50% oxygen concentrations but was also evidenced to be wasteful in terms of masks, attending nurses and resistance to breathing, with these hyperbaric oxygen wards a real medical step forward.[58] This pioneering medicinal advancement has largely been ignored in the scientific literature.

As for the long-term environmental legacy and effect of such wartime factories on human health of the nearby population of such sites, there has been little research to-date and a survey of this is beyond the scope of this paper. Nevertheless, there is no doubt that wartime contamination by chemical weapons and artillery fire persists in soils – as demonstrated by recent work on the Messines Ridge in Belgium which still evidences significant soil contamination over 100 years later.[59] For Stoke-on-Trent, a city with a long industrial legacy and areas of 'contaminated ground', finding an environmental signal that could be traced to the former H.M. Cylinder Depot might be difficult to determine, but is certainly worthy of consideration. If so, it is possible that the dangerous work of that factory could continue to influence the health and well-being of locals even today.

[57]Sowry, 'Discussion on the Therapeutic Uses of Oxygen', p. 91-92.
[58]Ibid, p.25.
[59]Jamie K Pringle, Adam J Jeffery, Alastair Ruffell, Ian G. Stimpson, Duncan Pirrie, Elina Bergslein, Charlie Madden, Ian Oliver, Kris D. Wisniewski, Jon P. Cassella, Neil Lamont, Sarah Gormley, and Julian Partridge, 'The use of portable XRF as a forensic geoscience non-destructive trace evidence tool for environmental and criminal investigations', *Forensic Science International*, 332, (2022), 111175.
https://doi.org/10.1016/j.forsciint.2022.111175