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The United States Army Air Force bombing campaign against the Leuna Synthetic Fuel Plant in 1944-45 and the German response.

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The Leuna chemical plant in Eastern Germany was initially developed during the First World War to produce artificial nitrogen for use in explosives. The world's first production of synthetic fuel from brown coal commenced at Leuna in 1927. From 1933 the Nazi government began to prepare for war and heavily expanded the Leuna complex to ensure that Germany had sufficient resources of fuel, nitrogen and rubber to support short campaigns. The synthetic fuel production technology developed in Leuna was also transferred to thirteen other sites in Greater Germany.

Commencing on 12 May 1944 the USAAF, and later the RAF, undertook a sustained bombing campaign against Leuna and the other synthetic fuel plants. However, due to the critical importance of Leuna to the war effort, the German state devoted significant resources to the defence of the plant, and to its repair and the maintenance of production. The USAAF and RAF attacked Leuna on 21 subsequent occasions until production finally ceased in March 1945. This sustained bombing ultimately overcame the Leuna workforce's ability to repair the utilities but did not seriously damage the core production equipment. This paper uses German, American and British archival sources to explore in detail the nature and impact of the air campaign against Leuna and to examine and explain the ways in which the Germans sought, with some success, to keep the plant operational. In addressing the bombing campaign from an alternative perspective, primarily from the ground looking up, the paper offers new insight into a topic most commonly viewed from the perspective of the Allied forces.

The First World War saw the widespread use of aircraft, motor vehicles and submarines in combat and supporting roles in addition to the introduction of the tank. These early aircraft, motor vehicles, submarines and tanks were powered by internal combustion engines driven by liquid fuels (petrol, diesel, aviation fuel etc). The use of internal combustion engines driven by liquid fuels also extended into applications previously dependant on steam power fuelled by coal, e.g. naval and commercial shipping and rail transport. Lord Curzon, shortly to become the UK Foreign Secretary, summarised the critical importance of the internal combustion engine and liquid fuels on 21 November 1918 by stating that 'The Allied cause had floated to victory upon a wave of oil'.[1]

The widespread use of internal combustion engines during the First World War highlighted the future importance of liquid fuels to the economic and military power of a

[1] Daniel Yergin, *The prize, the epic quest for oil, money and power* (New York, 1991), p. 183.

modern state. Liquid fuels are usually manufactured from the distillation of crude oil. However, prior to the 1950s Germany, and the remainder of northern Europe, had no identified naturally occurring large scale sources of crude oil which could be used to manufacture liquid fuels. Northern European countries therefore imported crude oil, and derivative products, from USA, USSR, Romania, Iran, Mexico, Venezuela and other regions.[2]

During the 1920s German scientists employed by IG Farben developed an industrial scale process based on high pressures and temperatures which converted brown coal to synthetic fuel for use in internal combustion engines. Through the appliance of science and industrial capital a low-quality raw material was transformed into a range of high value products including liquid fuels for aviation.[3] The process was inherently very material and energy intensive requiring 14 – 16 tonnes of brown coal for each tonne of synthetic fuel produced.[4] The process was also very capital intensive and required large complex reactors, distillation towers and other equipment and represented the pinnacle of industrial chemistry during the 1920s and 1930s.[5] The commercial production of synthetic fuel from brown coal commenced during the 1920s at Leuna, a major chemical production complex located 50 kms west of Leipzig near Merseburg in eastern Germany.[6]

In the event of war Germany expected to lose access to seaborne supplies of crude oil, and associated derivative products, as occurred from September 1939. Therefore, German synthetic fuel capacity was significantly expanded during the 1930s and early 1940s.[7] By 1943 the Leuna plant produced 600,000 tonnes per year of synthetic fuel products, in addition to large quantities of chemicals for use in the manufacture of explosives and synthetic rubber.[8] The Leuna plant was extremely large, length 3.5 kms, width 1.1 kms, and was located at a relatively long distance, 1,100 kms, from Royal Air Force (RAF) and United States Army Air Force (USAAF) air bases in the UK which reduced the risk of air attacks.[9]

The German synthetic fuel industry was identified as a key strategic target for the USAAF in support of the invasion of north west Europe planned for June 1944.[10] The USAAF therefore attacked the Leuna plant for the first time on 12 May 1944 with 232 heavy bombers.[11] The plant was damaged but was quickly restored to full production. However, the effect of the attack on the German leadership was profound. Albert Speer, German Minister for Armaments and War production recorded that 'I shall never forget the date May 12, … On that day the technological war was decided'.[12] Speer informed Hitler on 19 May that 'The

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[2] Ibid, Chapter 11.
[3] Diarmuid Jeffreys, *Hells' cartel, IG Farben and the making of Hitler's war machine* (London, 2008), Chapter 5.
[4] BIOS FR 1697, *Synthetic oil production in Germany* (IWM Duxford, 1946), p. 19.
[5] Jeffreys, *Hells' cartel,* Chapter 5.
[6] Rainer Karlsch, Raymond Stokes, *Faktor Öl*, *die mineralölwirtschaft in Deutschland 1859-1974* (Munich, 2003), p.137.
[7] Karlsch & Stokes, *Faktor Öl,* p. 189.
[8] LASA (Saxony-Anhalt State Archive), I 525, No. A 2293, *Leuna production 1917 to 1947.*
[9] Rainer Karlsch, *Leuna 100 jahre chemie* (Leuna, 2016), p. 70.
[10] Richard Overy, *The bombing war* (London, 2013), p. 370.
[11] USSBS, *Physical damage division report 43 ammoniawerk Merseburg at Leuna* (Washington, 1945), p. 8.
[12] Albert Speer, *Inside the Third Reich* (London 1970, reissue 2003), p. 468.

enemy has struck us at one of our weakest points. If they persist at it … we will soon no longer have any fuel production worth mentioning'.[13]

The German state therefore immediately deployed large numbers of anti-aircraft guns to protect Leuna and the other synthetic fuel plants.[14] The anti-aircraft guns were further supported by smoke screens and decoy sites.[15] The Luftwaffe day fighter force also assigned the highest priority to the defence of the synthetic fuel plants.[16] Extensive protective and remedial measures were also taken on site through the construction of blast walls, bunkers and the mobilisation of a large labour force to repair bomb damage. The USAAF continued to make strenuous efforts to destroy the Leuna synthetic fuel plant during May – December 1944. In total the USAAF dispatched over 5,200 bomber sorties against Leuna in eighteen major attacks which dropped over 11,600 tonnes of bombs.[17] RAF bombers also made four major attacks during December 1944 – April 1945. Leuna synthetic fuel production was maintained sporadically from May 1944 to March 1945 at a gradually decreasing level primarily through the commitment of a large labour force used to repair damaged utilities.[18]

An extensive academic literature addressing the bombing campaigns in Europe during 1939–45 has developed during the past seventy years. Much has been written by British and American scholars who approach the bombing campaigns primarily from the perspective of the nations, and air forces, which carried out the bombing. Overy (2013) has provided the most comprehensive recent study of the bombing campaigns in Europe and reviews the bombing campaign against the German, Romanian and Italian oil industries at a strategic level.[19] Levine (1992), Pape (1996) and Gray (2012) also review the developments in Allied bombing strategy and practice during 1942–45 including assaults on the synthetic fuel industry.[20] Cooke and Nesbit (1985) review the bombing campaigns waged by the UK and USA against German and Romanian oil production sites in 1940–45.[21]

Overy initially reviews the ineffective RAF night attacks on the German oil industry during 1940-41 which were suspended from June 1941 in favour of mass attacks on German cities.[22] Overy, Pape and Gray stress that the USAAF and RAF did not attack German synthetic fuel plants from June 1941 until May 1944 due to an incorrect understanding of the German oil supply and stock levels. These authors highlight that USAAF commanders identified the German oil industry as a key strategic target in early 1944 and launched a sustained bombing assault on the synthetic fuel plants from May 1944 which quickly reduced output. All agree

[13] Speer, *Inside the Third Reich*, p. 469.
[14] Donald Nijboer, *German flak defences vs allied heavy bombers 1942–45* (Oxford, 2019), p. 53.
[15] Edward Westermann, 'Hitting the mark, but missing the target: Luftwaffe deception operations, 1939–45', in *War in History* (October 2003), p. 220.
[16] Werner Girbig, *Die luftoffensive gegen die duetsche treibstoffindustrie und der abwehreinsatz 1944–1945* (Stuttgart, 2003).
[17] USSBS, *Report 43*, pp. 8-14.
[18] USSBS, *Oil division final report German oil, rubber, chemical, explosives and propellants industries* (Washington, 1945), Figure 100.
[19] Overy, *The bombing war*, Chapter 6, Chapter 9.
[20] Alan J. Levine, *The strategic bombing of Germany 1940-1945* (Westport, 1992) Chapter 9, Robert A. Pape, *Bombing to win air power and coercion in war* (London, 1996) Chapter 8, Colin S. Gray, *Airpower for strategic effect* (Alabama, 2012), pp 134-142.
[21] Ronald C. Cooke and Roy Conyers Nesbit, *Target: Hitler's oil* (London, 1985).
[22] Overy, *The bombing war*, p. 277.

on the significant contribution of the bombing offensive against the synthetic fuel plants to the defeat of Germany through the overall reduction in the quantity of fuel available to the German armed forces, and through the attrition of the Luftwaffe day fighter force in defensive battles in an attempt to protect the synthetic fuel plants.

Keller (2011) and Parramore (2012) provide a more operationally focused review of the USAAF bombing campaign against the synthetic fuel industry from a USAAF perspective.[23] The USAAF attacks on Leuna from the perspective of the aircrews are described in extensive detail by Bowden (2008).[24] A German perspective is provided by Girbig (2003) who reviews the USAAF and Luftwaffe air forces involved in all major attacks on German and Romanian oil production facilities.[25] The German anti-aircraft defence efforts to protect Leuna and other critical sites are described in detail in Nijboer (2019).[26]

These writers and the wider literature do not address in any detail the effectiveness of the USAAF and later RAF attacks on the synthetic fuel plants during 1944-45, i.e. why was it necessary to attack Leuna on twenty-two occasions? Neither does the literature review the steps taken by the German armed forces and plant management to minimise the effectiveness of the bombing, and to restore production. The potential for a more rapid and complete shutdown of German synthetic fuel production is not reviewed, nor is the potential for Germany to maintain production for a longer period examined.

Therefore the focus of this paper is to investigate the following questions, firstly, what changes in tactics could the USAAF have made to shut down synthetic fuel production in Leuna more quickly, and secondly, what were the key defensive actions which enabled Leuna to maintain production until March 1945? These questions are addressed through examination of the primary sources which comprise the United States Strategic Bombing Survey (USSBS) reports on Leuna and the Oil Industry held in the UK National Archives in Kew, the Leuna archives held in the Landesarchiv Sachsen-Anhalt in Merseburg and other primary source documents held by the UK Imperial War Museum.

The United States Secretary of War created the USSBS in November 1944 to assess the effectiveness of the strategic bombing campaign in Europe, primarily to enable the USAAF to apply the conclusions to the ongoing bombing campaign against Japan.[27] The USSBS survey teams focussed on individual industrial sectors, e.g. steel industry or rail transportation and included USAAF bombing analysts, non USAAF industrial specialists and other technically trained personnel. US Army troops occupied Leuna on 15 April 1945.[28] USSBS team 46 visited Leuna between 21 April and 5 May 1945 and comprised thirteen persons including USAAF bombing analysts, petroleum technologists, scientific consultants, structural engineers and others.[29] During the period of the visit USSBS team 46 interviewed the Leuna management,

[23] Shawn P. Keller, *Turning point A history of German petroleum in WW2 and its lessons for the role of oil in modern air warfare* (Air Command and Staff College, 2011), Woody W. Parramore, 'The combined bomber offensive's destruction of Germany's refined fuels industry', in *Air and Space Power Journal* (March – April, 2012), pp 72-89.
[24] Ray Bowden, *Merseburg: blood, flak and oil* (Dorset, 2008).
[25] Gerbig, *Die luftoffensive*.
[26] Nijboer, *German flak defences*.
[27] Overy, *The bombing war*, p. 398.
[28] Karlsch, *Leuna 100 jahre chemie,* p. 70.
[29] USSBS, *Report 43*, p. 4.

reviewed the plant and the effects of the bombing in detail and studied and seized a great number of the plant reports. Team 46 found that the Leuna plant management had maintained very detailed records of the accuracy of the bombing and the effects of the bombing on the plant, 'the Germans were found to have compiled their records with their habitual thoroughness'.[30] The information gathered by team 46 was used to produce a series of detailed reports on the effects of the bombing which were issued in July and August 1945.[31] The results of the examination of Leuna were combined with the examinations of other German oil, chemical rubber and explosives industry sites in the USSBS Oil Division Final Report issued on 25 August 1945.

The surviving Leuna archival documents held in the Saxony-Anhalt State Archive (LASA) in Merseburg include the twenty-two weekly damage and repair reports for the period 9 July – 9 December 1944, information on production and processes during 1931–46, detailed production history by product type for 1917–46, investments in air raid protection, reports on the air raids, and the photographic records of air raids.

Leuna lay within the USSR occupation zone of Germany agreed on 11 February 1945 following the Yalta conference.[32] Therefore during June the US forces withdrew and Red Army troops occupied the plant on 1 July 1945.[33] The USSR administration, and later GDR administration, had different priorities and did not devote resources to the examination of the effects of the bombing on Leuna. Western researchers had no access to the Leuna site and the historic records until the early 1990s.

Dr Heinrich Butefisch was a senior director of IG Farben and played a major role in the creation of the Leuna synthetic fuel plant in the 1920s.[34] In January 1946 Dr Butefisch was interrogated by British personnel to establish the technical characteristics of the German synthetic fuel industry and the effects of the bombing on production. The records of this interrogation, and the data tables provided by Dr Butefisch in response to detailed questions, are an additional primary source.[35]

Albert Speer devotes several pages in his memoirs to the effects of the USAAF bombing of Leuna on synthetic fuel production and to his subsequent discussions with Hitler and other senior German personnel.[36] These memoirs provide insight into the response of the Nazi leadership to these bombing attacks, but include some biases by the author.

Despite the importance of the bombing of Leuna to the overall success of the Allied war effort in Europe, and the existence of extensive archival records, historians have not examined the bombing of Leuna in detail until now. The author believes that the location of Leuna behind the Iron Curtain until 1990 and the complexities and specialist vocabulary of the chemical industry were major factors which contributed to the gap in the historical record.

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30 USSBS, *Oil division*, p. 1.

31 USSBS, *Team 46 plant report 1, appendix 1, section 1,* USSBS, T*eam 46 plant report 1, appendix 2.*

32 Cornelius Ryan, *The last battle Berlin 1945* (London, 1984), p. 115.

33 Karlsch, *Leuna 100 jahre* c*hemie,* p. 71.

34 BIOS 1697 9th January 1946, p. 1.

35 BIOS 1697 Interrogation on 2nd and 9th January 1946.

36 Speer, *Inside the Third Reich*, pp. 468-488.

The following paper represents the first detailed review of the bombing and the response of the plant management and constitutes a valuable original piece of research.

The paper is divided into five Parts, including this Introduction and the Conclusion. Part One introduces the development of the Leuna plant and the environment in which the management cadre operated. During the 1920s and 1930s IG Farben was the fourth largest industrial organisation on earth with the most advanced research facilities and highly developed product development programmes in addition to skilled plant operations and commercial teams.[37] By 1943 Leuna was the world's leading high pressure chemistry production site with the widest product range. Part Two reviews the development of the German synthetic fuel industry during 1933-43, its importance for the German armed forces, and the development of the USAAF and RAF bombing strategies prior to the initial attacks on 12 May 1944. Part Two also explores the aspects of USAAF operational practice which limited the effectiveness of the attacks, and the effects of countermeasures by German air defences outside the Leuna plant.[38] Part Three initially describes the response of the German senior leadership to the attacks on Leuna and the synthetic fuel plants and in addition examines the actions taken by the Leuna management to maintain production despite the sustained USAAF and RAF bombing.

PART ONE. The Development of the Leuna Chemical Plant from 1916 to 1944

Leuna was initially constructed to fulfil the German army's requirement for explosives during the First World War, and the selection of Leuna as a location was partially driven by the need to minimise the risk of air attacks. The demand of the German armed forces for synthetic fuels, explosives, synthetic rubber and other materials supported its later expansion during the 1930s and 1940s.

Prior to 1914 European demand for nitrogen for use in explosives and fertilisers was fulfilled by imports of guano from Chile. Following the outbreak of the First World War the Royal Navy imposed a blockade on Germany which prevented imports of guano, leading to a critical shortage of nitrogen, and ultimately artillery shells in early 1915. In 1909 Dr Fritz Haber had developed a laboratory scale high-pressure chemistry process which extracted nitrogen from the atmosphere in the form of ammonia.[39] The process was expanded to an industrial scale by Carl Bosch and the BASF organisation in 1914-15 to produce nitrogen for use in explosives.[40]

The first artificial nitrogen plant was constructed by BASF at Oppau close to their main plant at Ludwigshafen in south west Germany. Ludwigshafen was situated 250 kms from French air bases and was attacked by bombers in May 1915.[41] Therefore during April 1916 BASF began the construction of a large artificial nitrogen plant at Leuna which was located 600 kms from the French air bases and beyond the range of the bombing aircraft in use at that time. Dr Carl Krauch directed the construction of the Leuna artificial nitrogen plant and

[37] Jeffreys, *Hell's cartel*, p. 7.
[38] Sean H. Seyer, *The plan put into practice: USAAF bombing doctrine and the Ploesti campaign* (St. Louis, 2009).
[39] Jeffreys, *Hell's cartel*, p. 45.
[40] Ibid, p. 46.
[41] Jeffreys, *Hell's cartel*, p. 59.

the first rail tanker carrying synthetic ammonia left the site in April 1917.[42] Due to the major increase in the consumption of explosives Leuna's nitrogen capacity was significantly expanded from 36,000 tonnes in 1916 to 200,000 tonnes in 1919.[43]

The German army's demand for nitrogen decreased significantly following the end of the First World War. The widespread post-war food shortages increased the demand for fertilisers and Leuna commenced production of ammonium sulphate fertiliser which increased strongly in volume during the 1920s.[44] In December 1925 the major German chemical producers (BASF, Bayer, Hoechst, Agfa and others) consolidated their activities in the new IG Farben group with Carl Bosch as chairman.[45]

IG Farben continued to invest heavily in research and product development during the 1920s. Dr Butefisch was appointed director of technical development in 1920 and lead research and product development in Leuna.[46] In 1922 BASF scientists developed a process to synthesise methanol from coal using high pressure hydrogenation equipment similar to that employed in the production of synthetic ammonia.[47] Leuna production of methanol commenced in 1923 and reached 25 KT by 1929.[48] During 1925-29 IG Farben also invested heavily in Leuna to convert brown coal into synthetic fuel based on the process discovered by Freidrich Bergius in 1913.[49] The production of synthetic fuel also utilised high-pressure hydrogenation equipment similar to that employed in the production of synthetic ammonia. Leuna production of synthetic fuel commenced in 1927 and reached 69 KT in 1929.[50]

Haber was awarded the Nobel prize for chemistry in 1918 for his discovery of synthetic ammonia and Bergius and Bosch shared the prize in 1930 for their development of high-pressure chemical production methods.[51] By the early 1930s Leuna was the world's leading chemical production plant and was totally based on 'state of the art' high pressure chemistry. The production of synthetic fuel proved to be more difficult and expensive than initially expected. Dr Butefisch was appointed leader of the synthetic fuel project in 1930 and during interrogation in 1946 he estimated that the total cost of synthetic fuel produced using the Bergius process was Pfennig (Pf) 35–41 / litre.[52] In comparison during 1931 the world market price for petrol decreased to Pf 5.2 / litre following the discovery of new oil fields in Texas.[53]

IG Farben faced a crisis in the early 1930s due to its large investment in the Leuna synthetic fuel project which had become totally uneconomic due to the increase in the world supply of crude oil. In addition, the demand for fertiliser and ammonia products decreased

[42] Karl Heinz Streller, Erika Maßalsky, *Geschichte des VEB leuna werke 1916 bis 1945* (Leipzig, 1989), pp. 18-20.
[43] Karlsch, *Leuna 100 jahre chemie,* p. 26.
[44] LASA, I 525, No. A 2293.
[45] Karlsch, *Leuna 100 jahre chemie,* p. 40.
[46] BIOS 1697, *9th January 1946*, p. 1.
[47] Karlsch, *Leuna 100 jahre chemie,* p. 36.
[48] LASA, I 525, No. A 618.
[49] Karlsch, *Leuna 100 jahre chemie,* p. 45.
[50] LASA, I 525, No. A 2293.
[51] Jeffreys, *Hell's cartel*, p. 60, p. 127.
[52] BIOS 1697, *Dr Butefisch responses*, Table 1.
[53] Karlsch, *Leuna 100 jahre chemie,* p. 45.

by 70% from 1928 to 1931 due to the reduction in economic activity following the Great Depression.[54]

During 1929-31 the Nazi party increased its representation in the German parliament and was expected to enter government in the near future. Due to the combined effects of the losses in synthetic fuel manufacture and decrease in sales due to the Great Depression the survival of IG Farben was dependent on German government policy. Bosch therefore arranged for Dr Butefisch and the IG Farben press secretary to meet with Adolf Hitler to establish his views on the synthetic fuel project.[55] During the meeting in September 1932 Hitler confirmed his total commitment to the synthetic fuel project.[56]

From 1933 IG Farben and Leuna became extensions of the German state and later integral parts of the preparations for war. Import duties were maintained at a high level to protect Leuna and the synthetic ammonia and fuel programmes. In December 1933 the German state and Leuna entered into a seven-year agreement for the supply of synthetic fuel under which Leuna agreed to increase the annual synthetic fuel production capacity by 250 KT from 100 KT to 350 KT by December 1935.[57] In return the German state guaranteed Leuna a price equivalent to production cost.[58] Leuna production of synthetic fuels increased from 81 KT in 1930 to 345 KT in 1936.[59]

Leuna continued to develop new products and in 1932 was the world's first producer of isobutylene which was used as a fuel additive and in the production of synthetic rubber, (Buna).[60] The Nazi government regarded Buna as a critical strategic material and arranged for IG Farben to develop a large scale Buna plant at Schkopau, 10 KM north of Leuna, where construction commenced in late 1935.[61] Leuna production of isobutylene increased to 32 KT in 1937 and 103 KT in 1938, much of which was supplied to Schkopau.[62]

Total Leuna production of bulk chemicals decreased by 376 KT or 55% from 685 KT in 1928 to 309 KT in 1931 during the depths of the depression. Leuna production increased by a factor of 3.4 from 309 KT in 1931 to 1,043 KT in 1938 as the German economy recovered and preparations for war commenced.[63] The outbreak of the Second World War in September 1939 further increased demand for Leuna's products. By the early 1940s Leuna manufactured more than 80 products including liquid fuels, lubricating oils, ammonia, nitric acid, fertilisers, sulphuric acid, methanol, isobutylene and other chemicals and derivatives.[64] Total production of bulk chemicals increased from 1,043 KT in 1938 to 1,367 KT in 1943.[65]

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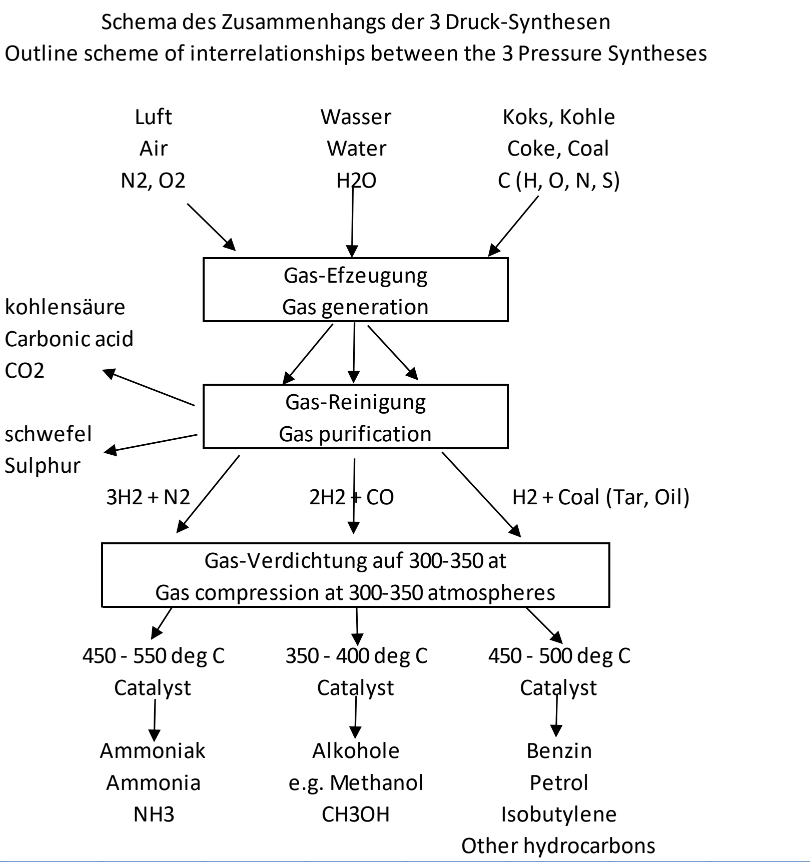
[54] LASA, I 525, No. A 2293.
[55] Karlsch, *Leuna 100 jahre chemie,* p. 49.
[56] Jeffreys, *Hell's cartel*, p. 137.
[57] Karlsch, *Leuna 100 jahre chemie,* p. 52.
[58] Karlsch & Stokes, *Faktor Öl*, p.167.
[59] LASA, I 525, No. A 2293.
[60] LASA, I 525, No. A 2293.
[61] Jeffreys, *Hell's cartel*, p. 172.
[62] LASA, I 525, No. A 2293.
[63] LASA, I 525, No. A 2293.
[64] LASA, I 525, No, A 2293, USSBS, *Appendix 1*, p. 1.
[65] LASA, I 525, No. A 2293.

An additional synthetic fuel production unit was installed in March 1941 which increased total capacity to 600 KT.[66] Leuna also supplied hydrogen, nitrogen and fuel gases by pipeline to the Buna synthetic rubber plant totalling seventy-three million m^3 in 1943. Product development continued, and Leuna produced caprolactam (for nylon), phenol, and a wide range of other specialist chemicals and catalysts.[67] Leuna produced critical high-octane fuel additives for the Luftwaffe without which a 2,000 hp engine would only generate 1,200 hp.[68] All these products were manufactured from the basic raw materials of coal, air and water using a three stage production process.[69]

In the first production stage coal, coke, air and water were converted into hydrogen, nitrogen and carbon monoxide gases. In the second stage the three gases were purified and depending on the desired end product combined with each other or with coal and coke under conditions of high pressure and temperature to form the three basic synthesis products, ammonia, methanol and other alcohols, and synthetic fuel. In the third final stage the three basic synthesis products were combined with other materials in further downstream processes to produce the wide range of final products (Image 1).[70]

LEUNA **IMAGE 1**

Source: LASA (Saxony-Anhalt State Archive), I 525, No. A 618



[66] LASA, I 525, No. A 3005.
[67] LASA, I 525, No. A 2293.
[68] USSBS, *Oil division*, p. 2.
[69] LASA, I 525, No. A 618.
[70] USSBS, *Appendix 1*, p. 1.

The gas generation, purification, compression and synthesis equipment were the core of the Leuna plant. Leuna's daily gas production of eleven million m^3 was almost twice the peak New York city daily winter gas consumption during the 1940s when the city population was 7.5 million.[71] The gas was generated, purified and converted using 65 gas generators, 18 gas blowers, 40 gas de-sulphurising units and 139 gas convertors all of which were located in a 12 hectare area.[72] The equipment was bulky, similar in construction and interchangeable between the various gases and syntheses.[73] The Leuna gas production plant was therefore extremely flexible, had large inbuilt spare capacity and could rapidly be reconfigured to produce different products from the core inputs of coal, air and water.

Leuna generated its own electrical power in seven separate generating plants which contained twenty-nine generating units and was also connected to the wider German electricity grid.[74] Leuna's average power consumption of 172,000 KW was similar to that of a US city of one million population during the 1940s. The total installed generating capacity of 285,000 KW provided spare capacity of 113,000 KW or forty per cent.[75] The electrical power was transmitted via 1,500 kms of underground cables to over 18,000 electric motors.[76]

The various production units were linked by a complex network of high- and low-pressure water mains, sewer systems, railway lines, storage tanks and other utilities. The pumping station on the nearby river Saale provided 900,000 m^3 of cooling and process water per day. The adjacent brown coal deposits provided over 25,000 tonnes per day used both as the raw material for the production processes and also as fuel to generate electrical energy. The Leuna internal rail network was 240 kms in length and was serviced by 51 locomotives and over 2,700 rail wagons. The Leuna plant operations were controlled via an extensive telephone network with 2,400 connections.[77] By 1943 the Leuna workforce had increased to over 35,000 employees which included almost 10,000 forced labourers.[78]

The simplicity of the inputs, the high degree of spare capacity, the flexibility in the production of final products and the high degree of interconnections must be understood in order to evaluate the effects of the bombing on Leuna, and the ability of the plant management to maintain production despite sustained attacks.[79]

By 1944 Leuna was the key German production plant for synthetic fuels (11-13% of total capacity), explosives (33% of total nitrogen and methanol capacity) and synthetic rubber (46% of total capacity, with Schkopau).[80] The Leuna chemical plant was one of the largest integrated production sites worldwide in any industry and in surface area exceeded both the Krupp steelworks in Essen and the Ford River Rouge car plant in Detroit, (Image 2).

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[71] USSBS, *Oil division*, p. 1.
[72] Ibid, p. 103.
[73] USSBS, *Report 43*, p. 5.
[74] USSBS, *Appendix 1*, p. 2.
[75] Ibid, p. 2.
[76] USSBS, *Report 43*, p. 10.
[77] USSBS, *Report 43*, p. 10.
[78] Karlsch, *Leuna 100 jahre* chemie, p. 63.
[79] USSBS, *Appendix 1*, p. 1.
[80] USSBS, *Oil division*, p. 10.

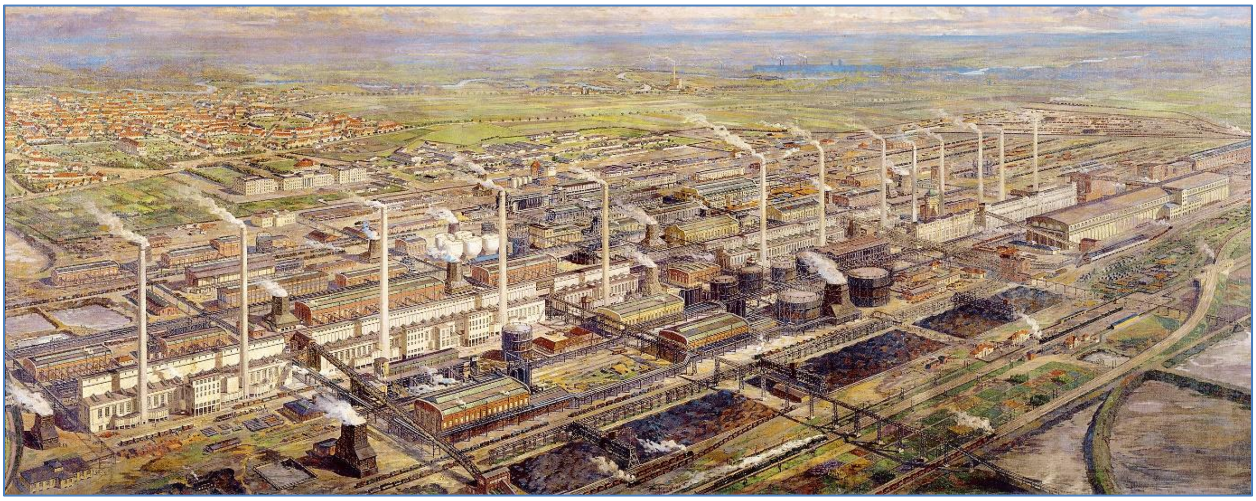

Image 2: Painting of Leuna plant viewed from North West in mid 1920s by Otto Bollhagen. Source: BASF Corporate History, Ludwigshafen a.Rh, Germany.

As of 12 May 1944, the Leuna plant had not been attacked by the Allied air forces since the last ineffective RAF night raid in December 1940 and continued to operate normally. The RAF night bombers had severely damaged many cities in western Germany during March-July 1943.[81] Following the devasting attacks on Hamburg in July 1943, the RAF repeatedly attacked Berlin during the winter of 1943-44.[82] The USAAF day bombers had attacked industrial targets inside Germany, e.g. Schweinfurt ball bearing plants in August and October 1943.[83] During 'Big Week' in February 1944 the USAAF attacked aircraft production plants in the Leipzig area close to Leuna.[84] However, prior to 12 May 1944 neither the USAAF nor the RAF had attacked in force the largest and most important German chemical plant, Leuna, which had a key role in the German aviation fuel, explosives and artificial rubber industries.

Leuna was the first location where German scientific and industrial skills, organisation and capital demonstrated that simple, readily available raw materials could be transformed into complex, high value products which were critical for the operation of modern industrial societies and armed forces. The lessons learned in Leuna were applied in other production sites in the late 1930s and allowed Germany to overcome the constraints arising from its lack of access to large natural sources of nitrogen, crude oil and rubber and to counteract the Royal Navy blockade. The scientific and industrial leadership in USA and UK did not appreciate the advances made in Leuna based on high pressure chemistry or the inter-relationships between the technology and the final products.

During early 1944 the USAAF planning staff finalised their preparations for the offensive against the German synthetic fuel industry. The development and execution of these plans are reviewed in the following section.

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81 Overy, *The bombing war*, pp. 321-326.
82 Ibid, pp 327-338, p. 368.
83 Ibid, p. 340.
84 Ibid, p. 369.

PART TWO. The Development of the German Synthetic Fuel Industry During 1933-43, the USAAF and RAF Bombing Offensive Against Leuna During 1944-45 and German Defensive Countermeasures.

The following section initially reviews the development of the German synthetic fuel industry during 1933–43, the critical role of IG Farben and Leuna and the development of the Allied bombing offensive. The USAAF and RAF commenced their assault on the German oil industry on 12 May 1944 which continued until the end of hostilities in May 1945. During this period the USAAF and RAF carried out twenty-two attacks on Leuna involving 6,630 aircraft sorties which dropped 85,412 high explosive bombs weighing 16,201 tonnes.[85] Despite this massive effort Leuna continued in production at a low level until March 1945. Therefore, the section also reviews the USAAF and RAF attacks on Leuna, the German defensive countermeasures and explains why the bombing attacks, while effective, were relatively inefficient. The efforts of the plant management to counteract the effects of the bombing and maintain production are reviewed in Part Three.

The Nazi regime assumed power in Germany in March 1933 following the passing of the enabling act and began to restructure German society and industry.[86] One of the regime's key political and economic goals was for Germany to achieve a state of economic independence or self-sufficiency, often described as autarky. The first systematic action undertaken was the New Plan of 1934 which created a virtual state monopoly of foreign trade, both exports and imports.[87]

During the 1920s and 1930s Germany's main external sources of crude oil and refined products were Romania, Venezuela, Mexico and the USSR.[88] During the 1920s and 1930s Romania was allied with France and its oil industry was dominated by British and French companies.[89] Prior to the defeat of France in June 1940 Romania wished to preserve its independence and remained outside the German sphere of influence.[90] Shipments of oil from Venezuela and Mexico to Germany were at risk of blockade by the French and British navies in the event of a war, and the political differences between Germany and the USSR reduced the long-term reliability of USSR supply.

Germany's reliance on external and unreliable sources of crude oil and refined products ensured that the drive for self-sufficiency in oil was a critical component of the autarky programme. During 1934 the German government encouraged IG Farben, several major German coal producers and other industrial organisations to form a new company, Braunkohle-Benzin AG (BRABAG), to manufacture synthetic fuel from brown coal. BRABAG was to construct several synthetic fuel plants with an initial annual capacity of 400-500 KT under license from IG Farben based on the Bergius process developed in Leuna.[91] Dr Krauch was appointed to the BRABAG management board as the representative of IG Farben, which also included representatives of the German military and the Nazi party. During 1934-37

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[85] USSBS, *Report No 43*, pp. 8-14.
[86] Jeffreys, *Hell's cartel*, p. 144.
[87] Mark Harrison, *The economics of World War II* (Cambridge 1998), p. 141.
[88] Rosemary Ann Kelanic, *The politics of international oil coercion* (Chicago, 2012), pp. 101-109.
[89] Cooke & Nesbit, *Target, Hitler's oil*, p. 66.
[90] Ibid, p. 66.
[91] Karlsch & Stokes, *Faktor Öl*, pp.182-184.

BRABAG developed three plants (Bohlen, Magdeburg and Zeitz) in eastern Germany with an ultimate total capacity of 770 KT (Map 1, following page).[92] The Bergius process was also adapted by IG Farben for use with hard, black coal and construction of two synthetic fuel plants in the Ruhr (Gelsenberg and Scholven) commenced in 1935. Also, during 1935 the German state commenced construction of synthetic fuel plants based on the Fischer-Tropsch process which used black coal as a raw material.[93]

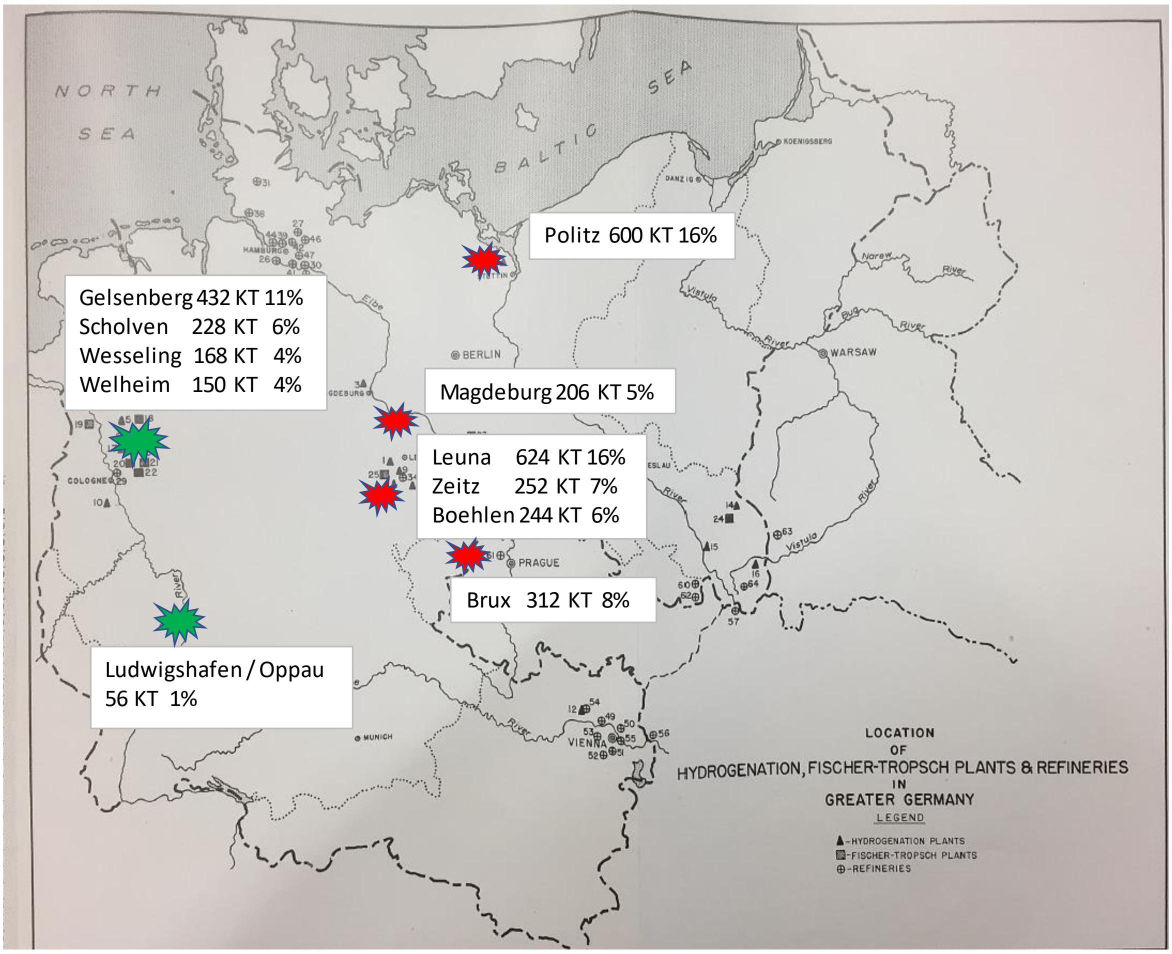
MAP 1

MAJOR USAAF AND RAF SYNTHETIC FUEL TARGETS: MAY 1944

(LASA, I 525, No. A 3005 Synthetic Fuel Output 1943)

The six indicated sites produced 59% of total German synthetic fuel in 1943 and were initially attacked by the USAAF between 12 May and 29 May 1944

The five indicated sites produced 26% of total German synthetic fuel in 1943 and were attacked by the RAF from 12 June 1944.



(Map Source: USSBS Oil Division Final Report Page 74)

By 1936 bottlenecks had developed in the supply of materials for rearmament, foodstuffs and the supply of fuel oil to the armed forces.[94] The Nazi regime therefore adopted a new Four-Year Plan which had the goal of ensuring that both the German economy and

[92] LASA, I 525, No. A 3005.

[93] Karlsch & Stokes, *Faktor Öl*, p.189.

[94] Harrison, *The economics of World War II*, p. 144.

armed forces were ready for war within four years, i.e. by 1940. Hitler assigned the highest priorities to the expansion of the German synthetic fuel programme, the synthetic rubber programme and the use of German iron ore resources.[95] Herman Goering was appointed director of the Four-Year plan and Dr Krauch, who had become a senior director of IG Farben, assumed a key role in the day-to-day management of the plan.[96] General Guderian as the intellectual leader of the developing German armoured forces was supportive of the plan, 'The Four-Year Plan has provided in a comprehensive way for synthetic fuel production … free us in the foreseeable future from the need to import petrol and oil. It will likewise not be long before Germany is independent of imports of foreign rubber'.[97]

Hitler called for the expansion of the synthetic fuel programme to be achieved within eighteen months.[98] Therefore over 90% of the initial investments of the Four-Year plan were allocated to the chemical industry primarily for the construction of synthetic fuel plants.[99] Between 1934 and 1939 a wide range of German industrial organisations commenced the construction of twenty two synthetic fuel plants with an annual total design capacity of 4,146 KT.[100] Due to the high investment the total German synthetic fuel production increased from 108 KT in 1933 to 1,434 KT in 1939. Leuna synthetic fuel production increased from 108 KT in 1933 to 444 KT in 1939. During the same period total German consumption of fuel increased by 95% from 2,238 KT in 1933 to 4,365 KT in 1939 (Table 1).

GERMANY OIL CONSUMPTION AND SOURCES: 1933 - 39 **TABLE 1**

Source: Rainer Karlsch, Raymond Stokes, Faktor Öl, (Munich 2003), p.190.
LASA, I 525, No. A 2993

	1933 KT	1936 KT	1939 KT	1933 % Total	1936 % Total	1939 % Total	Change 1933 - 39 KT	Change 1933 - 39 %
Germany Oil Consumption	2,238	3,497	4,365	100%	100%	100%	2,127	95%
Imports	1,898	2,582	2,215	85%	74%	51%	317	17%
Oil production in Germany	232	439	716	10%	13%	16%	484	209%
Synthetic Fuel Production	108	476	1,434	5%	14%	33%	1,326	1228%
Leuna	*108*	*345*	*444*	*5%*	*10%*	*10%*	*336*	311%
Other Plants	*0*	*131*	*990*	*0%*	*4%*	*23%*	*990*	
Leuna as % Synthetic Fuel	100%	72%	31%				-69%	

The large investment in synthetic fuel capacity, initially in Leuna and later in other plants, achieved the strategic goal of reducing Germany's dependence on sea-borne imports of fuel. In addition, the synthetic fuel programme crucially provided Germany with self-

[95] Ibid, p. 145.
[96] Jeffreys, *Hell's cartel*, p. 179.
[97] Heinz Guderian, *Achtung panzer* (1937, Translation London 1992), p. 207.
[98] Harrison, *The economics of World War II*, p. 145.
[99] Jeffreys, *Hell's cartel*, p. 180.
[100] Karlsch & Stokes, *Faktor Öl*, p.189, LASA I 525 A 3005.

sufficiency in aviation and motor fuel to support a short campaign by the Luftwaffe and the relatively small number of motorised army units.[101]

The construction of synthetic fuel plants required very large quantities of fabricated steel for use in process equipment, pipelines and railways. The USSBS estimated that a synthetic fuel plant required fifteen times as much steel as a conventional oil refinery of equivalent output.[102] The high steel consumption ensured that the synthetic fuel plants were constructed in an integrated manner with production equipment located close together in order to minimise the total consumption of steel and to maximise the use of the shared gas production facilities and other utilities.[103]

The total deliveries of steel to the synthetic fuel plants between July 1937 and March 1944 were 4,380 KT.[104] These steel deliveries were more than three times the total weight of the Royal Navy's vessels in 1940, 1,274 KT.[105] The German demand for steel for other uses increased significantly following the commencement of rearmament in 1935 and in later years the supply of steel for the synthetic fuel plants was rationed which delayed the construction.[106] Due to ongoing shortages and delays many synthetic fuel plants never achieved the planned output levels. The synthetic fuel plants achieved their maximum output of 3,788 KT in 1943, equivalent to 80% of the design capacity.[107]

During 1943 Leuna was the largest producer of synthetic fuel with output of 624 KT, 16% share, followed closely by the Politz plant (near Szczecin, Poland) with 600 KT, 16%. The total annual capacity of Leuna and the other Bergius process plants was 4,006 KT which represented 84% of total German synthetic fuel capacity. The Bergius process was very flexible and could produce a wide range of fuels while the less flexible Fischer-Tropsch plants primarily produced diesel.[108] The Bergius process plants were also the only plants capable of producing aviation grade fuel as the Fischer-Tropsch plants could not produce high octane fuels and the natural crude oils extracted in Germany and Austria were unsuitable for aviation fuel.[109] Therefore during 1943 the Bergius plants produced virtually all Germany's aviation fuel of 1,864 KT and were critical to the German war effort. During 1943 Leuna was the third largest producer of aviation fuel with output of 252 KT, 14% share, following the Politz plant (492 KT, 26%) and the Gelsenberg plant (360 KT, 19%).[110]

Romania developed closer relations with Germany following the defeat of France in June 1940 and joined the Axis powers in November 1940.[111] From mid-1940 the total Romanian oil production, 6,240 KT in 1939, was available for use by Germany and its allies,

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[101] Anand Toprani, *Oil and grand strategy: Great Britain and Germany 1918 – 1941* (Washington, 2012), pp. 402-403.
[102] USSBS, *Oil division*, p. 15.
[103] Ibid, p. 12.
[104] Ibid, p. 15.
[105] Toprani, *Oil and grand strategy*, p. 371
[106] Ibid, pp. 373-374.
[107] LASA, I 525, No. A 3005.
[108] Cooke & Nesbit, *Target, Hitler's oil*, pp. 138-139.
[109] USSBS, *Oil division*, p. 14.
[110] LASA, I 525, No. A 3005.
[111] Cooke & Nesbit, *Target, Hitler's oil*, p. 65.

including Italy from June 1940.[112] During 1940-43 on an annual basis Romania typically supplied 2,500 KT of crude oil and refined fuel products directly to Germany and 3,000 KT to Italy and other Balkan countries. From June 1941 Romania also supplied refined products directly to German forces on the Eastern Front. Total German and allies annual oil consumption increased from 7,600 KT in 1940 to an average of 10,250 KT in 1941-43. Total synthetic fuel production almost doubled from 1,934 KT in 1940 (25% of total) to 3,846 KT in 1943 (34% of total).

Germany's typical annual oil supply during 1941-43 of 10 MT can be compared with the USSR production of 25 MT (1935 values) and the combined production of USA, Mexico and Venezuela of 162 MT (1935 values).[113] Hitler was very conscious of the relative weakness of Germany's oil supply to sustain a global conflict and at the start of the offensive towards the Caucasus in June 1942 commented to Field Marshall Bock 'If we don't take Maikop and Grozny, then I must put an end to the war'.[114]

The British Empire's annual wartime requirement of 27 MT was primarily supplied by imports from USA and Venezuela which represented 93% of all British oil imports in 1944 (19.7 MT).[115] Crude oil and refined products delivered by sea to the UK were the essential enabler which allowed the USAAF and RAF to defeat the Luftwaffe and support the ground forces of the USSR and the Western allies in the conquest of Germany in 1945.[116]

The weakness of Germany's oil supply position was appreciated by the leading Allied politicians and armed forces commanders in 1939-43. The initial RAF war plan, W.A.5, was based on information compiled by the Industrial Intelligence Centre which developed lists of vulnerable German industrial targets and concentrated on attacks on the Ruhr and the German oil industry.[117] On 13 May 1940 the British cabinet approved bombing attacks against German oil and rail targets which commenced on 14-15 May.[118] Later in May the first priority for bombing missions was assigned to oil industry targets and this continued after the defeat of France in June.[119] During this campaign Leuna was attacked by RAF night bombers on five occasions between 16-17 August and 15-16 December 1940. The attacks were carried out by small numbers of aircraft (1 – 12) and caused minimal damage.[120]

RAF attacks on German oil targets continued throughout the winter of 1940-41 but were ineffectual owing to the difficulties in target identification in winter conditions and the inherent inaccuracies in night bombing.[121] In June 1941 the British Air Ministry recognised the inability of the RAF bomber force to effectively attack the German oil industry given the relatively small number of aircraft available, and the operational difficulties. In addition, Germany had gained access to French oil stocks in June 1940 and to all Romanian oil

[112] Seyer, *The plan put into practice*, p. 59.
[113] Yergin, *The prize*, p. 822.
[114] Simon Sebag Montefiore, *Stalin the court of the red tsar* (London, 2004), p. 424.
[115] Toprani, *Oil and grand strategy*, p. 253.
[116] Gray, *Airpower for strategic effect*, pp. 138-139.
[117] Overy, *The bombing war*, p. 240.
[118] Ibid, p. 244.
[119] Ibid, p. 251.
[120] USSBS, *Report 43*, pp. 77-78.
[121] Overy, *The bombing war*, p. 262.

production from spring 1941.[122] As a consequence oil was no longer the primary RAF target and the bombing effort was re-assigned to 'morale attacks' on working-class housing areas within German cities.[123] During the remainder of 1941 and throughout 1942, 1943 and early 1944 the RAF bomber force concentrated its attacks on German cities, and did not attack the German oil industry.

During the 1920s and 1930s the USAAF had studied industrial complexes within the USA and identified that a network of mutually dependent systems facilitated production. Based on this analysis the USAAF developed the theory of the 'industrial web' whereby sustained bombing attacks concentrated on certain critical nodes in an enemy industrial economy would lead to the collapse of the entire economic system.[124] The bombing attacks on the critical industrial nodes were to be carried out in daylight during clear weather using the sophisticated Norden bombsight to maximise bombing accuracy. The heavily armed B-17 and B-24 four engine bombers would fly to the targets in large defensive formations to resist attack from enemy fighters.[125]

As international tensions increased during 1940-41 the USAAF collected detailed economic intelligence information on German industrial and economic targets, primarily based on information supplied by the British Air Ministry.[126] In August 1941 the USAAF developed a detailed plan for a bombing offensive against Germany, AWPD-1, which was based directly on the industrial web theory and called for 'the breakdown of the industrial and economic structure of Germany. This conception involves the selection of a system of objects vital to the continued German war effort'. AWPD-1 listed 154 targets in three key target areas: electric power, fuel oil and communications.[127]

Following the entry of the USA into the war in December 1941 the USAAF further developed its plans for assaults on Germany. In September 1942 the USAAF produced a detailed operational plan, AWPD-42, which listed 177 targets distributed across seven target systems, the German air force, submarine construction, communications, electric power, fuel oil, aluminium and synthetic rubber. AWPD-42 required the USAAF to undertake over 66,000 sorties and drop over 132,000 tons of bombs.[128]

During the Casablanca Conference in January 1943 the American and British political and military leaderships agreed that the USAAF and RAF would undertake a combined bomber offensive (CBO) against Germany.[129] In April 1943 the USAAF developed a detailed plan for participation in the CBO which included seventy-six key targets distributed across three target systems, aircraft, submarines and ball bearings.[130] In order to accomplish these missions the USAAF assembled the 8th Air Force based in Britain to bomb targets in north west Europe and the 15th Air Force based in Tunisia in 1943, and in Italy from 1944, to bomb targets

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[122] Pape, *Bombing to win*, pp. 267-269.
[123] Overy, *The bombing war*, p. 263.
[124] Pape, *Bombing to win*, pp. 62-63.
[125] Seyer, *The plan put into practice*, pp. 24-29.
[126] Overy, *The bombing war*, p. 281.
[127] Douglas Birkey, *Aiming for strategic effect, the evolution of USAAF bombardment campaigns WW2* (Washington 2013), pp. 44-45.
[128] Overy, *The bombing war*, p. 305.
[129] Overy, *The bombing war*, p. 302.
[130] Ibid, p. 311.

in southern Europe and the Balkans. The RAF bomber command primarily continued its attacks on German cities as its contribution to the CBO in accordance with the preferences of its commander, Air Marshall Harris.[131]

Fuel oil had been a critical target for the USAAF in the original AWPD-1 plan of August 1941, was also included in AWPD-42 in September 1942 but was omitted from the CBO plan in April 1943. The reason for the omission of fuel oil from the CBO target priorities was that the air force commanders and their economic advisers had become conscious of the importance of stock levels and spare capacity in the German industrial system, which had significantly reduced the impact of bombing attacks on individual production plants.[132] Up to April 1944 Allied intelligence on the German oil industry consistently overestimated the output of the synthetic fuel plants by up to 33%.[133] Allied intelligence also overestimated the quantity of imports from Romania, and believed that Germany had large concealed stocks.[134] Therefore during the remainder of 1943 and early 1944 the USAAF concentrated its attacks on production plants for aircraft, submarines and ball bearings.

The German synthetic fuel industry was undisturbed by bombing for a period of thirty-four months from July 1941 to April 1944. During the period 1939-43 total German losses of fuel oil due to Allied bombing attacks equalled a negligible ten days production.[135] The USAAF carried out two unsuccessful daylight attacks on the Romanian oil fields at Ploesti in June 1942 and August 1943 from bases in North Africa which incurred losses of thirty per cent and lead to a cessation of attacks until April 1944.[136]

During the autumn of 1943 the Luftwaffe concentrated most of its available day fighters in Germany to protect the industrial base against USAAF attacks and reduced its strength in other fronts.[137] From February 1944 following the introduction of the P-51 long range escort fighter the USAAF was engaged in a battle of attrition with the German day fighter force to achieve air superiority over Germany.[138] The intense air battles over Germany increased the Luftwaffe’s monthly consumption of aviation fuel from 105 KT in December 1943 to an all-time peak of 195 KT in May 1944.[139] For comparison the Luftwaffe’s maximum monthly consumption during the battles of France and Britain in 1940 was 100 KT.[140] Allied intelligence became aware via signal interceptions that the German fuel supply situation was more vulnerable than earlier believed. Reductions in the German supply of aviation fuel would strongly assist the USAAF efforts to destroy the German day fighter force and establish air superiority.

On 5 March 1944 the Enemy Objectives Unit (EOU) committee recommended to the USAAF that attacks on oil production should have the highest priority, ‘no other target system holds such great promise for hastening German defeat’, followed by attacks on synthetic

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[131] Overy, *The bombing war*, p. 344.
[132] Pape, *Bombing to win*, pp. 263-264.
[133] USSBS, *Oil division final report*, p. 132.
[134] Overy, *The bombing war*, p. 370.
[135] Toprani, *Oil and grand strategy*, p. 435.
[136] Cooke & Nesbit, *Target, Hitler’s oil*, p. 83, p.93.
[137] Overy, *The bombing war*, p. 362.
[138] Ibid, p. 369.
[139] USSBS, *Oil division*, p. 27.
[140] Ibid, Figure 22.

rubber production.[141] The new plan intended to attack twenty-seven oil production targets within a three month period.[142] The EOU planners were confident that the attacks on the German oil industry would have a major negative impact on the German armed forces within six months.[143]

Based on the new plan the USAAF 15th Air Force resumed attacks on the Romanian oil fields and during the period from 5 April to 19 August 1944 carried out twenty high altitude daylight attacks on Ploesti which destroyed the refineries.[144] Red Army forces entered Romania on 20 August and occupied Ploesti on 30 August.[145]

The 8th Air Force commenced attacks on the German synthetic fuel plants on 12 May 1944 when 886 bombers escorted by 735 fighters attacked the synthetic fuel plant at Leuna and four other plants (Boehlen, Brux, Luetzkendorf and Zeitz) in the Leipzig and north west Czech areas (Map 1).[146] These attacks had an immediate effect and Leuna and the other attacked synthetic fuel plants ceased all production. On 13 May the Allied Ultra service, responsible for decoding German radio signals sent via the enigma system, intercepted an order to transfer all available anti-aircraft guns to the synthetic fuel plants, and away from the aircraft production plants.[147]

The initial attacks on 12 May were followed by a further attack on Leuna and five other synthetic fuel plants on 28 May and by the first attack on the major Politz plant on 29 May.[148] The second attack on Leuna on 28 May severely disrupted the repairs which had commenced following the initial attack on 12 May. The three major USAAF attacks during 12-29 May assaulted seven plants which had produced 59% of total German synthetic fuel output in 1943, and 57% of total aviation fuel output.[149] The USAAF targeting committee had identified the correct targets and the attacks achieved a major blow against the German war effort. Total German production of synthetic fuel decreased by 58% from 349 KT in April to 145 KT in June. The effect of the USAAF assaults on aviation fuel production was more pronounced with a decrease of 69% from 164 KT in April to 52 KT in June.[150]

Other Ultra interceptions in late May and early June provided further evidence of the adverse effects of bombing on German fuel supplies which lead to General Eisenhower's formal approval of the bombing offensive against the synthetic fuel plants on 4 June 1944.[151] General Spaatz, USAAF European commander, informed the USAAF bomber forces on 8 June that 'Primary strategic aim of U.S Strategic Air Forces is now to deny oil to enemy air forces' which policy was followed for the remainder of the war.[152] Based on this policy all German oil plants were to be bombed as systematically and severely as the air strength permitted, and

[141] Birkey, *Aiming for strategic effect,* pp.101-102.
[142] Overy, *The bombing war*, p. 370.
[143] Pape, *Bombing to win*, pp. 277-278.
[144] Overy, *The bombing war*, p. 592.
[145] Cooke & Nesbit, *Target, Hitler's oil*, pp. 106-107.
[146] Overy, *The bombing war*, p. 371.
[147] Ibid, p. 371.
[148] Girbig, *Die luftoffensive,* p.217.
[149] LASA, I 525, No. A 3005.
[150] LASA, I 525, No. A 3005.
[151] Overy, *The bombing war*, p. 371.
[152] USSBS, *Oil division*, p. 1.

the attacks were to be repeated with sufficient frequency to ensure that production did not resume.[153] Between 12 May 1944 and 8 May 1945 the USAAF 8th and 15th Air Forces and the RAF Bomber Command dropped 191,256 tons of bombs on eighty seven oil industry targets.[154]

Allied air reconnaissance photographed a synthetic fuel plant immediately following the bombing attack and a damage assessment was prepared. Based on the conclusions of the damage assessment, predictions were made of the length of time required for the plant's repair and what percentage of the plant's original production could be achieved. The plant was photographed at regular intervals to establish the level of activity within the plant. When assessment of the photographs indicated that production was about to resume, or had resumed, the plant was then included in the schedule of bombing targets and a further attack was made.[155]

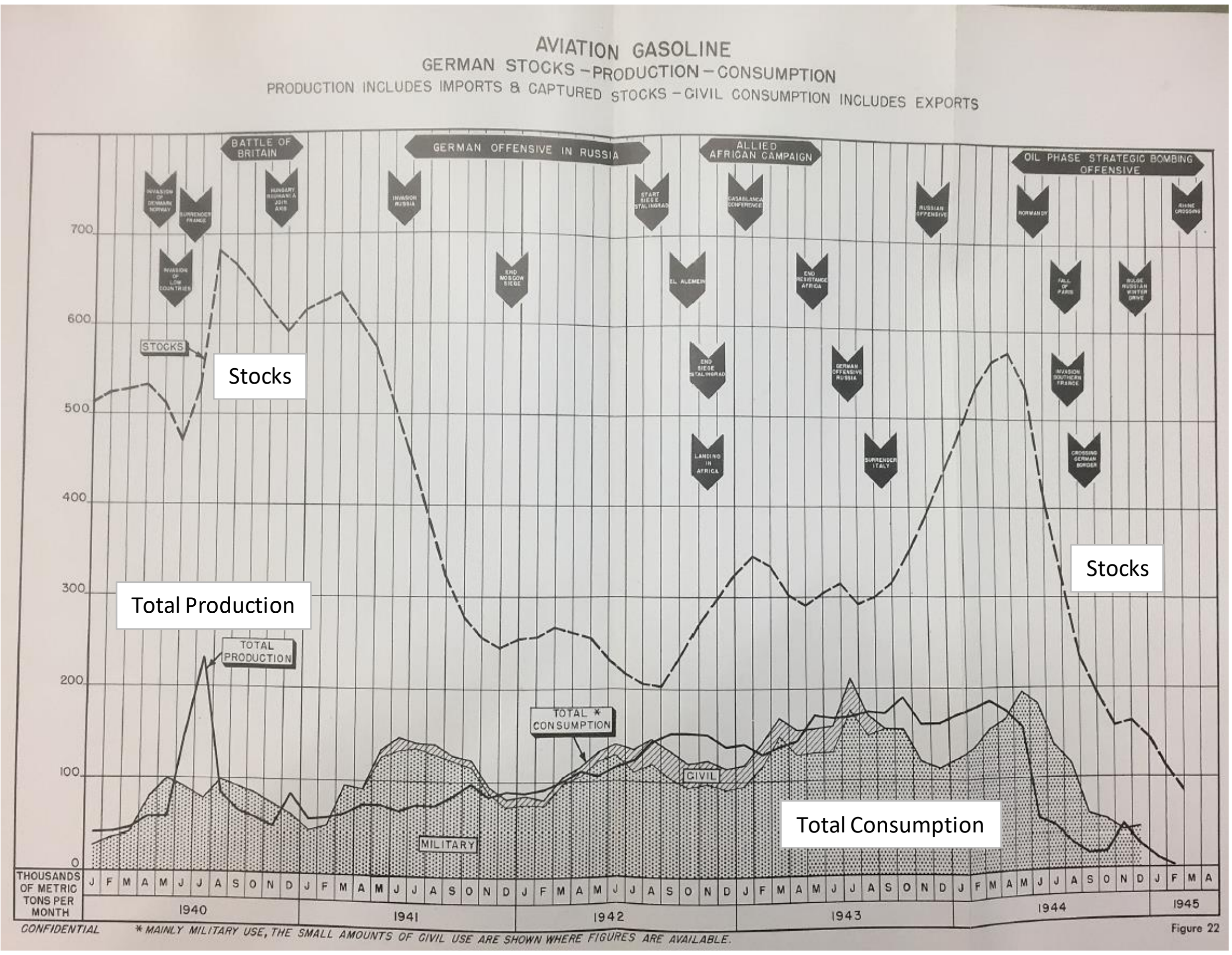
Based on this approach the attacks on the major synthetic fuel plants were repeated at regular intervals, thus restricting repairs and the preventing the resumption of full production. During May – September 1944 Leuna was attacked on ten occasions, Bohlen six, Brux six, Gelsenberg seven, Politz three, Scholven twelve and Zeitz on three occasions.[156] Due to these sustained attacks by October 1944 total German synthetic fuel production decreased to 38 KT, 11% of April's production, and total aviation fuel production decreased to 14 KT, 9% of April.[157]

German synthetic fuel production recovered slightly to 20-22% of April levels during early November 1944 as the intensity and effectiveness of allied air attacks reduced. However the intensity of allied air attacks on the synthetic fuel industry increased from mid-November 1944 to January 1945 leading to a further reduction in synthetic fuel production in February and March 1945 to 3-4% of April 1944 levels and the complete cessation of aviation fuel production.[158] The limited German stocks of aviation fuel, motor fuel and diesel were practically exhausted by November 1944 with consequent adverse effects on German army and Luftwaffe operations.[159]

Between August 1944 and May 1945 German monthly consumption of aviation fuel exceeded production, except for December 1944 (Figure 1).[160]

[153] Ibid, p. 1.
[154] Ibid, p. 2.
[155] USSBS, *Report 43*, p. 75.
[156] LASA, I 525, No. A 3005.
[157] LASA, I 525, No. A 3005.
[158] LASA, I 525, No. A 3005.
[159] USSBS, *Oil division*, Figures 22, 23, and 24.
[160] USSBS, *Oil division*, p. 2.

Figure 1
German aviation fuel production, consumption and stock levels 1940 – 1945
(Source: USSBS Oil Division Final Report, Figure 22)



German pilot training ceased in September 1944 as fuel stocks were almost exhausted which curtailed the ability of the Luftwaffe to benefit from the continuing high production of fighter aircraft.[161] General Guderian, promoted to Chief of the German General Staff in July 1944, commented that the final destruction of the synthetic fuel plants by allied air attacks during 13-15 January 1945 was a particularly severe blow and forced Germany to totally rely on the minor Austrian and Hungarian oilfields.[162]

In addition to the reduction in synthetic fuel production the USAAF and RAF attacks on Leuna and Oppau also reduced the production of nitrogen and methanol, which were key ingredients in the manufacture of high explosives, and which led to widespread ammunition shortages by early 1945. Total monthly nitrogen production decreased by 94% from 82 KT in May 1944 to 5 KT in February 1945.[163] The repeated attacks on Leuna also significantly reduced the supply of raw materials to Schkopau for the production of Buna. Total monthly

[161] Ibid, p. 2.
[162] Heinz Guderian, *Panzer leader* (1952, Translation London 1974), p. 352, p. 417.
[163] USSBS, *Oil division*, Figure 5.

synthetic rubber production decreased by 85% from 13 KT in March 1944 to 2 KT in December 1944.[164]

Between 12 May 1944 and 4 April 1945, the USAAF and RAF attacked Leuna on twenty-two occasions with over 6,600 aircraft sorties which dropped over 85,000 bombs weighing 16,657 tonnes.[165] The initial attack by 232 aircraft on 12 May 1944 resulted in the immediate shutdown of all Leuna production. Despite the second attack by fifty-nine aircraft on 28 May production resumed in early June and reached 75% of normal production by the time of the third attack by forty-five aircraft on 7 July when production again stopped. During the following nine months Leuna would restart production on six further occasions and undergo nineteen further bombing attacks.[166]

As the attacks continued, the length of the production stoppages increased, and the maximum production level achieved before the subsequent bombing attack was reduced to 20–30% of normal. During the period May 1944 – April 1945 the average daily production of Leuna was 9-10% of the average in the months preceding the initial attack. Despite the persistent attacks the plant management believed that they could return to 70% of normal production within six to nine months if the attacks ceased, and that this recovery could be achieved without the need for external supply of machinery and equipment.[167]

The massive and repeated aerial attacks on Leuna did achieve the USAAF's objective to eliminate Leuna as a major production unit for the German war economy. However the very high level of resources required to achieve the objective was a concern to the authors of the USSBS reports, 'tremendous bombing tonnages had to be flown from England in order to hit the vital parts of plants with a relatively small tonnage'.[168] The very high level of resources expended was primarily due to the interaction between the USAAF bombing practices, the force's payloads and equipment, and the nature of Leuna and its defences.

The Leuna plant management kept very accurate records of the number of bombs which fell within the plant boundaries, the number and type of bombs that failed to explode, and the damage resulting from those bombs which detonated within the plant boundaries. These records later allowed the USSBS to carry out a very detailed assessment of the effectiveness of the USAAF and RAF attacks on Leuna.

Based on the German records 1,239 tonnes of bombs, 8.5% of total, released over the Leuna area exploded within the boundaries of the plant.[169] The remaining 15,418 tonnes of bombs landed outside the plant boundaries or failed to explode within the plant. The major contributory factor was the inherent inaccuracy of horizontal bombing using unguided free fall bombs. The USAAF attacks were typically carried out from altitudes between 7,100 m and 8,200 m to minimise the effect of anti-aircraft fire on the bombers. Bombs released at an altitude of 7,650 m at a speed of 360 kph fall for 28 seconds and strike the ground 2,800 m in

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[164] Ibid, Figure 52.
[165] USSBS, *Report 43*, pp. 8-14.
[166] USSBS, *Oil division*, Figure 100.
[167] USSBS, *Report 43*, pp.1-2.
[168] USSBS, *Oil division*, p. 4.
[169] USSBS, *Report 43*, pp. 8-14, p.224, p. 226.

advance of the release point.[170] If the release is delayed by one second the bomb strikes the ground a further 100 m from the intended impact point.

The inaccuracy inherent in the flight of an individual bomb was amplified by the USAAF practice whereby the bombers approached the target in a defensive formation of typically thirty-six or fifty-four aircraft. The formation was designed to maximise the defensive power of the bombers' machine guns against attacks by German fighters. A fifty-four aircraft formation was 2.1 km in width, 0.5 km in depth and 0.8 km in height. All aircraft in the formation released their bombs once the leading aircraft released its bombs. Therefore, it was physically impossible for all USAAF bombers in a formation to attack the same precise location on the ground. Instead the bombs released almost simultaneously by the formation struck the ground within an approximate rectangle 2.1 km by 0.5 km.[171] Effectively the USAAF attacks took the form of area bombing of large industrial targets, and not of precision attacks on selected industrial equipment as originally envisaged by USAAF doctrine. RAF bombing practice differed from USAAF practice as each RAF bomber made an individual approach to the target in night-time darkness and each bombardier independently aimed the aircraft's bombs.[172]

The leading USAAF bombardiers required very good visibility of the target in order to achieve acceptable levels of bombing accuracy for the entire formation. The first and second USAAF attacks on 12 and 28 May were carried out in clear weather with ground haze, when Leuna was not protected by a smoke screen, used visual bomb aiming techniques and were comparatively very effective. Leuna was protected by a smoke screen during the third attack on 7 July and many of the later attacks.[173] In certain weather conditions the upper portions of the thirteen chimneys of the Leuna power stations which were 150 m in height penetrated through the smoke screen and provided a landmark for the USAAF aircrews.[174]

The combination of the smoke screen and increased cloud cover during the autumn and winter significantly reduced the visibility of Leuna from an altitude of 7,500 m and led to the use of inaccurate 'blind bombing' techniques by the USAAF. The 'blind bombing' techniques used H2S radar equipment, originally developed by the RAF for use in night bombing, to locate the target.[175] Bombing accuracy decreased from 29% using visual observation methods to 5% using blind bombing techniques.

The importance of visibility to bombing accuracy is highlighted by the experience of the tenth to thirteenth USAAF attacks by a total of 1,181 aircraft between 28 September and 8 November which took place in total overcast conditions, with a smoke screen, used blind bombing techniques and released over 13,000 bombs (2,562 tonnes). During these four attacks only 109 bombs (0.8%) fell within the perimeter of Leuna.[176] The difficulty of accurate bombing during conditions of poor visibility was reinforced by the Luftwaffe's development

[170] Author's calculation.
[171] Seyer, *The plan put into practice*, p. 27.
[172] USSBS, *Oil division*, p. 125.
[173] USSBS, *Leuna appendix 2*, pp. 7-10.
[174] USSBS, *Report 43*, p. 5.
[175] Birkey, *Aiming for strategic effect,* pp.92-93.
[176] USSBS, *Report 43*, p. 226.

of decoy ground structure targets which attracted 4,550 bombs from the first seven USAAF attacks, equivalent to the 4,727 bombs which landed within the plant during these attacks.[177]

These difficulties were amplified by the effects of the intense anti-aircraft fire over Leuna. The number of anti-aircraft guns protecting the plant increased from 50-60 medium calibre guns in May to 550 guns in November, of which 25% were the largest 128 mm heavy calibre and the remainder 88 – 108 mm medium calibre.[178] The USAAF bombers typically approached Leuna from the south west, between 1100 and 1300 hours, at an altitude between 7,100 to 8,200 m, and at a speed of 360 kph. The German anti-aircraft batteries were centrally controlled and concentrated their fire in a barrage on the release point used by the leading bombers, i.e. typically 2.8 km south west of the plant.[179] The effective ceiling of the German anti-aircraft batteries was 10,000 – 14,800 m which required the USAAF bombers to fly through the flak barrage.[180] The USSBS authors' description is concise 'Leuna was the largest of the synthetic plants and protected by a highly effective smoke screen and the heaviest flak concentration in Europe. Air crews viewed a mission to Leuna as the most dangerous and difficult assignment of the air war', (Image 3 following page).[181]

Image 3: B-17 Flying Fortress bombers fly through antiaircraft artillery fire over Merseberg, Germany, in November 1944.
Photo By: Air Force photo VIRIN: 441102-F-ZZ999-037.JPG
https://media.defense.gov/2020/Oct/30/2002526798/-1/-1/0/441102-F-ZZ999-037.JPG

[177] USSBS, *Oil division*, p. 135.
[178] USSBS, *Leuna appendix 2*, pp. 11-13.
[179] Ibid, p. 11.
[180] Seyer, *The plan put into practice*, p. 56.
[181] USSBS, *Summary report (European war)* (Washington, 1945), p. 9.

The anti-aircraft batteries surrounding Leuna were supported by the batteries protecting the nearby Boehlen and Zeitz synthetic fuel plants, and by the batteries protecting the aircraft manufacturing plants in the Leipzig area. Depending on the route flown by the USAAF these batteries could engage the bombers on the approach to, or withdrawal from, Leuna.[182]

The USAAF lost 119 bombers in the attacks on Leuna, equivalent to 2.3% of the total bombing aircraft engaged, of which 75% where shot down by anti-aircraft fire.[183] USAAF bomber losses peaked at twenty-seven aircraft, 6.4% of total, during the seventh, eighth and ninth attacks between 24 August and 13 September 1944. The twelfth and sixteenth attacks on 2 and 30 November also experienced losses of forty-one aircraft, 5% of total. The USAAF losses during the other thirteen attacks were relatively low, fifty-one aircraft, or 1.3% of total. RAF losses in night attacks during December 1944 – April 1945 were also very low at eight aircraft or 0.6% of total.[184] During the later period the ammunition supply to all German anti-aircraft defences were significantly reduced, primarily due to the bombing of Leuna and the other nitrogen production plants, and which significantly reduced the intensity of the barrage.[185] In addition the aviation fuel shortages restricted the ability of the Luftwaffe fighters to attack the allied bombers.

The effectiveness of the relatively small proportion of bombs which fell within the perimeter of Leuna was further reduced by the high incidence of bombs which failed to explode. Based on German records a total of 1,387 unexploded bombs were found within the perimeter of Leuna, equivalent to 16% of the total number of bombs which fell inside the perimeter during the twenty-two attacks.[186] German records for the first nine attacks (12 May to 13 September) indicate that the defect was concentrated in the lightest (100 lb) and heaviest bombs (1,000 lb) released by the USAAF. Later investigation by the USSBS indicated that in most cases the cause of the problem with these bombs was that they had landed flat and their fuse was not triggered, often due to the loss of the tail fin through collision in flight. Unexploded bombs lacking tail fins continue to be unearthed during excavations at Leuna (Image 4).

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182 Bowden, *Merseburg: blood, flak and oil*, p. 9.
183 Ibid, p. 9.
184 USSBS, *Report 43*, pp. 8-14.
185 USSBS, *Oil division*, p. 3.
186 USSBS, *Report 43*, p. 224.

Image 4: Unexploded bomb without tail fin unearthed during excavations on Leuna site, November 2021
Source: Infraleuna

The USAAF selection of bomb types and sizes was heavily influenced by the size and layout of the Leuna plant. The total plant area was 328 hectares of which 23% was occupied by buildings, plant and equipment.[187] 'Open space' therefore represented 77% of the Leuna area, which was occupied by roads, railways, pipe racks, cable runs and also empty space. Due to the inherent inaccuracies in target identification and bomb aiming the USAAF therefore attacked Leuna with relatively light 500 lb bombs which were used in seventeen of the eighteen USAAF attacks.[188] The next most common bomb size was the lighter 250 lb bomb which was used in nine attacks. The heaviest bomb used by the USAAF was 1,000 lb which was used in two attacks, while the lightest 100 lb bomb was used in four attacks.

The USAAF employed an 'area bombing' approach whereby it attacked Leuna with a large number of relatively light high explosive bombs intended to damage utilities and thereby stop production.[189] The high explosive bombs also created breaks in pipelines and other equipment as a result of exploding bomb fragments which led to outbreaks of fire in certain cases.[190] The USSBS carried out a detailed examination of the bomb damage to the Leuna synthetic fuel production area which indicated that 81% of the damage to buildings

[187] USSBS, *Report 43*, p. 3, p.10.
[188] Ibid, pp. 8-14.
[189] USSBS, *Oil division*, p. 6.
[190] USSBS, *Report 43*, p. 220.

and tanks resulted from high explosive blasts, 7% due to fire and 12% due to a mixture of high explosive and fire.[191] The 250 lb and 500 lb bombs were too light to damage the large items of production equipment employed in Leuna, which were often well protected by blast walls and other defences (see Part Three). In contrast the RAF during its attacks from December 1944 to April 1945 used heavier bombs of up to 12,000 lb which could damage production equipment.[192]

Over 90% of the bombs released by the USAAF over Leuna were fitted with fuses with delays of 0.025 seconds and 0.1 seconds. The majority of USAAF bombs therefore penetrated into the ground before exploding with the consequence that much explosive energy was absorbed in the creation of a crater, and reduced energy was transmitted as blast.[193] In contrast the RAF used instantaneous fuses with the 2,000 lb and heavier bombs which maximised the blast effect at ground level and the damage to equipment.[194]

High explosive bombs represented 98.5% of the total bomb weight released over Leuna, incendiary bombs 1.4% and fragmentation bombs 0.1%. The USAAF used incendiary bombs in one attack and the RAF in two attacks, both without major success. The lack of success for incendiary bombing attacks is partially due to the wide spacing of buildings and equipment within the plant as discussed above. However, a further contributory factor was the relatively short duration of the USAAF attacks, on average twenty minutes.[195] The short attack duration allowed the German defence personnel to promptly leave the air raid shelters and attend to incendiary bombs and supress incipient fires before the fires could take hold (see Part Three). A combination of longer raid durations, delayed action high explosive bombs dropped by the first wave and timed incendiaries dropped by a second wave could have reduced the ability of the German personnel to supress fires before they could take hold.[196]

The USAAF and RAF also used seventeen different aiming points for the attacks on Leuna, with some attacks using five different points.[197] This policy distributed the bombing effort widely across the large site to the benefit of the German defence organisation. Several members of the USSBS team who visited Leuna in April-May 1945 were petrochemical industry engineers who believed that the USAAF should have concentrated all bombing attacks on the critical gas generation plant which occupied 12 hectares.[198] The USAAF selection of aiming points was handicapped by its lack of detailed understanding of the Leuna production process and the failure to identify the critical process equipment.

The attacks on Leuna were effective, in that the production was stopped for increasingly long periods. However, the attacks were inefficient in that very large tonnages of bombs had to be transported from the UK to Leuna in order to create a temporary cessation in production.

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[191] USSBS, *Report 43*, p. 3, p. 79.
[192] USSBS, *Oil division*, p. 6.
[193] USSBS, *Report 43*, p. 15.
[194] Ibid, pp. 13-14.
[195] USSBS, *Report 43*, pp. 8-14.
[196] USSBS, *Oil division*, pp. 6-8.
[197] USSBS, *Report 43*, aiming points table and plans.
[198] USSBS, *Oil division*, pp. 6-9.

The inefficiency of the USAAF attacks on Leuna was due to the inter-relationships between the USAAF equipment and operational practices, the nature of the Leuna plant and the strength of the German defence. The inherent inaccuracy of horizontal bombing was amplified by smoke screens and cloud cover from late July which significantly reduced the target visibility and frequently lead to the use of blind bombing by the USAAF. The strength of the German fighter force compelled the USAAF bombers to maintain a large defensive formation whilst bombing and did not permit bombers to leave formation, and to individually aim and release bombs as originally anticipated with precision bombing.

Bombers making sequential individual approaches would also have become targets for all anti-aircraft batteries. The strength of the anti-aircraft fire in the Leuna region forced the USAAF commanders to minimise the duration of the bombers' exposure to the barrage, leading to concentrated short duration raids. Sequential bombing waves with high explosive and incendiary bombs widely separated in time would each have potentially faced the full strength of the barrage. The wide dispersion of the production equipment across the large Leuna site ensured that direct hits on equipment by bombs released by formations in conditions of poor visibility would be purely random events.

Given these interrelated constraints the approach taken by the USAAF commanders during the attacks on Leuna had merit and were a valid response to the problems of plant size, low target visibility, defence strength and limited bomb size carrying capacity. During the eighteen assaults the USAAF aircraft released over 31,000 250 lb bombs and 30,000 500 lb bombs, of which approximately 10% landed within the Leuna plant and primarily damaged the utilities.[199] The use of 0.025 and 0.1 second fuses increased the damage to underground electrical cables and water mains, whilst reducing the damage to equipment on the surface. The cumulative effect of the repeated damage to the utilities eventually eroded the plant management's ability to restore production, which is explored in the following section.

Germany's development of the synthetic fuel industry in the late 1930s provided the German armed forces with critical strategic autonomy during the period of German victories in 1939-41. Despite further expansion in 1942-44 the German synthetic fuel industry, in combination with the relatively small scale European crude oil resources, was too small to enable Germany to sustain a prolonged conflict with global competitors with superior resources. Intelligence failures prevented the USAAF and RAF from exploiting Germany's weaker fuel position until May 1944. A lack of understanding and intelligence failures also ensured that the USAAF and RAF did not appreciate the strong linkage between the German explosives, synthetic fuel and synthetic rubber industries and how a concentrated assault on a small number of plants could seriously affect the German war economy. Once the USAAF attacks on the synthetic fuel plants commenced, Germany devoted the highest priority to the defence of these plants and the related industries which impeded, but did not prevent, further attacks. The operating practices adopted by the USAAF for the sustained attacks on Leuna were not efficient, but ultimately were effective.

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[199] USSBS, *Report 43*, pp. 8-15.

Part Three. The German Senior Leadership and Leuna Management Responses to the USAAF and RAF Bombing and the Steps Taken to Restore Production.

The original selection of the Leuna area as the location for a large-scale artificial nitrogen plant in 1916 was partially driven by the desire to minimise the risk of air attack. Following the Nazi assumption of power in 1933 the perceived risk of air attack increased and construction of air raid shelters for the Leuna workforce commenced in 1934. Construction of air raid shelters continued steadily through the 1930s and the total shelter capacity reached 6,000 persons by 1939. The initial RAF bomber offensive against the German oil industry in 1940 stimulated further construction and shelter capacity increased to 10,500 persons by December 1940. Air raid shelter construction was suspended from early 1941 to May 1944 due to the cessation of allied air attacks.[200]

Between March and July 1943, the RAF carried out a sustained night bombing campaign against cities and industrial plants in the Ruhr region of western Germany. The large Krupp steel and armaments plant in Essen was a frequent target of these attacks.[201] Speer visited the Krupp plant during this period and arranged for a detailed report on the effects of the bombing to be circulated to other large-scale industrial plants. The report outlined the organisational changes and physical preparations that plant management should undertake to minimise the damage from expected future bombings and to support a prompt recovery of production following an attack. Leuna received a copy of this report in early 1943.[202]

Based on this report Leuna plant management created a large-scale air raid protection organisation which divided the plant into six major process groups, each of which included fire watchmen, dedicated teams for gas detection, fire protection, first aid, building repair, pipe repair, cable repair and firefighting. The plant was also divided into 143 patrol districts each of which had six to twenty fire wardens. Large stocks of firefighting materials, first aid supplies, and gas protection equipment were prepared, and reservoirs of firefighting water were created within the plant. Detailed operational procedures were also developed, and responsibilities assigned.[203]

The Office of the Four-Year Plan had overall responsibility for the German chemical industry and for the organisation of the protection of plants against air attack. In December 1943 the Office circulated a booklet containing instructions, pictures and drawings to chemical plants which detailed the best practice to protect equipment, with particular emphasis on the protection of critical or bottleneck equipment.[204] The booklet illustrated a range of equipment protection techniques including the use of blast proof walls to isolate critical adjacent distillation columns (Image 5).

[200] USSBS, *Leuna* a*ppendix 2*, p. 2.
[201] Richard Worrall, *The Ruhr 1943* (London 2021), pp. 7-10.
[202] USSBS, *Leuna appendix 2*, p. 1.
[203] Ibid, pp. 2-7.
[204] LASA, I 525, No. A 872, letter 9 December 1943.

Image 5

Blast proof wall installed between distillation columns

Source: LASA, I 572, No. A 872.

Guidance for the protection of chemical plants against air raid attacks 1944.

(Office of Four-Year Plan,

9 December 1943)

Additional protection was provided by prefabricated shelters, sometimes described as dog houses, to cover large compressors and similar equipment and by the protection of large tanks using reinforced concrete blocks (Image 6).[205]

Image 6

Storage tank being covered with concrete blocks

Source: LASA, I 525, No. A 872. Guidance for the protection of chemical plants against air raid attacks 1944.

(Office of Four-Year Plan,

9 December 1943)

Leuna installed many of these protective structures during 1944 which were to prove effective against USAAF attacks from May.[206]

Between the final RAF night attack on 16 December 1940 and the first USAAF daylight attack on 12 May 1944 the Leuna plant was undisturbed by air attack for 1,243 days. Due to this long interval of calm the first USAAF attack on 12 May 1944 came as a shock to the Leuna management and workforce, despite their detailed preparations. The first attack was very effective as it was conducted in clear weather using visual bombing techniques, in the absence

[205] LASA, I 525, No. A 872, *Documents for the protection of chemical plants against air raids 1944*.
[206] USSBS, *Oil division*, p. 135.

of a smoke screen, opposed by relatively weak anti-aircraft defences and achieved surprise. Based on German records 1,263 bombs (95 tonnes) exploded in the plant leading to a total cessation of production. The bombs created more than fifty breaks in the water mains, over 100 breaks in both the steam lines and power cables, started fifteen major fires and resulted in RM (Reichsmark) 45.8 m of damage.[207]

The effect of the USAAF attacks of 12 May 1944 on Leuna and the other synthetic fuel plants on the German leadership was immediate. On 13 May Speer travelled to Leuna to personally inspect the damage and to discuss the situation with the senior management. Speer later wrote that 'we groped our way through a tangle of broken and twisted pipe systems', (Image 7).[208]

Image 7: Extensive damage to pipe racks in Leuna following air raid.
Source: LASA, I 525, No. A 1509

Leuna, and the other synthetic fuel plants, had proven to be extremely vulnerable to bombing and Speer concluded that production could not resume for many weeks. Speer informed Hitler in person of the gravity of the situation on 19 May.[209]

On 23 May Speer, Dr Krauch, Dr Butefisch and two other senior industrialists, met with Hitler, Goering, Keitel (Army Commander) and Milch (Luftwaffe Procurement Director) to discuss the synthetic fuel crisis. During the meeting Hitler asked Dr Krauch, Dr Butefisch and the other industrialists for their opinions of the situation. Speer reported that 'speaking as sober, statistically minded businessmen, they all testified to the hopelessness of the situation

[207] Ibid, Table 39-1
[208] Speer, *Inside the Third Reich*, p. 468.
[209] Speer, *Inside the Third Reich*, p. 469.

if the raids were continued systematically'.[210] The industrialists maintained their pessimistic view despite Goering's optimism and Keitel's highlighting of the national fuel reserve of 570 KT.[211] Speer described that 'they held fast to their verdicts, supporting them by data and comparative figures'. Following a detailed discussion Hitler summarised the situation as follows, 'the fuel, buna rubber and nitrogen plants represent a particularly sensitive point for the conduct of the war, since vital materials for armaments are manufactured in a small number of plants'.[212]

The USAAF carried out a second effective attack on Leuna on 28 May in clear weather, using visual bombing techniques in the absence of a smoke screen and opposed by relatively light anti-aircraft defences. Based on German records 511 bombs (37 tonnes) exploded in the plant which created 150 major breaks in the utility piping, over 110 breaks in the power cables, severely damaged the telephone exchange and in total resulted in RM 9.9 m of damage.[213] Production had not resumed following the first attack on 12 May and no major fires took hold.

Due to the fast developing crisis in the synthetic fuel industry, Speer persuaded Hitler to appoint Edmund Geilenberg to a new role with total authority to repair the synthetic fuel plants and restore production.[214] Geilenberg was appointed as the General Commissioner for Immediate Measures on 30 May.[215] On 3 June he travelled to Leuna where he inspected the damage arising from the USAAF attacks of 12 and 28 May which had struck the plant with a total of 1,774 bombs, (132 tonnes).[216]

The first attack had resulted in 103 fatalities amongst the workforce and 348 injured. The second attack on 28 May resulted in a further forty fatalities and seventy-seven injured. The combined fatalities and injuries in the first and second attacks represented 54% and 62% of total fatalities and injuries during all twenty-two attacks and indicates the initial low level of preparedness of Leuna to air attack.[217] The attacks on 12 and 28 May were reported to have resulted in serious disorder amongst the workforce many of whom fled the plant and sheltered in basement cellars.[218] The capacity of the existing air raid shelters, 11,500 persons, was inadequate to protect the entire workforce at shift change, some 26,500 persons. This lack of shelter capacity contributed to the disorder.[219]

Following a site tour Geilenberg held a meeting with the senior management to assess the damage, organise the construction of additional air raid shelters for the workforce, and develop a plan to enable the plant to achieve 100% of previous normal production by 30 September 1944.[220] The meeting on 3 June considered twenty-eight major discussion items which included eighty major breaks in the underground water mains, 108 breaks in electrical cables, 450 breaks in the rail network, damage to 300 electrical motors, fifteen major breaks

[210] Ibid, pp. 470-471.
[211] USSBS, *Oil division*, Figure 22
[212] Speer, *Inside the Third Reich*, p. 470.
[213] USSBS, *Oil division*, Table 39-1.
[214] Speer, *Inside the Third Reich*, p. 474.
[215] USSBS, *Oil division*, p. 29.
[216] USSBS, *Report 43*, pp. 8-14.
[217] Leuna Archives, A 1369.
[218] USSBS, *Leuna appendix 2*, p. 7.
[219] Ibid, p. 2.
[220] LASA, I 525, No. A 874, *Minutes of meeting 3 June 1944,* pp. 1-5. translated

in pipe racks and extensive damage to gas generators, gas compressors, circulating pumps, boilers and other equipment and facilities. The minutes of the meeting on 3 June were copied to Speer, Geilenberg, Krauch, Butefisch, other senior managers and local political figures. Following the meeting Dr Strombeck, the Leuna plant director, was to maintain direct contact by teleprinter with Geilenberg to advise him of the progress of the work.[221]

The immediate priority was to increase the capacity of the air raid shelters to ensure that the entire workforce could be protected at times of shift change. To this end, Leuna was to arrange for the construction of large air raid shelters with a capacity for 15,000 persons in five phases with planned completion from 31 July to 30 November. During early June the Leuna engineering department developed plans for the construction of twenty-six air raid shelters with a total capacity of 15,000 persons.[222] Organisation Todt assumed responsibility for the physical construction of the air raid shelters on 15 June and construction commenced immediately.[223]

The cascades of lightweight bombs released by the USAAF caused extensive damage to the water pipelines, gas pipelines, steam pipelines, sewers, electrical cables, telephone and rail networks, and lead to the immediate shut down of production (Image 7). In contrast the lightweight bombs caused limited damage to buildings and heavy equipment (Image 8). Following the air attacks on 12 and 28 May the Leuna workforce had to repair 94% of the damage to the utilities before production could recommence, while only 8% of the damage to buildings had to be repaired.[224]

Image 8: Limited damage to buildings and equipment in Leuna following air raid (Building Me 5 13 May 1944). Source: LASA, I 525, No. A 1509

[221] LASA, I 525, No. A 874, *Minutes of meeting 3 June 1944,* p. 5. translated
[222] LASA, I 525, Nos. A 874, BZ 173c, BZ 191.
[223] LASA, I 525, No. A 874, *Organisation Todt memo re bunker construction 15 June 1944,* translated
[224] USSBS, *Oil division*, p. 3.

The repairs in early June were intended to allow Leuna to resume production at 10% of normal output by 14 June. Further ongoing repairs were expected to enable the plant to reach 40% of normal output by 30 June and ultimately 100% by 30 September.[225] The meeting recognised that achievement of the recovery schedule was dependent on the availability of labour. Therefore, arrangements were made for the immediate transfer of 1,000 German skilled workers to Leuna from other plants, and for their accommodation in Merseburg. In addition, a further 7,000 manual workers (forced labour) were transferred to Leuna and the local Gauleiter (regional Nazi party leader) arranged suitable accommodation facilities for them.[226]

The recovery plan necessarily excluded the effects of further USAAF attacks. By 7 July production had recovered as planned to 70% of normal output when a further small attack occurred which resulted in a short shutdown. Production recovered to 55% by 20 July when a larger attack occurred. Production again stopped for several days and recovered to 35% by late July.

The USAAF made two major attacks on 28 and 29 July employing a total of 1,199 aircraft which achieved surprise by approaching from the north and north west between 0930 and 0955, and not later in the day from the south and south west as during the first four attacks.[227] The attacks of 28 and 29 July struck Leuna with 1,470 bombs (264 tonnes) using blind bombing techniques despite the presence of the smoke screen and the reinforced anti-aircraft defences.[228] The bombs created over 400 major breaks in the water lines and over 400 breaks in the steam pipelines. Major damage was also caused to the electrical cables and substations and the coal conveyors to the power station were immobilised for periods between six and fourteen weeks. The bombs also damaged over 300 housing units outside the perimeter of Leuna.[229] These attacks resulted in widespread damage valued at RM 66.5 m, equivalent to 24% of the total damage sustained by Leuna during the bombing campaign and the highest of any attack.[230]

Due to the effects of these successive large attacks Leuna production ceased for seventy days until mid-October which was the longest continuous shutdown period between 12 May 1944 and 30 April 1945.[231] The effects of the attacks of 28-29 July represented a major deterioration in the ability of Leuna to resume production. Prior to 28 July Leuna could resume 25% of normal production within three to five days following an attack and 50% within six to ten days. Following the 29 July attack the recovery period was significantly increased to between 27 to 40 days to achieve 25% of normal production and to between 75 to 103 days to achieve 50% of normal production. The underlying cause was the cumulative effect of the damage to the utility systems which is discussed in detail in the following pages.[232]

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[225] LASA, I 525, No. A 874, *Minutes of meeting 3 June 1944,* translated.
[226] Ibid.
[227] USSBS, *Report 43*, pp. 8-9.
[228] Ibid, pp. 8-14, p. 17.
[229] LASA, I 525, No. A 1369*, Air Raid 5 and 6.*
[230] USSBS, *Oil division*, Table 39-1.
[231] Ibid, Figure 100.
[232] USSBS, *Report 43*, p. 218.

During the period from May 1944 to April 1945 production was resumed on eight different occasions once sufficient utility systems were restored. Production had recovered to 20% in March 1945 when the twenty-second and final attack by the RAF on 3 April 1945 led to the ninth and final shutdown.[233]

The highest casualties were incurred in the first attack on 12 May which resulted in the death of 103 personnel within Leuna, twenty-three persons outside the plant and injured a further 368 persons.[234] The attacks of 28 May, 20 July and 28 and 29 July resulted in a further 127 deaths and injured 326 persons. Non-German forced labourers represented most of the casualties in the attacks of 28 and 29 July suffering forty-one deaths (72% of total) and 149 injuries (86% of total). Casualties in Leuna from bombing attacks were significantly reduced from August due to the improved use of smoke screens, strengthened anti-aircraft defences and increased air raid shelter capacity. Total Leuna casualties during the fifteen attacks from 24 August 1944 to 14 January 1945 were eighty-one deaths (30% of total) and seventy-five injured (11% of total) while the USAAF released 62% of all bombs during this period.[235]

Table 2 presents a summary of the key details of the twenty-one air attacks from 12 May 1944 to 14 January 1945 for which the Leuna management reported the value of the estimated damage and casualties. The effectiveness of the individual bombing attacks is measured by the damage ratio which compares the value of reported damage in RM ’000 with the tonnage of bombs that exploded within the perimeter of Leuna during the same attack. The damage ratio peaked in the first attack on 12 May at RM 481 K / tonne while the damage ratio in all subsequent attacks varied in a range RM 78 – 266 K / tonne.[236] The first attack achieved the maximum damage ratio as it was an effective surprise attack on a previously undamaged environment which also started large fires in several plant areas. In all subsequent attacks the element of surprise was reduced, large fires did not take hold and some of the new explosions struck previously damaged areas, all of which served to reduce the damage ratio.[237]

[233] USSBS, *Oil division*, p. 91.
[234] LASA, I 525, No. A 1369.
[235] Ibid.
[236] USSBS, *Report 43*, pp. 8-14, p. 17, pp. 223-226.
[237] Ibid, p. 212.

TABLE 2

LEUNA

Air attacks: 12 May 1944 - 14 January 1945

Details of Air Attacks, Estimated Damage and Casualties
(Sources: Bombing Data; USSBS Report 43, Pages 8-14; 223-226;
Estimated Damage; USSBS Report 43, Page 17;
Casualties; LASA, I 525, No. A 1369)

Bombing Data									(Note 1)	Estimated Damage (Note 2)			(Note 3)	Casualties (Leuna)	
Attack Number	Attack Date	Air Force	Bomb Sighting	Aircraft Total	Losses %	Bombs Total	Bombs Tonnes	% Bombs in plant	Effective Bombs (tns)	Buildings RM m	Equipment RM m	Total RM m	Damage Ratio	Killed	Injured
1	12-May-44	USAAF 8	P.F.F & Visual	232	0%	6,509	490	23%	95	10.8	35.0	45.8	481	103	348
2	28-May-44	USAAF 8	Visual	59	0%	1,651	120	36%	37	2.6	7.3	9.9	266	40	77
3	07-Jul-44	USAAF 8	Visual	45	4%	1,383	85	43%	28	1.8	4.1	5.9	209		5
4	20-Jul-44	USAAF 8	Visual	148	1%	2,291	327	26%	78	5.1	9.0	14.1	181	10	29
5	28-Jul-44	USAAF 8	P.F.F. (Blind)	645	2%	6,334	1,437	14%	194	22.0	44.4	66.3	252	57	174
6	29-Jul-44	USAAF 8	P.F.F & Visual	554	2%	10,887	1,235	6%	70						
7	24-Aug-44	USAAF 8	Visual	191	6%	2,831	409	20%	69	4.5	12.4	16.9	246	2	6
8	11-Sep-44	USAAF 8	P.F.F. (Blind)	96	10%	957	217	7%	14	4.7	8.4	13.1	147	7	21
9	13-Sep-44	USAAF 8	Visual	133	5%	1,040	299	29%	75						
10	28-Sep-44	USAAF 8	P.F.F. (Blind)	303	0%	1,955	657	5%	30	1.0	2.2	3.2	107		2
11	07-Oct-44	USAAF 8	P.F.F. (Blind)	114	2%	1,112	252	0%	1	0.0	0.0	0.1	78		
12	02-Nov-44	USAAF 8	P.F.F. (Blind)	574	5%	8,000	1,201	0%	1	0.1	0.0	0.1	129	3	7
13	08-Nov-44	USAAF 8	P.F.F. (Blind)	190	1%	1,990	451	0%	0	0.0	0.0	0.0	0		
14	21-Nov-44	USAAF 8	P.F.F. (Blind)	210	4%	2,271	460	12%	44	1.9	6.5	8.4	191		
15	25-Nov-44	USAAF 8	P.F.F. (Blind)	672	1%	6,986	1,584	4%	50	1.8	3.4	5.1	103	2	4
16	30-Nov-44	USAAF 8	P.F.F & Visual	250	6%	4,761	540	8%	35	2.2	4.1	6.2	178	2	2
17	06-Dec-44	USAAF 8	P.F.F. (Blind)	472	1%	8,321	947	5%	42	9.2	16.4	25.6	221	24	4
18	06/07-Dec-44	RAF	Pathfinder	511	1%	3,544	1,861	4%	74						
19	12-Dec-44	USAAF 8	P.F.F. (Blind)	348	1%	3,938	893	2%	16	0.5	1.5	2.0	125	3	
20, 21	14-Jan-45	RAF	Pathfinder	560	0%	6,107	2,207	15%	233	20.3	37.5	57.8	248	13	13
Total				6,307	1.9%	82,868	15,673	16%	1,185	88.5	192.1	280.6	237	266	692

Note 1: Effective bombs = Total weight of bombs in tonnes which exploded within perimeter of Leuna

Note 2: Estimated damage = value of damage to equipment and buildings estimated by Leuna management immediately following bombing assault; Units = RM m

Note 3: Damage ratio = (Leuna management estimated damage / Effective tonnes of bombs); Units = RM'000 / Tonne

From early July 1944 the Leuna management reviewed the damage resulting from the repeated attacks and the progress of ongoing repair work on a weekly basis. The archives include twenty-two weekly damage reports for the period from 9 July to 9 December 1944. These reports include details of damage and repair activities on a consistent basis under thirteen major headings; water channels, lighting, electrical cables, debris removal from roadways, pipe bursts, building repairs, roof repairs, removal and reconstruction of heavily damaged buildings, air raid shelter construction, window glazing, carpentry and railway track repair. These reports summarise the manpower assigned to each major activity, the progress achieved, and the damage from successive attacks. The allocation of manpower between these activities provide a detailed insight into the priorities of Leuna management during July to December 1944.[238] The average total weekly manpower engaged in damage repair and air raid shelter construction during this period was 7,520 persons (Table 3).

LEUNA **TABLE 3**

Air Raid Damage Repair and Shelter Construction: Weekly Manpower

9 July to 9 December 1944

(Source: LASA, I 525, No. A 399 Weekly Reports)

Activity Description	Total Weekly Manpower			% Total Weekly Manpower		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Utilities Repairs	1,870	2,857	1,171	25%	36%	18%
Building Repairs	1,630	2,314	800	22%	32%	11%
Air Raid Shelter Construction	1,411	2,047	768	19%	25%	10%
Carpentry and Other Trades	1,065	1,347	679	14%	20%	10%
Damage Removal	1,005	1,583	672	13%	21%	9%
Railway Repairs	539	1,089	359	7%	16%	5%
Total	7,520	8,205	6,592	100%		

The repair of the utilities was the largest single activity and typically engaged 1,870 persons which represented 25% of the total workforce. The manpower committed to the repair of utilities increased to 2,857 in early August (36% of total) immediately following the major attacks on 28 - 29 July. Building repair and air raid shelter construction were the second and third most important activities representing 22% and 19% of total average manpower. Railway repairs were typically less manpower intensive absorbing 7% of total. Railway repairs also increased to 16% of total manpower in early August immediately following the major attacks on 28 - 29 July, in a similar manner to utilities. The manpower allocated to air raid shelter construction varied from 10% to 25% of the total available and was assigned a lower priority than utility and railway repair.[239]

The key inputs to all production processes in Leuna were water, air and brown coal as discussed in Part One. Therefore, the first priority following a bombing attack was to restore the supply of water to the production process.[240] Water was taken from the nearby Saale river

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[238] Leuna Archives, A 399 Weekly reports 9 July to 9 December 1944.
[239]LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.
[240] USSBS, *Report 43*, p. 219.

by the pumping station at Daspig and pumped 2.5 kms to Leuna via five 1.2 m diameter cast-iron water mains. The underground water mains were vulnerable to damage both from direct hits from bombs and from the shock waves from exploding bombs which were transmitted through the water and damaged cast iron valves at distances over 100 m from the point of impact. The damaged water mains required immediate repair to enable production to restart. Many production units also required unimpeded access to the sewer system to dispose of wastewater. The underground sewer system was composed of brick and concrete panels and was also vulnerable to damage by bombs. The status of the water mains and sewer systems, and the progress of the repairs, was the first item of business in the weekly review of ongoing repair work.[241]

By mid-July the damage control organisation had repaired 69% of the forty-five breaks in the water systems sustained in the first three attacks. The attacks in late July, August and September created a further thirty-three breaks which reduced the completed repair rate to 51% in September. The damage control teams successfully repaired all damage to the water systems by 19 November. However, the major raids in late November created a further twenty-nine breaks which decreased the completed repair rate to 75% and the repair cycle recommenced.

The second priority was to resume the generation and transmission of electric power.[242] The initial task was the repair of the rail network and the coal handling equipment which transferred the brown coal to the power generation plants. In contrast the available capacity of the boilers and generators always exceeded the quantity of brown coal which could be delivered to the plant and conveyed as fuel to the power generation plants. Once electricity generation had resumed the subsequent bottleneck was the transmission of the power to the appropriate production units within the plant. The cascade of bombs damaged the underground transmission cables which required significant excavation before repairs could be undertaken. In addition to breaking the cables the bombs also weakened the cable insulation which led to failures in testing. Many long sections of electrical power transmission cables had to be excavated and replaced.[243]

By mid-July the damage control organisation had repaired 84% of the 16,000 metres of damaged cable systems sustained in the first three attacks. The attacks in late July damaged a further 7,000 metres, of which the majority was promptly repaired. Further attacks and failures in testing damaged 5,000 metres of cable during August–November and the major raids in late November and early December damaged another 1,200 metres. The cable repair rate increased from 84% in mid-July to 93% in mid-September and then stabilised.

The third major priority for repair was the water and gas transmission pipeline network which was primarily supported on pipe bridges four metres above the road surface (Image 7).[244] The pipeline network was directly damaged by bomb impacts and indirectly by steel fragments from bombs which exploded nearby and penetrated the walls of the pipelines.[245]. These penetrations allowed air to enter the gas pipelines and mix with the gases

[241] LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.
[242] USSBS, *Report 43*, p. 219.
[243] LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.
[244] USSBS, *Report 43*, p. 220.
[245] LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.

present to create an explosive mixture which frequently exploded leading to significant damage to the pipelines and destruction of the associated gasholders.[246]

By mid-July the damage control organisation had repaired 94% of the 368 pipe bursts sustained in the first three attacks. The attacks in late July created a further 772 pipe bursts and the completion rate decreased to 52%. Further attacks and failures in testing created a further 542 pipe bursts during August–November and the major raids in late November and early December created another 100 pipe bursts. The pipe burst repair rate decreased from 94% in mid-July to 47% in mid-September and recovered to 62% by December.

The three initial attacks in May and early July damaged 560 buildings which required an estimated 735,000 man-days to repair. The major fourth and fifth attacks in late July damaged a further 528 buildings and the later attacks in August–December damaged an additional 664 buildings. From late July the priority for building repair was assigned on average to 100 critical buildings, with the consequence that the remaining over 1,500 damaged buildings were not actively repaired. The total man-days expended on building repair increased slowly from 9% of the quantity required for complete repair in July, to 19% in December demonstrating that the repair of the utilities had a higher priority for the available manpower.[247]

The bomb damage to the roofs and walls of buildings partially exposed the heavy process equipment within the buildings to the elements (Image 8). However, the equipment was undamaged by the bombs and once the utilities were restored, could operate normally while the openings in the rooves and walls were covered by tarpaulins.[248]

The construction of air raid shelters had a high, but secondary priority, as manpower was allocated to the higher priorities of repair of the water network, transmission cables and pipe bursts in the immediate aftermath of air attacks. Despite these interruptions the air raid shelter construction programme proceeded rapidly and total capacity of 17,055 persons was achieved by 22 November.[249]

The attacks by the USAAF during the period 12 May to 12 December 1944 were primarily carried out using 100, 250 and 500 lb bombs which represented 95% of the total number of bombs released against Leuna, equivalent to 80% of total bomb weight released.[250] As discussed earlier these bombs were capable of damaging water mains, electrical cables, gas pipelines and other utilities and could lead to the shutdown of production. However, these bombs were too light to damage the heavy process equipment which remained intact. In order to inflict permanent damage on the heavy process equipment the air forces required larger bombs (4,000 lb) which could cause extensive and permanent damage to process equipment both from direct hits and near miss detonations.[251]

[246] USSBS, *Report 43*, p. 220.
[247] LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.
[248] USSBS, *Oil division*, p. 91.
[249] LASA, I 525, No. A 399 Weekly reports 9 July to 9 December 1944.
[250] USSBS, *Report 43*, p. 15.
[251] USSBS, *Oil division*, pp. 134-135.

The heavy process equipment was vital in the sense that if damaged beyond repair, many months were required for its replacement. However much of this equipment was protected by protection walls of concrete or brick (Image 5). In order to damage such equipment, it must be struck directly by a large bomb, or experience a near miss by a very large bomb. For illustration the RAF attacked the Welheim synthetic fuel plant in western Germany in September 1944 and struck the compressor house with eight 1,000 lb and three 4,000 lb bombs.[252] The seven heavy compressors were totally destroyed and production at Welheim ceased.

A direct hit by a USAAF 500 lb bomb on a compressor in Leuna could lead to damage. However, Leuna operated many compressors, pumps and similar equipment in parallel with spare capacity. Therefore 'lucky hits' by light bombs on individual pieces of heavy equipment did not significantly reduce the available capacity.[253]

The RAF used 1,121 heavy 4,000 lb bombs in four attacks from 6 December 1944 to 4 April 1945 which did permanently damage heavy process equipment.[254] However by this period the sustained assault on the Leuna utilities by the USAAF during the autumn of 1944 using lighter bombs had exhausted the ability of the damage repair teams to restore production above a 10-20% level. The loss of individual production equipment was not a critical factor limiting the output of Leuna in January-April 1945.

Bomb damage to certain electrical switch gear and other specific equipment did have the potential to reduce Leuna's production capacity. However, the restoration of production in Leuna had the highest priority for the entire German chemical industry repair effort due to Leuna's importance for the production of synthetic fuel, explosives and synthetic rubber. Undamaged electrical and other equipment was therefore transferred to Leuna from other plants which had been bombed and ceased production.[255]

Fires resulting from damage by explosions to pipelines and gasholders caused significant destruction immediately following the first USAAF attack on 12 May. Thereafter the Leuna plant fire department and workforce were successful in limiting the spread of fires. Leuna had an extensive high-pressure fire water pipeline network to support firefighting. However, the bombing attacks damaged this network which resulted in shortages of water in the period immediately following an attack. To compensate for this damage Leuna developed a network of static fire reservoirs using storage tanks and basins throughout the plant. Fire water was also stored in storage tanks in the synthetic fuel production area to ensure that a supply was close to hand. In general, the Leuna fire department dealt quickly with small fires but were unable to suppress large fires in storage tanks due to the high radiant heat and the shortage of water immediately following attacks due to damage to the water mains.[256] As discussed in the preceding section major changes were required in the USAAF selection of bomb loads and execution of air attacks in order to create large sustained fires in Leuna which could have significantly damaged the plant.

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[252] Ibid, p. 4.
[253] Ibid, p. 104.
[254] USSBS, *Report 43*, pp. 13-14.
[255] USSBS, *Report 43*, p. 220.
[256] Ibid, pp. 203-208.

The repeated USAAF attacks created widespread damage in the Leuna utility systems. By November 1944 the Leuna water system had been damaged in 1,500 locations which were described by the Leuna plant director as ‘each of which in peace time would have been considered a serious interruption to production’.[257] The information in the weekly damage and repair reports demonstrates that despite strenuous efforts the Leuna damage control and repair organisation was unable to restore the utilities to 100% of normal capacity during July–December 1944. Leuna continuously employed 7,500 persons on damage control and repair activities during this period but suffered long periods without any production. When production was resumed it only recovered to a maximum of 30% of normal production before subsequent USAAF and RAF attacks led to a further shutdown.

The German senior political, industrial and military leadership was acutely aware of the importance of Leuna to the German war effort. Speer personally visited Leuna the day following the first attack. Hitler, Speer and senior military and industrial personnel met to review the situation on 23 May, eleven days after the first attack following the preparation of damage reports. The German senior leadership responded quickly and decisively and Geilenberg was appointed with full authority to take immediate measures. Three days after his appointment Geilenberg visited Leuna and agreed a comprehensive programme of work with the site management. Large additional resources of German and forced labour were assigned to Leuna to assist in the repair of the damage utilities. Through the remainder of 1944 the Leuna plant management, the German workforce and the non-German forced labourers worked effectively to repair the damage to the utilities and to restore limited production taking advantage of the large spare capacity within the plant.

However, the continued bombing gradually eroded the Leuna management and workforce’s ability to repair the utilities and restore production. The USSBS team discussed the effects of the bombing with the Leuna chief engineer during April 1945. He reported that in practically all cases manpower, rather than material, was the critical bottleneck when restoring production during the period May 1944 – April 1945.[258] The chief engineer’s summary was that ‘the air attacks destroyed manhours rather than equipment’ and serves as a fitting conclusion to this section.[259]

By May 1945 the Leuna plant was a scene of major destruction (Image 9).

[257] USSBS, *Oil division*, pp. 3-4.
[258] USSBS, *Report 43*, p. 220.
[259] Ibid, p. 220.

Figure 117. View of Leuna Works, taken by the Eighth Air Force in May, 1945. Foreground, the organic products division. Right middle distance, the hydrogenation area. The group of 11 chimneys in the distance marks the older boiler and power plants. To the left of them is the gas production area.

Image 9: Aerial view of Leuna plant in May 1945 from the South,
Source: USSBS Oil Division Final Report, Figure 117

CONCLUSION

Soviet army units occupied Leuna and the surrounding area in early July 1945 following the withdrawal of US forces to the USA occupation zone.[260] Ammonia production resumed during June prior to the departure of the US forces, synthetic fuel production resumed in August and methanol production in September.[261] The rapid resumption of Leuna production following the cessation of bombing in April validated the Leuna management's view that production could be restored to 70% of normal within six months of the cessation of bombing, without the requirement for external equipment.[262]

Following the defeat of Germany General Eisenhower commissioned a report to review the contribution of IG Farben to the German war economy. The report concluded that the IG Farben's manufacturing capacity, scientific ingenuity and technical expertise had been crucial to the early success of the Nazi regime and that IG Farben should be broken up. Over

[260] Karlsch, *Leuna 100 jahre chemie,* p. 70.
[261] LASA, I 525, No. A 618 Production by product 1945.
[262] USSBS, *Report 43*, pp. 220-21.

the following years the various components of IG Farben were absorbed into new entities within the four occupation zones.[263] Leuna was absorbed into the centrally planned economy of the USSR occupation zone.[264]

On 4 May 1947 the USA filed indictments against twenty-four IG Farben senior managers including Dr Krauch and Dr Butefisch. Both Dr Krauch and Dr Butefisch were found guilty in May 1948 of participation in slavery and mass murder, primarily due to their involvement with the construction of the Auschwitz chemical plant and were both sentenced to six years imprisonment.[265]

In Part One the development of Leuna during the 1920s and 1930s as the world leading centre for high pressure chemistry was outlined. By 1943 Leuna demonstrated that German scientific and industrial skills, organisation and capital could transform simple, readily available raw materials into industrial scale volumes of complex, high value products which were critical for the operation of modern industrial societies and armed forces. The technologies developed in Leuna allowed Germany to overcome the constraints arising from its lack of access to large natural sources of nitrogen, crude oil and rubber and to achieve to victories during 1939-41. Until May 1945 the scientific and industrial leadership in USA and UK did not appreciate the advances made in Leuna or the interrelationships between the high-pressure technology and the final products.

Failures of intelligence and understanding also prevented the USAAF and RAF appreciating the relative weakness of Germany's fuel resources until the spring of 1944 as explored in Part Two. With the benefit of hindsight, the initial four USAAF attacks on Leuna from 12 May to 20 July 1944 were made with insufficient force, used too light bombs and did not focus their attacks on the critical gas generation area. These attacks were made in clear weather with limited smoke screen, achieved high accuracy using visual bomb aiming, and were opposed by relatively weak anti-aircraft defences. In particular the first attack achieved surprise on a pressurised hydrogen gas plant in full production, created panic in the workforce, and started many fires which contributed to the damage. During this initial period the USAAF had the opportunity to rapidly and permanently reduce Leuna's capacity.

From the fifth attack on 29 July the smoke screen was fully effective, the USAAF had to use inaccurate blind bombing techniques, bombing accuracy was significantly reduced, the anti-aircraft defences were reinforced, and the German plant management were fully prepared. Thereafter the USAAF had to commit increasingly large resources to damage the utilities but was unable to damage the core production facilities. The USAAF bombing productivity decreased by 80% from RM 76 K / tonne during the first four attacks to RM 14 K / tonne in the subsequent fourteen attacks, (Table 4 following page). The later RAF attacks also achieved similar low bombing productivity of RM 14 K / tonne despite the use of heavier bombs.

[263] Jeffreys, *Hell's cartel*, p. 302.

[264] Karl Heinz Streller & Erika Maßalsky, *Geschichte des VEB leuna werke >walter ulbricht< 1945 bis 1981* (Leipzig, 1989), p. 80.

[265] Jeffreys, *Hells cartel*, p. 316, p. 338.

LEUNA **TABLE 4**

Air attacks: 12 May 1944 - 14 January 1945

Details of Air Attacks, Estimated Damage and Casualties

(Sources: Bombing Data; USSBS Report 43, Pages 8-14; 223-226;
Estimated Damage; USSBS Report 43, Page 17)

				Primary	Aircraft Data			Bomb Data			Total	Productivity	
Air Force	Attack	Attack Dates		Bomb	Aircraft	Aircraft	Aircraft	Bombs	% Effective	Effective	Damage	RM K /	RM K /
	Numbers	From	To	Sighting	Total	Losses	Losses %	Tonnes	Bombs	Tonnes	RM m	Aircraft	Tonne
USAAF 8	1 - 4	12-May-44	20-Jul-44	Visual	484	5	1.0%	1,022	23.3%	238	76	156	74
USAAF 8	5 - 17, 19	28-Jul-44	12-Dec-44	P.F.F. (Blind)	4,752	114	2.4%	10,583	6.0%	639	147	31	14
RAF	18, 20, 21	06-Dec-44	14-Jan-45	Pathfinder	1,071	6	0.6%	4,068	7.6%	307	58	54	14

Note 1: Effective tonnes = Total weight of bombs in tonnes which exploded within perimeter of Leuna

During mid 1944 the USAAF had many competing priorities and the opportunity to achieve a knockout blow on Leuna during mid-1944 quickly passed. However, the reduced priority for attacks on Leuna reflects the failures of intelligence and understanding discussed earlier. Leuna was not only a major production site for synthetic fuel, but also produced 33% of Germany's explosives and 46% of its synthetic rubber.

In contrast as described in Part Three the German leadership was fully cognisant of the importance of Leuna to the war effort. Germany immediately committed significant resources of fighter aircraft, anti-aircraft guns and personnel to the protection of Leuna. In addition, Geilenberg was appointed the Commissioner for Immediate Measures and arranged for the transfer of large numbers of skilled German labour and forced labour to Leuna to assist in the repair work. The Leuna plant management worked very effectively throughout 1944-45 to repair the repeated damage to the utilities and to restore limited production taking full advantage of the spare capacity within the plant. Despite their best efforts the continued bombing and resultant damage eventually exceeded the capacity of the Leuna workforce to restore production from early 1945.

Many historians agree that the USAAF and RAF victory over the Luftwaffe in February-June 1944 was the key enabler for the invasion of north west Europe on 6 June 1944. The victory over the Luftwaffe also contributed to the success of the USSR's offensive against Army Group Centre in June 1944, through the Luftwaffe's earlier transfer of fighter aircraft from the eastern front to the defence of Germany. The USAAF assault on Leuna and the other synthetic fuel plants was a crucial element in the victory over the Luftwaffe as the German fighter force was compelled to attack the USAAF bombers and their escorting fighters in order to defend the Luftwaffe's sources of aviation fuel. The damage to the synthetic fuel plants was an equal benefit from these USAAF attacks.[266] In this view the relative inefficiency of the eighteen USAAF attacks on Leuna during May-December 1944 is compensated by the attrition of the Luftwaffe fighter force by the escorting USAAF fighters.

In conclusion, Speer's assessment of the significance of the USAAF attacks on Leuna and other synthetic fuel plants on 12 May 1944 was correct. The USAAF had struck one of the weakest points of the German war economy which was of critical importance to Germany's ability to sustain modern warfare. The continued attacks rapidly reduced synthetic fuel production which severely curtailed the operations of the Luftwaffe and of the German

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266 Gray, *Airpower for strategic effect*, pp. 138-143.

armoured forces. The sustained efforts of the German plant management and workforce were unable to offset the degradation of the Leuna utilities arising from the unrelenting cascade of bombs. The successful USAAF campaign against Leuna and the other synthetic fuel plants determined the outcome of the '*technological war'* as described by Speer and was a major factor in the ultimate defeat of the Third Reich.[267]

[267] Speer, *Inside the Third Reich*, pp. 468-469.