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THE PLANNING AND DEVELOPMENT OF BOMBS
FOR THE GERMAN AIR FORCE
1925-1945

PART A

CHRONOLOGICAL SEQUENCE

CHAPTER I

BACKGROUND 1925-1927

1. Initial Situation. After the end of World War I of 1914-1918 the German Air Force had been completely dissolved, both in the organizational and in the technological sense. The Army and the Navy had been permitted to maintain small staffs and small units, which had only light weapons.

In 1925 the German Government came to an agreement with the Western Allies, under which the last French and British troops withdrew from the Rhineland and the Inter-Allied Control Commissions, which in the past had exercised military and industrial supervision over German disarmament, ceased to exist.

In return, the German Government gave the assurance before the League of Nations that no secret rearmament would take place on German soil and agreed to submit to sanctions which might be imposed if this promise was not kept.

Technical concepts had even been established for civil aviation to prevent possible "misuse" of commercial aircraft for military purposes. These specifications not only prohibited the inclusion of any features of military significance in the body of aircraft, such as machine-gun mounts and bomber cockpits or the manufacture of substitute fuselage sections intended for such purposes, but also placed restrictions on the power of the engines used. Even in multi-engine planes this power was not to exceed 500 horse power.

The large triple-engine Junkers G-23, for example, although it had a central BMW engine of 240 horse power, had two Mercedes side engines of each only 120 horse power. The Udet aircraft factory in Munich even attempted to develop its Condor plane with four Siemens radial engines of each 110 horse power. However, all of these aircraft were completely uneconomical and could not compete against commercial aviation in foreign countries.

German aircraft factories at this time therefore established branches abroad. The firm of Dornier founded a factory at Altenrhein on the Swiss shores of Lake Constance, where it developed and tried out seaplanes, such as the Wal and later the Do X models. The firm of Rohrbach established a factory at Kopenhagen, where the Rodra seaplane and the ~~la~~ large Roland Commercial planes were developed. Junkers opened a factory at Limham in southern Sweden, where it manufactured its G-24 model, powered with three Junkers engines of

Xxxdax 300 horse power each, in order, with Swedish approval, to engage later in commercial aviation.

The branches established in foreign countries by the German aircraft factories previously mentioned soon also commenced supplying military aircraft, since Germany at the time had a lead in the construction of all-metal aircraft and such aircraft were vastly superior to those constructed of steel tubing, timber, and fabrics for use under difficult climatic conditions.

The easiest adjustment here was that of the seaplanes mentioned above to adapt them for service as naval reconnaissance planes (long-range), since it was possibl to build in circular tracks for machineguns in the nose and tail after appropriate reinforcement of the fuselage.

The types designed as land aircraft required bigger alterations to the fuselage if they were to have bombing installations in addition to mounted weapons.

Even at this early stage it soon transpired that the designs for commercial aircraft of the sizes then in use could not be made consonant with the requirements of aircraft for military purposes.

In commercial aircraft the primary factor is the safety and comfort of passengers. The designs therefore provided for large spaces within the body to insure a relatively

3 even distribution of loads which would remain constant while the plane was in flight and for fuel tanks placed in the wings and close to the engines.

In contrast, the specific weight of bombs is a multiple of that of humans. Therefore, the aim must be to load them one over the other so as to prevent any shifts of gravitation center during bombing, since any such shift could prove a serious flight hazard. Furthermore, large openings must be provided beneath the bombbays and these weaken the overall structure, particularly since the frame joints have to be subjected to greater strains than is the case in commercial aircraft.

To increase the striking range of military aircraft, it is often necessary to install fuel tanks within the body, which was specifically avoided in commercial aircraft. In bomber aircraft this position of the fuel tanks was an advantage, since they could be given better protection against weapons fire by means of armor plating or other coverings which could break the force of projectiles and prevent fuel leakages. As a rule the wing-installed tanks were too flat for this purpose.

4 The firm of Junkers for their Type K-30 three- 3-engine bomber constructed a special middle fuselage section to carry the same type of engine nacelles, wings, undercarriage and controlling surfaces as their Type G-24 commercial plane. Of

4 this model, the firm produced two series of K-30 planes, partly on undercarriages for delivery to Russia, the rest on floats for delivery to South America. In addition to the machinegun circular track on the top fuselage surface, the Type K center section had a retractable floor gun mount (ausfahrbare Bodenlafette) for rearward and downward defensive fire.

For the German representatives at the Geneva Permanent Disarmament Conference the Junkers solution was admirable in every respect. It clearly stressed the fundamental difference between military and civil types of aircraft, and they did not have to counter any argument that aircraft designed for civil aviation could at small cost be adapted for military purposes.

Owing to the complete dismantling of Germany's armament factories after World War I, the foreign branches of the German aircraft factories had to procure abroad the military equipment required for their planes manufactured for export. Junkers used Danish Madsen machineguns and Swedish Bofors bombs, while Dornier procured from Switzerland "Orlikon weapons up to a caliber of 20-mm. These weapons and bombs were still from World War I production and a common feature in all of them was in their designing no allowances had been made for their appropriate storing and/or installation in

5 aircraft. This had a particularly hampering effect on the adaptation of commercial planes to serve as bombers.

None of the foreign branches of German aircraft factories carried out any proper airborne tests of the weapons and bombing equipment; only a few functional tests were conducted on the ground and at low altitudes over water.

In any case, the sections of air warfare specialists formed in the Army and Navy General Staffs at the Troops Office of the Reich Defense Ministry in Berlin could learn nothing from all of this work on the subject of how a future German air force should be technically equipped. Furthermore, even for the Great Powers of those days, any implementation of Italian Air General Douhet's ideas on future air warfare was still a matter relegated to the far distant future. For the moment there was still another problem to clarify.

2. Concern over Possible Airborne Gas Warfare. In 1924-1925, the illustrated weekly papers frequently and in a sensational manner protrayed the horrors of airborne gas warfare, much the same as they did 30 years later with the subject of war with atomic weapons. According to their published reports, a few aircraft would suffice to poison the entire population of a large city by spraying liquid chemical war agents from great altitudes, which would settle down into

5 the roads and streets as a "Deathdealing Dew."

These descriptions were based on the use of Yellow Cross (vesicant) gas, a chemical warfare agent with a physical action similar to that obtained only by subjecting a living body to radiation and fire. It had been fired in shells by the German side for the first time in the autumn of 1917, at the time when the battle of materiel in the plains of Flanders was approaching a critical point.

Whereas the socalled volatile war gases of the Green Cross type, such as phosgene, were only effective in relatively dense concentrations which could only be achieved by means of intensive fire into a closely circumscribed area, Yellow Cross gas (Dichloroethyl sulphide--mustard gas) is effective even in weak concentrations and because of its persistence. Whereas Green Cross gas could only be expected to have an effect lasting for minutes, Yellow Cross gas could contaminate the ground for days.

Against volatile gases, the gas mask could afford protection, but a thick protective suit was necessary against Yellow Cross gas, since it affected the entire surface of the body.

If the claims of the Press, supported by alleged experts, were justified, airborne chemical warfare was more to be feared than concentrated bombing attacks and necessarily must have an incisive impact on high-level politics, particularly for Germany in her exposed and vulnerable position.

For this reason the most important mission assigned by the military high command of that time--in 1925--to the departments of weapons technology concerned a study of the possibilities of airborne chemical warfare.

In contrast with the Press versions, many alleged experts doubted that a fluid ejected by aircraft would reach the ground at all. To prove their point they quoted the fact that the water carried as ballast by zeppelins, when ejected, was completely absorbed by the atmosphere within a few hundred yards of altitude. It was also held that the slipstream of an aircraft would dissolve even oily fluids, such as Dichloroethyl sulphide into extremely minute droplets, which would be carried far away by air currents and thus be rendered ineffective, since they would become hydrolised by the atmospheric moisture.

Contentions of this kind could only be proved or disproved by means of practical tests. Under the existing circumstances, this meant that airborne tests with large quantities of test gases would have to be carried out at a time when Germany was prohibited from carrying out military air tests of any kind.

For this reason adequate and credible means had to be found to conceal the purpose of the tests even from German ~~au~~ authorities. Furthermore, the work could only be done by

7 private firms.

In 1925 the use of aircraft had been adopted in Germany to combat insect pests in forestry. These aircraft sprayed a poison dust, chiefly clacium arsenic from low altitudes over forest sections infested by caterpillars. The firm of Junkers had received requests from Africa and South America for contact poisons to also be used from aircraft against swarms of locusts in flight and on the ground, and for the development of appropriate chemical spraying instruments.

The possibility thus existed to tackle both problems, that of pest extermination and that of gas warfare, from the same angle, without any fear of accusation that the preliminary
8 tests carried out with aircraft served military purposes.

It was only natural that all-metal aircraft were considered most suitable for the purpose because of the greater ease with which they could be decontaminated xfatax after use in tests with poison sprays. The firm of Junkers, in addition to its aircraft factory, also had the largeKalorifer sheet metal works and its geyser manufacturing works.

The Troops Office of the Reich Defense Ministry in Berlin assigned the contract to the main office of Professor Junkers in Dessau, from where a special controller handled the designing of the necessary chemical apparatuses and supervised their construction in the manufacturing works. The

Work on the problem of pest extermination also commenced in the same office so that adequate concealment was provided in the Junkers concern.

In the insect extermination project the firm of Junkers had a contract with the chemical factory of E. Merck, Darmstadt. The firm of Merck negotiated with the forestry officials and supplied what was called the "Moth Powder."

Junkers designed and manufactured the spray apparatuses, for use in type F-13 and W-33 aircraft and carried out the aviation part of the program. The firm of Merck had only one interest: the sale of its powdered insect exterminator "Esturmit."

The firm taken into consideration for the supply of liquid sprays was that of Hugo Stolzenberg in Hamburg, namely for the supply of contact poisons for use against locusts in the tropics as well as for the supply of Yellow Cross gas for chemical warfare.

At that time--in the spring of 1925--this firm was establishing a factory for the synthetic production of mustard gas in Russia (at Ssamara on the Volga River) under the Rapallo Agreement of 1922, which agreement will be discussed later. The plan was, to use the gas produced there for airborne tests, also on Russian soil.

The apparatus for the spraying of dust poisons consisted primarily of a wind-driven rotor, which ejected the insecticide evenly from the loading bins within the aircraft. Once outside the slipwind spread it out. This apparatus has and had no military importance and will not be further mentioned.

For reasons of safety, the tank for fluid poisons to be sprayed was to be mounted on the outside of the aircraft (Photo 1), to protect the crew against the consequences of a possible leakage.

Junkers first constructed a tank to hold 200 liters (52.53 gallons) with a square base and a wing profile cross section. It was so mounted on the aircraft that it was between the undercarriage with its flat surface on the fuselage and its curved side--the suction side--facing downwards. The profile was cut off at the rear, allowing an ejection slit approximately 12 centimeters wide, which was closed with a firmly sealed flap.

For emptying, the tank was tipped downwards, the front remaining suspended in bearings. Simultaneously a current of air streamed between the tank and the fuselage to prevent the latter being sprayed. When at an angle of approximately 32° the closing flap was opened by pulleys and the fluid flowed out within a few seconds and was vaporized by the slipwind to form a cloud of tiny drops. Even very viscous viscuous fluids could ? be finely vaporized with this tank without contaminating the aircraft. However, the apparatus was first tried out with a water filling, the water being colored red by an eosin or blue by a methly additive. It was soon found that ~~even dur-~~ ing dry weather the water reached the ground even from altitudes of 550 yards without considerable loss through evaporation. From traces on long strips of cloth on the ground it was found that when sprayed with the wind the densest fall on the ground was in the front part and that the size of the droplets decreased considerably with the wind. Observers on the ground noted that at the moment of ejection a dense cloud formedwhich was strongly blown away by the wind and was no longer visible after a few seconds. The estimated speed of fall was 5 meters per second. This meant that even for spraying from low altitudes the wind would have to be gauged very accurately in the target area to insure that a specific surface would be sprayed.

Very soon the water was replaced by a socalled innocuous comparative solution corresponding to mustard gas in its physical characteristics. For abbreviation Dichloroethyl sulphide was designated "Lost" after the two chemists who first produced it, namely, Lommel and Steinkopf. The comparative solution consisted of a chloromagnesium mixture with a specific weight of 1.3, which was colored and to which sufficient glycerine was added to give it the same surface ~~ten~~

Photo 1

Junkers F-13 plane with Type G-200 spray apparatus

Junkers F-13 plane at moment of spraying with
Type G-200 apparatus (Rossitten)

10 tension as mustard gas. These characteristics increased the fall speed of the large droplets to between 8 and 10 ~~xasondx~~ meters per second.

Under conditions of moderate wind from the front or rear the dispersion pattern on the ground formed a ellipse of be-
11 tween 330 and 440 yards in length and 55 to 110 yards wide; during sidewinds, the dispersion pattern was almost a square with sides between 440 and 550 yards.

For military purposes a minimum density of 5 grams mustard gas per square meter was desirable to effectually seal off a sector with persistent gas during defensive operations, and the spread was to be as even as possible.

As previously mentioned, however, the largest drops always fell on the windward side, where densities of up to 100 grams per square meters were measured, while it was difficult to determine at what point of the other end of the dispersion pattern the effectiveness ceased.

For offensive purposes, in contrast, it was desirable to achieve gas cloud formation, the poison-saturated clouds to blow across the combat area in which the enemy troops were present. Photo 2 shows the test area in the Kurische Nehrung in Eastern Prussia, which was eminently suitable for test spraying with comparative solutions from higher altitudes.

In the fine sand of the dunes which occur there northeast

11 and southwest of Rossitten, it was easy to trace the pattern of dispersion. The aircraft crew merely had to wait for the cloud of moisture to settle to the ground and then circle over the target area until they discovered a blue or red patch in the terrain. This showed them whether their aim had been correct and they informed the ground personnel by means of arranged signals.

To determine the point of gas release in the air the following method was used during exercises: shortly before the plane took off the wind velocity was measured with a pilot balloon set to rise at the fall speed of the gas cloud. The point ~~at which~~ in the terrain at which the balloon was when reaching the planned test altitude was then twisted 180° into the wind and the appropriate angle was set with a special ~~target instrument~~ aiming instrument.

Photo 2 shows a dark strip against the white dune sand. This strip was colored by 200 liters of comparative solution released in September 1925 from an altitude of 5,280 feet; the descent of the moisture cloud took 3.5 minutes. This provided ~~prro~~ proof that airborne chemical warfare was feasible.

Tests were also carried out to determine the usability of gas by means of gas-containing bombs released from great altitudes. One advantage here was that precise aiming was possible, another that there was no wastage during the drop.

Photo 2

Gas marked strip from gas sprayed at an altitude of 5,280 feet over the testing terrain at the Kurische Nehrung, Eastern Prussia.

On the other hand, it was feared that the detonation of the explosive charge required at impact to distribute the gas would cause serious losses of the same, as experience had shown when gas shells were fired containing mustard gas during World War I.

Mustard gas solution is an oily solution (Allylen-mustard-oil) which when very finely vaporized is burnt by an explosive flame. Also, volatile gases, such as phosgene and in particular hydrocyanide (Cyanwasserstoff), rise in high temperatures instead of being carried over the field of combat by the wind.

However, bombs were the only means of delivering gases other than mustard gas from aircraft. Besides the previously mentioned poisons of the Green Cross class, which affected the respiratory organs, irritants in the White Cross class, such as Chloroacetophenon, had in the meanwhile become available in place of the old Blue Cross types, such as Diphenylchloroarsin.

Always conscious of the need for concealment against detection by German or foreign authorities, the construction of and testing of chemical bombs were also cloaked as tests for insect extermination. The Forestry Department had suggested the development of forest fire extinguishers which would enable aircraft to combat forest fires by dropping containers filled with carbon-dioxide or foam forming substances. These

13 were to burst on impact without any explosive charge and distribute their contents. For this purpose, the nose part was of glass, but owing to the inertia of the contents, the containers penetrated too deeply into the ground and were thus ineffective. Success was only achieved after the containers were given a soft sheet copper nose, which on impact flattened out into the shape of a spray plate, and after the cone had been provided with a notch. The bombs naturally could not be~~e~~ too bulky, for which reason their content was restricted to between 2 two and 5 five liters (1 liter = 1.0507 quart), but this would have been necessary anyway to insure even distribution within the target area.

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concealment was insured within Germany to a reasonable extent by combining the military problems with those of insect extermination

In its business dealings abroad, however, the firm of Junkers felt no inhibitions when the question was one of finding a sale for its all-metal aircraft. It has been mentioned previously that, in common with other German aircraft factories, Junkers also had established a factory abroad, namely, in Sweden in 1924. The firm also had two other subsidiaries, one in Fili, near Moscow, another in Kaisarie, Turkey. The former had been established in 1924 under the Rapallo Agreement signed by German Foreign Minister Rathenau and the Russian Tshitsherin; the factory in Turkey was established on the initiative of the firm itself. Junkers also endeavored to gain a footing in Western Europe, namely in Spain. That country at the time was engaged in a costly small-scale war in Morocco and its colonial troops had been driven back to the Mediterranean coast by the Rif Kabyls.

As ~~had been~~ was the case with the Italians in Abessynia in 1935, the Spanish as early as 1925 evolved the idea of putting their bare footed opponents out of action by the use of mustard gas, hop-
15 ing for particularly spectacular results because of their opponents' ignorance of gas defense requirements. At small cost and within a short time, it was hoped, it would be possible to master the enemy and spare Spanish blood.

Since the Spanish had a number of type F-23 aircraft, the model used in Germany for the chemical warfare tests, the export branch of the firm of Junkers surreptitiously copied a number of the gas containers which had been developed and supplied them to Spain. For the larger type G-24 plane they even constructed a container with a content of 1,000 liters.

That no chemical warfare agents were used at the time, as used ten years later by the Italians in the Abesynnian conflict was due exclusively to Spain's lack of specialists in this type of warfare. The Spanish weapons technicians and gas chemists were unable to handle the supplied equipment properly, for which reason they remained in disuse in the Moroccan war.

However, the matter had become widely known, since foreign states had sent numerous military observers to the African scene of conflict, including Germany, which had sent Jeschonnek, who later became Chief of the Luftwaffe General Staff. These military observers became aware of the Spanish preparations for gas warfare, which was to be waged with aircraft and equipment supplied xxxxxxxxxxx by German firms.

The Berlin Defense Ministry drew its logical conclusions from this incident and decided to halt the work at Junkers and to carry on the experiments with its own facilities.

In the field of airborne weapons and bombing equipment ~~then no longer relied~~ the German military authorities from then on no longer relied on recommendations and designs from the aircraft manufacturing firms but instead employed their own engineers.

It was around the same time that the firm of Junkers found itself in financial difficulties. These difficulties were due not only to the fusion of the Junkers Airways with the German Aero Lloyd Airways brought about under Government pressure for reasons of subvention activities, but also to the collapse of the Junkers enterprise in Moscow owing to the fact that the Russians placed no contracts with the firm. All of this happened towards the end of 1925.

3. The Testing of Chemical Warfare Equipment in Russia.

The subject to be discussed here is not one of German participation in Russian gas warfare tests, but of German research and experiments and tests carried out on Russian soil.

Russo-German cooperation under the so-called Rapallo Agreement has been mentioned previously above.

At the Genoa Conference of the victors of World War I in the spring of 1922, Russian and German delegates were only present as observers. On this occasion German Foreign Minister Rathenau and Soviet Russia's Foreign Affairs Commissar, Tshitsherin met at near-by Rapallo and signed an agreement, the

16 contents of which, in broad outline, were as follows:

1. War debts on both sides were annulled.

2. By granting credits and supplying machinery, Germany was to support Russia in her industrial development and in return was to receive concessions for

17 a. The manufacture of all-metal aircraft

b. The establishment of an air service between Berlin and Moscow

c. The exploitation of aluminum

d. The exploitation of oilfields in various parts of Russia

e. The establishment of ammunition factories.

3. Russia was to consider it a cause for military intervention against Poland, if that country wnould infringe German territory with arms.

Whereas main emphasis in the agreement was in the field of economics, the military considerations expressed in the final paragraph in the end preponderated, while the economic concessions were only partly exploited owing to reluctance on the part of German industrialists.

The German province of Eastern Prussia, separated from the rest of Germany by the Polish Corridor, was considered as strongly threatened because of Polish annexation desires following conclusion of the Russo-Polish war.in 1921. After the forced occupation of Vilna, the Capital of Lithuania, by Polish General Zalewski, the German Government was compelled to reckon daily with a similar act of aggression against Eastern Prussia.

17 Russia felt herself robbed by the separation from her territory of White Russia and a large part of Ukraine, which areas were east of the Curzon Line, a line suggested by the the British Foreign Minister in 1920 as the border between Poland and Russia. After their victory over Russia, however,
18 Poland had disregarded this Agreement and had annexed territory which was unmistakably Russian.

It was this protection of German soil against Polish robber instincts which the German experts had in mind who proceeded to Russia to fulfill the various military and economic missions. One remarkable feature is, however, that the really important German industrial leaders were reluctant to travel to Moscow, and sent only their junior employees, probably fearing to compromise their interests with the West. Professor Junkers and Professor Dr. Haber (head of the IG Farben Concern), for example at no time visited Russia.

On the subject of the Junkers factory in Fili, near Moscow, it is gathered from other sources that it was a well equipped factory which, under German management, manufactured a few hundred reconnaissance and fighter aircraft and was then turned over to the Russians.

On the other hand, the efforts of the IG Farben Concern to establish a mustard gas factory in Russia under the Rapallo Agreement are probably not generally known.

In World War I mustard gas (dichloroethyl sulphide) had been produced by a process using Glycol, a secondary product~~s~~ manufactured by the German chemical industries as a base for numerous trade commodities. Russia, in contrast, completely lacked industries of this kind, just as there were, at least up to the outbreak of World War II, no factories in Russia producing artificial fertilizers with their byproducts, such as
19 ammonium nitrate and other important explosives.

The I G Farben Concern being extremely reluctant to partidipate in the industrial ventures in Russia, the idea was taken up of exploiting the method for the manufacture of synthetic mustard gas ascribed to Dr. Stolzenberg, a chemical scientist who had formerly worked together with Professor Haber~~m~~ who recommended him highly to the Government agencies concerned.

The process patented by Stolzenberg was based on the use of large coal operated generators to produce ethyl gasfor use as a base~~s~~ to produce mustard gas by ~~that~~ the addition of chlorine and sulphur.

A factory operating by these methods was established in 1924-26 at Ssamara on the Volga River , but proved a complete tehhnical failure when production was to begin.

The delivery contracts awarded to this factory specified , among other things, that the final product was to contain not

19 more than 5% impurities (most of them free hydrochloric acid), a specification justifiable in every respect because of the requirement for the long storage of gas ammunition. The product turned out by the new factory proved that it was not possible to manufacture mustard gas on a large scale by the ethyl process and that the final product might contain up to 5% mustard gas, while the balance was made up of what must be considered impurities.

After the entreprise under the concession covering the manufacture of all-metal aircraft had failed to develop to the satisfaction of its inaugurators (in this case a fault of the Russians, who desired to take over the Junkers Works
20 after they had proved a workable proposition) it was a matter of primary importance to the responsible German military command authorities, particularly General von Hammerstein-Equord, to demonstrate something which at least showed indications of success, and this was the spraying of chemical warfare agents from the air.

For a proper understanding of the whole situation as it existed at the time it is also necessary at this point to deal with the matter of the Junkers Works.

The standard type of aircraft in use by the Russians at tthe end of World War I was the de Haviland 9, an English model used on the Western Front as a reconnaissance plane and daytime bomber. It was a wood and fabric plane and being

20 very able woodworkers, the Russians were well able to manufacture it in small workshops. The last strenuous effort in this direction was made in 1922, when a mass national movement was organized which resulted in the production of thousands of aircraft of this type with the motto painted on them: "Our Reply to Chamberlain," after that British Minister had announced that the other Allies ~~had~~ intedded to cease participation in the intervention in Russia, and after he had called for the inauguractio of a new Crusade there.

Structurally, the De Haviland 9 was not very suitable for the extremes of the Russian climatic conditions, and the firm of Junkers was considered throughout the World as the champions of all-metal aircraft construction, so that the interest of the Russians is understandable.

Owing to the poor lines of vision downward from the De Haviland 9, however, Russian airmen had developed the idea of demanding a high-wing monoplane, a structural requirement directly opposite to the features of the basic patents of

21 Professor Junkers.

Neither for politico-military nor for private industrial reason was Professor Junkers interested in the enterprise in Russia and therefore raised no objections to any attempt to disprove his theories of aircraft construction. In 1924-25 he therefore had a series of roughly 100 H-21 (two-seater)

21 and H-22 (single-seater) high-wing monoplanes manufactured in the works at Fili near Moscow. The constructional equipment and special tooling machines were brought in from Dessau for the purpose, and roughly 150 foremen and engineers trained the Russian experts.

The factory then turned out approximately 20 low-wing aircraft on floats for the Russian Navy. These were of the A-20 model, also manufactured in Germany.

The manufacture of a twin-engine bomber was undesirable to the German side. Russian demands in this direction were therefore turned down in spite of the fact that the Russian Commissioner for War, Voroshiloff, promised German Air Attache Lieth-Thomsen that the Communist paper *Die Rote Fahne* would cease attacking the German defense force if planes of this type were constructed in Russia.

As a substitute for the 2-engine bomber Junkers offered to construct a large Model J-25 multi-purpose plane powered by the newly developed BMW VI 600 horsepower engine, but the Russians seized on his refusal to construct the bomber as a reason to award his works no forther contracts. The last German employees thus left the Fili factory in the spring of 1926 . The factory passed into Russian ownership and was redesignated Aircraft Factory No. 22. It was there

22 that the Russians as early as in the late 1920s commenced

manufacturing 4-engine bombers after a Russian design but along typically Junkers designs (corrugated sheeting, divided spar system--but as a semi-highwing monoplane).

The Rheinische Metallwaren Fabrik, Duesseldorf, as the only factory in Germany permitted to manufacture artillery guns (up to a caliber of 150-mm) and ammunition, also was not much inclined to follow the suggestions made by the German Defense Ministry that it should establish a factory in Russia equipped along up-to-date lines for the manufacture of artillery shells and propelling charge containers.

Since that part of the Rapallo Agreement which concerned the establishment of armament industries was thus inadequately fulfilled, the military aid program was expanded all the more.

Besides the aviation school at Lipezk and the armor training school at Kazan, a testing station for the practical use of chemical warfare agents from the air was established under German management in 1926 about 12 miles southeast of Moscow on the Uchtomskaya airfield. Two planes of the Junkers F-13 model and one A-20 were used in these tests. A new container, the Chemical Container G-125 had been constructed for suspension under the wings. It could contain 125 liters of mustard gas and was streamlined similar to the Parseval type airship model. The ejector slit was at the bottom and was covered by a 1-meter length of metal sheeting soldered on. By means of a crank mounted in the observer's bay

22 and a length of cable this flap could be opened to allow the
23 escape of the gas.

The new container was absolutely airtight and was delivered ready-filled. It was moved to under the aircraft on a single axle cart and suspended beneath the wing. Each airplane could thus carry two containers. When emptied over the target area the emptied container was ejected, usually over a nearby stream in order to avoid contaminating areas outside the target area. The G-125 container was so designed as to avoid any contamination of the aircraft.

In later designs compressed air was used to eject the chemical warfare agent, but the basic features of the G-125 were retained and large numbers of these containers were procured by the Russians even during World War II.

Close to the Uchtomskaya airfield, near Moscow, was the Russian Gas Polygon, where the Russians had long been carrying out tests with gas, since they anticipated that gas warfare would play a major role in any future conflict. This attitude of the Russians was probably due to the great impact which few German gas attacks against the poorly protected Russian troops in World War I had had, in which attacks use had been made of chlorine and/or diphosgene.

The Russians expected far more effective results from the use of the Yellow Cross (mustard gas) types of gas, particularly

23 in airborne gas warfare.

24 Within the Gas Polygon near Moscow, areas were marked marked out and boards had been set up by means of which the density of the contamination with persistent type chemical warfare agents could be determined. At a later stage, experimental animals (dogs) were also placed in the target area to obtain biological reasearch data.

A number of spraying tests with actual gas were thus carried out sucessfully in the late autumn of 1926, which served to once more raise German prestige. Non-explosive gas bombs were also released, an interesting feature here being that they were released from a towed balloon towed over the gauging point in the terrain by a truck.

However, in the following winter the entire German camp was destroyed in a fire and the airborne gas warfare tests were interrupted for a number of years. In 1929 they were resumed in a much larger test terrain on the western banks of the Volga River near the small town of Volsk. The German test station established there was known ander the the name Tomka.

The responsible Defense Force authorities in Berlin were for the time being satisfaied with the practical proof that the conduct of gas warfare by aircraft was possible, but their interest was more in the devising of protective measures than in that of themselves starting air-gas airborne gas warfare. The only possible enemy envisaged during the late 1920s was Poland, and that only if Poland made an attempt to seize German territory by force of arms. Any such attempt could be met better by the use of conventional weapons, but these would have to include bomber aircraft to take action against military targets in the enemy rear, from where the attacks would be staged.and supported.

Under the Treaty of Versailles Germany was not permitted to have any military aircraft and the German Government had given the undertaking that no tests with prohibited weapons would be carried out within Germany.

As previously explained, the sales made by subsidiary firms of the German aircraft factories to foreign countries provided no tebhnically useful datafor German national defense, since the aircraft thus sold and delivered were armed with foreign weapons and bombs, resupply of which would not have been possible in the event of any war.

The only aircraft which could have been made available were those already present in appreciable numbers, and the only aircraft users of any appreciable size in Germany were the Lufthansa Airways with their commercial planes of the models Junkers G-24, Rohrbach Roland,and from 1929 on Messerschmitt M-20.

4. Bomb Testing in Sweden, 1927-1928. In developing a weapon the first step is fundementally that of determining

25 the effect of the weapon on the target. Only then comes the problem of placing the weapon on the target.

Aircraft were available in the Lufthansa Airways, but there were no bombs available in Germany. No technical data whatever was available on their ballistics and target effects, nor on bomb release and bomb sighting devices.

Bombing tactics involved principally the conduct of night attacks in successive waves and directed against area targets.

26 It so happened that there was another country, which was friendly towards Germany, which was in a similar position insofar as armaments were concenned. That country was Sweden, which had disarmed almost completely after World War I, retaining only a militia type force, a few warships and a few squadrons of fighter and reconnaissance aircraft. It was only after Sweden in 1926 was forced to realize that the ~~conf~~ Geneva conferences on general disarmament were making no progress whatever, that the Swedish Government resolved to build up an air force of its own and to procure modern types of aircraft.

In view of the high quality of Swedish steel, that country was greatly interested in aircraft of composite structure, with a fuselage of welded steel tubing and surfacings of plywood, since Sweden also had a highly effecient wood-working industry.

The Swedish Government thus decided to purchase the licence rights to copy the two-seater Fokker C V biplane, designed in Holland, and the British 500-horse power Jupiter motor. This aircraft was intended as the standard model for reconnaissance and daytime bomber units.

Shortly after World War 1 the Swedish gun factory of Bofors had purchased from the German firm of C.P.Goerz, Berlin, the licence covering the German air bombs of the German Proving Station, the so-called "Proving Bombs (P-und W-Bomben), with which the new Fok C V planes were to be equipped.

Since these new planes had a speed and altitude far exceeding those of World War I bomber aircraft, tests to determine the ballistical data of these bombs for aimed bombing became a project of the first priority.

Here it became possible for the technical experts of the German Defense Ministry in Berlin, working through the firm of Carl Zeiss, Jena, to participate in the tests planned in Sweden.

The entire complement of photogrammetric apparatus to trace the bomb trajectory and the necessary servicing personnel were made available by the German Aviation Research Institute (*Deutscher Versuchsanstalt fuer Luftfahrt*) and the German Defense Ministry provided the funds to pay for the licence, as well as 50% of the manufacturing costs for 100 Proving Bombs of 110-pound caliber, while the rest of the costs were borne by the firm of Bofors. The Swedish Air Force thus had to

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27 provide exclusively for the aviation part of the whole program. The results were to be made freely available to all participants.

Consonant with the standard methods used at the time to determine the ballistical properties of bombs, which information was essential for the setting of sighting devices to allow for the time of fall and the angle of drift while falling, bombs were dropped at night over a measuring base formed by brilliant phototheodolites with a vertical optical axis, while the bombs had tracers so that the trajectory would be visible on the photographis plate. A searchlight was mounted in the aircraft, its beam directed at the ground, and by means of a snychronized opening and closing of the camera shutters coordinated points of the aircraft course and the bomb trajectory were photgraphed. Since these timings were recorded precisely, in fractions of a second, by a chronograph it was possible to determine the distance and time factors of the bomb's ballistics uninfluenced by wind pressures.

28 Here is another note on the ballistics of bombs in general: Within the Inspectorate for Weapons and Equipment, which later became the Proving Branch of the Army Ordnance Office, there were initially some points of contention between airmen and artillermen. The Munitions Branch demanded that the test bombings should only take place when there was no wind in order to exclude wind influence factors in a

26a

Photo

Swedish Fokker C V Plane used in Tests of Bombs simple manner and had furnished a few PuW 2,200-pound bombs (which could have served as museum exhibits) from World War I, so that "one could better see the bombs falling."

The Aviation Branch had to point out that in our latitudes dead calms and aviation weather rarely occurred together, and that for the time being no plane was available which could carry a bomb of this size. Furthermore, in aviation the time in trajectory and the rearward drift of a falling bomb were not measured in relation to any fixed coordinates in the terrain but in relation to the plane itself, and that up to the moment of bomb impact on the ground the plane and the bomb were subject to the same wind influences (insofar as wind velocity and direction do not change in the lower air strata).

The current wind velocity and direction do not figure at all in bomb release chartd. Once the altitude has been read off on the altimeter and the aiming device has been set for the appropriate bomb time in trajectory and the rearward drift, the plane is steered on a course to cross over the target and only the wind velocity is measured during the final target approach run. The moment for release is then shown by the aiming device or the bomb is released automatically.

The difference between the two schools of thought was so great that the airmen were soon left a relatively free hand

29 in carrying out the tests. The artillerist continued to think in terms of the position of his gun, while the airman's coordinate, ~~the~~ his plane, was in motion in space.

The ballistic tests of the PuW bombs, considered the best available at that time, were carried out between September 1927 and March 1928 in the zone of the Swedish II Air Corps at Malmstätt. Subzero temperatures as low as minus 30° ~~degrees~~ centigrade made testing activities exceptionally difficult.

To outward appearances the scientific control was also in Swedish hands. The results obtained were to be available only to Germany and Sweden. Unfortunately, an indiscretion by an industrial concern once again occurred when the firm of Zeiss sold Lotfernrohr 2 bombing sights to other countries together with the newly computed tables. The German Army Ordnance Office was unfortunately unable to prevent this, at which Sweden took serious offence.

The most important result obtained in the bombing tests conducted in Sweden, however, was not the newly gained ballistical data for greater speeds and bombing altitudes. Rather, it was the finding of a serious defect in the PuW bombs, inherent in the structure, which it proved impossible to remedy in spite of all efforts. When released from altitudes above 14,850 feet (3,500 meters) the 110-pound and later also the 660-pound PuW bombs used as a countercheck, broke into numer-

29 numerous pieces while falling so that only fragments and loose

30 explosive powder reached the ground. During World War I this had never happened, although the bombs then used had also been in three separate sections, as was the case with the practice bombs supplied from Bofors. The bombs consisted of a thick walled nose piece welded to a thin walled center section while the steering tailpiece consisted of a conus with three vanes and ~~carried its explosive charge~~ and was screwed to the bomb body carrying the explosive charge.

The point of fracture was immediately discernible on the fragments of sheet metal found on the ground, and was the same in all cases, namely at the point where the vanes emerged from the conus and [illegible] at the weakest point of the conus.

In tests carried out during daylight it was possible to observe with the naked eye that the tailpiece first became detached and that the rest of the bomb then broke apart while hurtling downward.

An extemporary reinforcement of the conus with welded angle sheeting proved fruitless and serious doubts arose concerning the usability of the detonators, the functioning of which required a precise vertical bomb impact on the ground.

If the only trouble had been the stress resistance of the shell casing there would have been room for hope that BuW bomb casings made of one piece might have offered sufficient

30 ten tensile resistance to the centrifugal forces involved. If increasing aircraft speeds and increasing bombing altitudes placed the stability of the PuW bombs in doubt, however, this was a defect which could not be remedied by means of any local or general reinforcement of the bomb casing.

A minute examination of the broken-off steering vanes revealed that torsion was not the cause of the fractures, but bending stresses along the entire length of the bomb.

To explain these phenomena it is necessary to enter into more detail on the construction of the bombs.

The socalled PuW bombs were designed in 1916-1917 by the Optical Instute of C.P. Goerz, Berlin, to insure more precise bombing than was possible with the APK bombs supplied formerly by the Artillery Proving Commission (<u>Artillerie Pruefungs Kommission</u>) of the Army to the air units. The new bombs rotated during their fall, since their steering vanes were placed at an angle and not paralelel with the bomb axis. All other bombs used abroad had no rotation.

There were possibly two reasons governing this design: firstly, the activation of the trigger device by centrifugal force--the percussion pin only being released after a certain distance of fall, and secondly the highly perfected aerodynamic shape of the PuW bombs which required a bomb spin in order to insure stability in trajectory.

31 Tests were carried out using PuW bombs without rotation, but the results were unsatisfactory. With the increasing ~~drop~~ speed of fall the relatively small vanes came under the influence of burble of the bomb slipwind and thus could not perform its purpose. The bombs fell apparently in a ~~xxxxx~~ stable drop for a few thousend yards but then began to wobble and then turned over in the air, in doing which they also broke. Besides causing the bomb to rotate around its longitudinal axis, the purpose of the vanes was also to keep the bombs tagential with their fall parabola so as to reduce to a minimum the air resistance which would have increased their fall time and thus have reduced bombing precision.

When dropped from great altitudes the PuW bombs rotated so fast (speeds of 3,000 revolutions per minute were photogrametically recorded) that the bomb formed what might be called a gyroscope striving to maintain its axis in space and offering more and more resistance to the curve into trajectory until the tensile strength of the tailpiece was exceeded and the bomb tail broke off, causing disintregation of the bomb body due to centrifugal forces.

That these features only became evident at this stage and had not been observed during World War I must be ascribed to the increased aircraft speeds which had meanwhile been attained. At these increased speeds the trajectory flattened out more

32 (as described in the previous paragraph the test bombs dropped vertically when released from an anchored balloon) so that the leverage with which the force of the air exerted on the bomb's tail steering became longer, leading soon to a fracture. Difficulties of this kind are not encountered in other types of bombs.

For the higher part of the bomb's fall trajectory sufficient data was available after conclusion of the bombing test series in Sweden to compile the necessary ballistical tables as well as the bomb-release tables required for bombing sights, but in the field of ammunition technicalities serious uncertainties had been created.

What worsened matters was the fact that in the meanwhile the Troops Office of the German Defense Ministry had instructed Branch 8 of the Army Ordnance Preving Services to determine, by means of practical tests, the usability of the large commercial aircraft of the Lufthansa Airlines as temporary bombers. It was hardly advisable to recommend the procurement of bombs of limited usability.

32a

Fire serving as target

Impact of a 110-pound PuW practice bomb with tracer dropped from an altitude of 13,200 feet (4,000 meters)

CHAPTER II

DEVELOPMENT OF BOMBS IN 1926-1932

1. <u>Equipment of Makeshift Bomber Aircraft</u>. In 1926 the testing of certain military equipment within Germany was still prohibited. This included the strict prohibition of tests with airborne weapons.

The experience of the Defense Force (Reichswehr) with industrial concerns was very discouraging both in the matter of security and in that of finances. After closing down its works at Moscow the firm of Junkers had sued the German Government for compensation in the sum of 26,000,000 marks and had threatened to publish the secret documents.

The only course open to the Defense Force Command was to exploit the military clauses of the Rapallo Agreement. There was of course no intention to reveal the most up-to-date developments to the Russians, and this intention was still adhered to in 1940 when Russian commissions came to Germany after signature of the Moscow Agreement in August 1939, but the makeshift adaptation of commercial aircraft for use as bombers was nothing from which the Russians could learn. What they wanted to see was real bomber aircraft equipped with the most modern weapons.

Furthermore, the misadventures with the Swedish bombs could not be applied unreservedly to bombs of German manufac-

1 manufacture and, after all, the maximum altitude of the Junkers G-24 and Rohrbach Roland aircraft was below the critical altitude of roughly 15,000 feet (4,400 meters) and their speed was considerably less than that of the Fokker CV planes.

As early as in 1927-1928 a number of Puk bombs in calibers of 26 pounds (fragmentation bombs) and 110 and 330 pounds (mine-bombs) had been ordered from the firm of Maschinenfabrik W. Wurl, Berlin-Weissensee. The individual parts of these bombs were produced in various works as "middle buffer couplings" and were assembled by particularly reliable workers. The steering tails came from Silesia as ornamentation for fireplaces. Most of the bombs were given a training explosive charge and only enough for two live-ammunition missions by each type of aircraft used were filled with trotyl at the Kummersdorf artillery firing range.

The 220-pound Puk mine type bomb used so frequently in World War I was not reconstructed, since it appeared unnecessary as an intermediate caliber between the 110- and 330-pound bombs.

The fuzes had also been redesigned to metric standards. Each bomb type had a special nose or base fuze with various settings for delayed action. Experiments with standard fuzes in World War I had not been completed, so that great difficulties were encountered in the manufacture.

2 The bombs were copied at the Materials Proving Institute II of the Siemens Works in Berlin, all under guise of individual parts manufactured for various purposes.

Transportation of the ammunition to Soviet Russia was by sea from Stettin to Leningrade on specially chartered schooners. For testing purposes the Type G-24 and Roland aircraft had been equipped with machine-gun rings and bomb release devices prior
3 to their departure by way of Koenigsberg-Duenaburg-Moscow to Lipezk.

The machine gun to be mounted in the aircraft was the old Type MG 08/15, with a special shoulder piece, and the machine-gun rings for this purpose had also been constructed by the firm of Siemens-Schuckert. This firm had also designed the bomb release equipment for the G-24 planes, following the pattern of former equipment in which the PuW bombs were held by two steel cables. The bombs had no suspension eyes because these would have created difficulties in the case of rotating bombs.

The firm of Rohrbach in Berlin North had been allowed the opportunity to equip its Type Roland aircraft in accordance with the experience the firm had gained in foreign trade.

Both bomb release ~~mechanisms were~~ systems were mechanical, that is, wire cables led from the release cranks in the bomb aimer's cockpit to the release devices, which were combined in 3's to 6's according to the bomb calibers. Each aircraft was

3 to carry a maximum load of 2,200 pounds of bombs made up of 110- and 660-pound bombs as decided on the spot; adaptations to the equipment could be carried out with field facilities very speedily if required.

In the case of the Junkers G-24 low wing plane all bombs--3 at 660 and 15 at 110 pounds--were suspended under the fuselage side by side. The machinegun stand was on the upper fuselage in the middle of the passenger cabin, exactly as was the case in the middle section of the Junkers K-30 model. The plane could not take more bombs since their suspension under the wings would have been a relatively complicated matter.

4 Only minor modifications to the fuselage were necessary in the G-24, the biggest job being that of reinforcing the machinegun section. The long exhaust pipe of the center engine was replaced by a short one leading upwards, so that the bombardier, seated in the right-hand pilot seat, would have an unobstructed view of the Goerz Fl 219 bombing sight mounted on the outside. The bomb-release equipment was fastened by ordinary fittings clamped to the tubular spars of the middle fuselage section.

In contrast with this typical night-fighter type of equipment, the ambition of the firm of Rohrbach was to make their reinforced high-wing plane suitable for daytime action by giving it increased fire power, for which purpose the firm had

4 been given a free hand. Besides the upper rearward machine-gun stand, a bay for a machinegunner was attached to each of the two side engines, so that the Roland plane had triple the fire power of the G-24, in particular rear- and downward.

The bombload of the Roland plane was restricted to 2 PuW 660-pound bombs suspended far out under the wings beyond the lift wires, and 10 ~~XX~~ 110-pound bombs. Of the latter five were in a bottom opening and the release gear was to be reloaded with the help of a carriage when the first five had been dropped. It was also possible to reload the carriage if the risk was accepted of having loose bombs within the cabin.

Favorable as this bomb suspension was in aerodynamic respects, the advantages thus expected were more than outweighed
5 by the disadvantages of the disposition of the weapons.

The fastening of the bombs, which were suspended by only one cable in the Rohrbach, was an extremely slow process. The heavy caliber bombs were almost 10 feet above the ground, so th that a lift was necessary for the purpose, and reloading of the 110-pound bombs took more than fifteen minutes, during which the aircraft had to circle over the target area.

The bomb-aiming device used in the Rohrbach was the Goerz Fl 218 optical bombing telescope and the bombardier had no clear view of the target.

After transfer of the two experimental planes to the

5 German airfield of Lipezk, roughly 160 miles south of Moscow and where the Air Scietific Tests and Personnel Training Center (Wissenschaftliche Versuchs- und Personalausbildungsstelle Luft) was situated, they were outfitted by teams from the two firms and given aviation tests by the Weapons and bomb experts of Branch 8 of the Ordnance Office. A bomb aiming area of 988.4 acres was available in the vicinity of Lipezk and had been leased for the purpose. An 11.75-inch cement slab on a stone foundation 19.5 inches thick was placed in the center of the area to test the hardness of the bombs.

Following the mechanical and technical tests, the two aircraft were placed at the disposal of the air observer course training at the same place for a few flights in order to obtain a field opinion on the usability of the planes.

On the whole the simpler and more practicable equipment of the Junkers G-24 was given preference over that of the Rohrbach Roland model.

6 The latter model was to be resubmitted a year later, and thus in 1929, with aerodynamically improved machinegun cockpits and standardized Siemens bomb release equipment. This established the rule that in future the aircraft manufacturers when supplying aircraft for military equipment were to supply only the accessories sets specified for the type of aircraft involved which were needed for the mounting of gun mounts,

6 machine gun base rings and bomb release devices, while these latter items of equipment themselves were to be manufactured uniformly and supplied by special firms under the general heading of weapons.

The 26-pound PuW fragmentation bombs were intended for use only by reconnaissance planes and daytime fighters, and equipment for stick bombing in series of six had been designed, also by the firm of Siemens. The model used for test flights was the Junkers A-35, carrying two 110-pound and six 26-pound (12 kilograms) bombs. The tests were to show whether PuW bombs produced within Germany would encounter the same difficulties when dropped from altitudes of 1,650 feet as those which had arisen in Swedish manufactured bombs. However the results obtained in the tests were just as bad as those obtained in Sweden: the 110-pound bombs fractured at the same point and many of the 26-pound bombs richocheted, most of these failing to detonate. In a few cases the 26-pound bombs fell prematurely from their belt suspension, an occurrence which had frequently caused own losses in World War 1. Plans were therefore that a modern reconnaissance plane should carry these bombs in magazines of each five, in which the bombs would be held one above the other, an added advantage of this arrangement being the reduced air resistance. The two 110-pound bombs suspended under the wing roots, however, had no measurable influence on the aircraft

6 speed. In aircraft of the size used their length of 66.5 inches (170 centimeters) made it impossible anyhow to load them in magazines within the aircraft body.

2. Improvements to Auxiliary Bomber Aircraft; Resumption of Tests with Chemical War Agents (1929); Incendiary Bombs. In 1929 it also became necessary to thest the Junkers G-24 auxiliary bomber aircraft with additional equipment for the delivery of electron incendiary bombs.

In contrast with all other incendiary bombs used in World War I, this incendiary bomb had a weight of only 2.2 pounds and no experience whatever was available on its use in the field. All that was known was that while it was under development very serious difficulties had been encountered in the matter of its stabilization. Only after long series of tests was it realized that the stabilized trajectory was governed not by the length of the steering tail but by the sharp-edged flat nose of the bomb, which in the first series manufactured had had a semiround nose.

Wild hopes were based on the assumed effectiveness of the electron incendiary bomb. It was assumed that the high flash point of its magnesia charge would more than balance the disadvantage of its light weight and it was maintained that because of the oxyhydrogen gas it engendered, the bomb would be non-extinguishable.

7 Compared with the incendiary bombs used until then, which had a liquid filling and a weight of between 22 and 55 pounds, the electron B-1-El incendiary bomb had primarily the advantage that it had no waste weight. Apart from minute residues it consisted exclusively of combustible materials and nevertheless was heavy enough to penetrate house roofs. The principal advantage was, however, that it could be dropped in masses; this increased the probability of easily flammable material being struck within the target area.

8 In Germany, the 2.2-pound (1-kilogram) type of electron incendiary bomb was termed the "dispersion" bomb because, owing to its ballistically caused dispersion it had to be dropped in large numbers to strike a closely circumscribed target; in contrast, the incendiary bombs developed later, such as the Incendiary C-50 (<u>Brand C-50</u>) type, had a coagulated incendiary fluid filling and were termed "intensive incendiary bombs" because they could also set on fire less easily flammabable materials. During Wolrd War II Germany's opponents called their Napalm bombs "dispersion" bombs since they spread ~~the~~ their incendiary charge, and the hexagonal indendiary bombs "intensive" bombs because their incendiary force remained concentrated at one point.

It was no less a person than the firt Inspector of German Air Units, Lieutenant Colonel Siegert, who at that very early

8 stage already foresaw that when used in large numbers, the 2.2-pound electron indendiary bomb, because of the combined effect of the large number of small fires they could start, could cause what was called a "fire storm" within a town, and used the German equivalent--Feuersturm--" in a tactical order to the 3d Bomber Wing in 1918.

Weeks of hard work had been spent on reequipping the Friedrichshafen G-III and Gotha G-IV aircraft of the wing for the use of electron incendiary bombs, with which the wing was to attack Paris. Suddenly the order for this attack was countermanded. The concept of a "fire storm" had caused concern at Army High Command: already burdened with the guilt of having initiated chemical warfare in 1915, and overestimating the effectiveness of the electron bombs, the Army High Command was reluctant to accept the risk of using them at a time so critical as the summer period of 1918 was for Germany.

It is interesting by way of comparison to mention here the dropping of the Atom bombs over Japan in August 1945, at a time, thus, when America had already won the war, the object being to prevent the efforts expended on its ~~developed~~ development being wasted and at the same time to warn Russia. In contrast, both sides in the 1918 conflict believed that World War I would be the last world war.

In the large-type aircraft mentioned above, the bodies

9 were loaded full with magazines which ejected the B-1-El incendiary bombs in salvos of five. Consonant with its increased speed, the G-24 model plane was equipped with an experimental device to eject salvos of between 10 and 20 bombs.

Besides the G-24 and the Roland models, the single-engine M-20 Messerschmitt commercial plane was also equipped in 1929 as an auxiliary bomber, since planes of this model had been ordered in larger numbers by the Lufthansa Airlines for use on short routes. It was given a machinegun ring on the top of the fuselage and two magazines, each containing five 110-pound PuW bombs were placed in its cabin. The co-pilot served simultaneously as the bombardier and aimed through a type Fl-219 Goerz nightsighting device mounted outside on the fuselage as was the case with the G-24 plane.

In the case of the Rohrbach Roland plane, the undercarriage supports were lengthened, so that three 660-pound PuW bombs could be suspended under the fuselage; this made it possible to suspend five 110-pound bombs under each of the wings.

By the end of 1929 the testing of the three auxiliary bomber aircraft with the equipment discussed above was completed, the Observer School having previously declared that this equipment was usable under the given circumstances.

Both in its ballistical properties and its incendiary ~~pxa~~ effectiveness the 2.2-pound electron incendiary bomb functioned

9 satisfactorily, the only drawback being the time spent in loading the magazines, the process being far too slow. In the further
10 improvement of packaging and in the development of bomb-release equipment it was essential to insure that an aircraft could, without any appreciable reconstruction, carry the same weight in incendiary bombs in place of the explosive bombs for which it was originally intended. The dispersal of the small bombs was so wide that even if fired in salvos of 40 to 50 they would not fall too closely.

In low altitude bombing with 110-pound PuW bombs a further defect became apparent: when fitted with an all-around Mine-type time fuze set for 30 seconds, all bombs broke on impact on the concrete slab. The PuW bombs had been designed only for use in high-altitude bombing.

The explosive-bomb problem thus remained unsolved in 1929. As previously mentioned, experiments had been made in dropping 26- and 55-pound PuW bombs with straight steering vanes to preclude bomb rotation. Since the PuW fuzes functioned with a centrifugal release, a new type of fuze had to be ~~developed~~ used. The device adopted here was the electrical impact fuze developed by the firm of Rheinmetall, Soemmerda, which later played such an important role in the introduction of completely new bomb shapes. However, the non-rotating PuW bombs were just as unstable in trajectory as the normal bombs of this kind.

10 A project of very high priority for the coming year was the replacement of the old PuW type bombs by bombs of more up-to-date construction.

After an interruption of two years, work was resumed on tests with the airborne use chemical warfare agents which had ceased in the vicinity of Moscow in the autumn of 1926.

The gas polygon near Uchtomskaya had become too small for the large scale tests planned by the Russians, who had there-

11 fore evacuated the population from an area near the small town of Volsk (roughly 60 miles north of Sarativ). This area had an extent of more than 24,700 acres and was kept constantly sealed off for the carrying out of tests.

The German Army High Command placed great value on a separate and independent evaluation and processing of the results of tests carried out. For this reason the Experimental Station Tomka was established. From 1929-1931 this station cooperated with the Russians and it was staffed not only by aviation personnel but also had a considerable number of chemical, biological and medical research personnel and was subordinate to the Army.

The chemical ejector known as <u>Giessgeraet G-125</u> had in the meanwhile been improved and was now designated Chemical Spray (<u>Spruehgeraet</u>) S-125, because it used compressed air to force the chemical agent out of a pipe protruding rearwards at the same speed at which the aircraft was travelling.

11 In this way the mustard gas, to the very last drop, could fall freely downward once it was out of the pipe and was not dispersed by the plane's slipwind as had been the case when the old type of ejector was used.

There was a typical difference between the views held by the German gas tacticians and Army chemists on the one hand and their counterparts on the Russian side. The German side considered a minimum saturation of 5 grams mustard gas per square meter essential to create "yellow areas" through which enemy troops would be unable to move except at a grave cost in casualties. Experience showdd that for this purpose it was essential to have droplets as evenly sized as possible with a diameter of 3-4 millimeter and that in order to properly saturate specified areas, the planes would have to operate at altitudes of approximately 330 feet. In the enemy rear and for offensive purposes, however, use was to be made of gas bombs which would be delivered on the target area from high altitudes.

In contrast with the German views, the Russian objective was all-out chemical air warfare, using large masses of chemical agents.

A As early as in 1930 the Russians carried out squadron-size exercisesin which as much as 6 tons mustard gas were released simultaneously from an altitude of 10,000 feet. For

12 this purpose the Russians had used their model R-5 reconnaissance aircraft, suspending two type VAP 200 containers under the wings to spray the gas.

The thoroughness with which the Soviets even at that early stage were preparing for gas warfare is illustrated by the fact that at the edge of the maneuver terrain they also demonstrated a large vehicle company in action for the decontamination of a complete battalion at wartime strength within a half-day.

Within a few seconds after release from the aircraft at an altitude of 10 000 feet, the gas clouds were no longer visible behind the aircraft. The onlookers were requested to wait a few hours until gas detector personnel had marked off the contaminated area.

The after-action inspection showed that an area of several square kilometers (1 square kilometer = 247.104 acres) was so slightly contaminated that traces could only be detected by means of absorption instruments.

The reply to a German question as to the purpose of such a weak concentration was: "The Polish soldier is also a proletarian! we do not want to kill him but only to give him an opportunity to escape the orders of his superiors when he becomes ill after crossing the contaminated terrain."

13 In actual fact, the Soviet Russian system was suitable for

13 the conduct of airborne gas terrorization attacks against the entire population of densely populated areas and cities.

At a later stage the Soviets also developed a whole series of gas bombs, containing various types of gas and varying in caliber between 33 and 440 pounds.

In order to be able to use persistent types of chemical warfare agents in high altitude attacks, the German side developed 200 liter-(1 liter = 1.0567 liq.qts.) time-fuze bombs and tested them. Only a very small explosive charge was necessary to disintegrate the thin bomb wall, so that the oily mustard gas did not burn. When dropped from the usual test-bombing altitude of 13,200 feet, the bombs were exploded for practical purposes at altitudes between 660 and 990 feet above the target. The released liquid formed a vertical pipe-like cloud approximately 220 yards long, which settled down to the ground in the direction of the wind, contaminating a ground surface area roughly 330 to 440 yards in length and 55 yards wide.

One drawback in the use of these time-fuze bombs was that it was not possible to place such terrain obstacles in the vicinity of friendly positions and that the longitudinal axis of the contaminated area was rarely in the desired direction.

In these tests use was made of a modified AAA clockwork time fuze which was set in operation by pulling out a switch prior to dropping. This "arming" of the bomb had to take place before the bomb was suspended under the plane.

14 With development of the spray apparatus and the time-fuze bomb mentioned above, tests with the use of chemical warfare agents from aircraft could to a certain degree be considered as having brought to some degree of technical completion in 1929. The 1930-1931 tests in Tomka had to do in chemical and physical aspects only with the warfare agents as such and with their biological effects, test activities with which the aerotechnological experts had nothing to do.

It was only after Germany's rearmament that the tests with gases were resumed in Germany, as will be described in the next chapter of this study. Main emphasis in these later tests was on the development of gas bombs with impact fuzes, because this was the simplest method.

3. Development of New Types of Demolition Bombs (1930).

In the winter of 1929-1930 interest was concentrated on the development of new types of demolition bombs and fuzes. It was obvious that completely new solutions would have to be sought. The large night bomber, a 4-engine Dornier P plane, was already under construction. Patterned on the "Giant" aircraft of World War I, this plane was to carry bomb loads up to 3 tons. The Do-P had been designed for the loading of PuW bombs and could not be converted in 1929 to use the new types of bombs. However, the experience gained in loading the old types of bombs into the Do-P were of great value in the

14 development of new aero bombs. Above all, it was the excessive length of the PuW bombs which had made them so difficult to load into the bodies of aircraft. Even the small 110-pound PuW bomb with its diameter of 180 mm had a length of 170 centi-

15 meters, while the 660-pound PuW bomb was all of 280 centimeter in length, giving thus caliger lengths of 950 and 800 centimeters, and thus triple that of artillery shells. Furthermore, these bombs had an accentuated torpedo shape, which was expensive and complicated in the manufacturing processes.

Following the ballistically unfavorable ball- and pear-shaped bombs produced prior to World War I by the Army Artillery Proving Commission (Artillerie-Pruefungs-Kommission) and/or by the various explosives manufacturers themselves, the firm of optical instrument makers C.P.Goerz, Berlin, in 1915, followed up wind-tunnel experiments by recommending strict streamlining for aero bombs in order so to reduce ballistically caused dispersion that their optical bomb aiming instruments could be used to advantage when bombing small size targets.

At that time the aircraft had been so small and slow that the bombs were suspended outside, exposed to the air currents, without any thought of loading them inside the aircraft.

The 26-pound (12 kilogram) PuW bomb was comparatively thick-walled for use as a fragmentation bomb against personnel.

15 In contrast with British and French aero bombs of that period, which were all thick-walled, It was recognized at an early stage in Germany that after a bomb had penetrated the force of the exploding gases did more to destroy inert targets than the destruction caused by the bomb fragments, for which reason the 110-, 220-, and 660-pound bombs, and later also the 2,200-pound caliber bombs were developed as thin-walled mine type bombs. They had nose fuses, that of the 26-pound bomb being an advanced ignition fuse while the mine-type bombs had late ignition fuses. To insure detonation the larger calibers also had a base fuze. All fuses were of the rotation-cocking type, as used in artillery shells.

16 That thin-walled mine-type bombs were the proper solution was proved when the British, profiting from experience during the German bombing attacks against targets in England in 1941, replaced their thick-walled general purpose bombs by thin-walled mine type bombs.

The air resistance offered to a projectile in flight is made up of two factors: conformation and friction resistance. The latter resulting directly from the surface area of the projectile, it was obvious that shorter bombs with slightly greater conformation friction factors would have good trajectory properties if they were properly stabilized while falling.

During World War I the Americans used British and French bombs, and it was they who first introduced bombs with

16 a cylindrical middle section stabilized during their fall by relatively short stabilizing vanes. The steering unit in these bombs was a box from which the four actual steering vanes protruded beyond the outer circumference of the bomb. During bombing tests it was found that the cylindrical shape had certain inherent stability factors and that the protruding vanes during the fall were always in a laminary position related to the air current, which prevented bomb wobble.

Normally, bombs are suspended lengthwise and with the nose facing forwards. Here the French and Italians were exceptions, since they always suspended bombs in their aircraft perpendicularly. Being armed with nose fuses, they were always suspended with the steering tail up.

Perpendicular suspension is admittedly somewhat unfavorable for ballistic reasons, since the released bomb must first
17 right itself to the tangential fall trajectory and only does s so after some swervings, the amplitudes of which are governed by the bomb center of gravity and therefore vary somewhat. The great advantage of vertical suspension of the bombs in the aircraft is that the exit for the bomb magazines in the floor of the aircraft need only be the same size as the bomb caliber. In the Junkers construction system of spread spars (aufgeloestes Holmsystem) the distance between spars in the fuselage middle section was only a few decimeters and in

17 aircraft of other structure the floor required considerable reinforcing if the bombs were to be loaded horizontally in the magazines.

Another favorable factor on the vertical magazine was the stability of the suspension by one point and the absence o of the risk that bombs with cocked fuses could fall one onto the other if the lowest bomb for some reason or other failed to fall free.

Planning in the winter of 1929-1930 therefore required great foresight if all requirements for the new types of bombs were to be met.

Prior to World War I the ammunition experts of the Army had been responsible for the development of the APK or Carbonite bombs, with no consideration being given to aviation requirements. During World War I it had been a firm of optical instrument makers who had overestimated the aerodynamic influences and had introduced the ballistically over-accentuated PuW bomb designs. .

Now, however, responsibility rested with the aviators of World War I, who meanwhile had learned how to construct aircraft and who had many years of experience in air bombing before they were assigned the mission of designing new bombs.

19 In the matter of target effect it was obviously necessary to adhere to the proven sub-division in small fragmentation bombs and larger-caliber mine-type bombs in the

18 work of developing the new type of "C" bombs as they were designated, because of their shape.

For reasons of simplified manufacture all bombs were given a cylindrical middle section, with an ogivale nose section and a short steering or stabilizing tailpiece.

In establishing the diameter of mine type bombs the determining factor was the the diameters preferred by the steel rolling mills in Germany producing seamless pipes, since this made it possible to make extensive use of their installations in the procurement of this type of armaments.

The new Type C bombs had to be roughly one-third shorter than the old PuW bombs if their loading in aircraft was to be appreciably facilitated, and if possible they were to be suspended vertically in certain aircraft models. To meet this latter requirement it was not possible to keep the steering tail ~~xxxxxx~~ section of the C bombs as short as was the case in the American "Demolition Bombs", where their length was only approximately one-quarter of the overall bomb length, since the American bombs were dropped exclusively from horizontal suspension.

Without discussing the tests carried out, it can be said here that results showed that the steering tail of the Type C bombs had to be approximately one-third of the overall bomb length to insure satisfactory ballistics when dropped verti-

vertically. Furthermore, in contrast with the Italian and French system, the Type C bombs were suspended by the nose, so that the stabilizing vanes would be out of the plane floor first where they would immediately be forced backward by the slipwind, their proper position while falling. This completely obviated bomb tumbling and the swerve movements were completely normal until the bombs became quite steady in the falling trajectory. As was the case with the trail angle of bombs dropped horizontally, the swerve process into trajectory (Einpendelungsvorgang) was governed by the speed of the aircraft, so that the forward travel of vertically dropped bombs is slightly shorter than in the case of bombs dropped from the horizontal. However, this factor could easily be compensated by an appropriate setting of the aiming device.

Nose suspension was only made possible by the fact that the electrical ignition was developed as a central ignition fuse placed horizontally in the bomb a few centimeters from the suspension ring and thus in the center of the explosive charge.

Since the Type C bombs were non-rotating, they could have suspension rings as had proved practical in the case of all other bombs. This did away with the troublesome cable suspension system, in which the cables ~~had to be~~ were difficult to fasten and did damage to equipment when blown about by the

19 wind after the bombs were released.

One important decision still remained to be taken, that of whether the type C bombs should be suspended by one ring, as was done by the Royal Air Force, or by two rings, as was the case with the US Air Force, in the bomb release equipment. The governing factor here was that of safety. With two-ring suspension the possibility exists that only one ring might be released, leaving the bomb suspended by one ring until it drops off unexpectedly, possibly over friendly territory or, in the worst case, during the landing of the plane. However, safety here had to be obtained at the cost of extra expenditure in the case of horizontal magazines, in which the bombs had to be specially secured. In the vertical suspension system, in contrast, matters were simplified.

In the matter of the development of new fuses also, the experts in the Air Weapons Proving Branch (Branch 8 of the Army Ordnance Office) had to go their own way, although all instructions to the industry were still channelled through Bra Branch 1 (Ballistics and Ammunition).

A person who has never sat in the pilot seat of an aircraft will not be in the position to create usable equipment for air units even if all conditions are precisely prescribed for him. This became particularly evident in the case of the mechanical impact fuse for the SC-10 22-pound fragmentation

20 bomb, the first bomb produced in the new series. This bomb had a nose fuse No (3), which could be set at supersensitive for high-altitude bombing or at 5-seconds dealy action for low-altitude bombing. The setting had to be done before the bombs were suspended in the aircraft. Although it proved possible in many years of testing to remedy the inescapable minor defects of this fuse, it remained nothing but a modified artillery shell fuse not basically suited in its structure for the different combat conditions of air units, and it remained the cause of a whole series of serious mishaps during transport and during loading operations. The worst of these was the explosion of an ammunition ship in the port of Tripolis in April 1941.

The development of the fuse is described in Part B, Chapter III. All that need be said here is that from the outset the principle of electric ignition Appeared predestined for use in bombing. In many years of cooperation with the firm of Rheinmetall, Soemmerda, the bomb experts of Branch 8 succeeded in developing a condenser ignition which was charged 21 at dropping and which was safe for use by troops in the field. Tens of thousands of test fuses were dropped in experiments without a single accident before the Air Force General Staff authorized their introduction for use by the troops.

Added to the above factors was the fact that even before

21 Germany started rearming the manufacturing facilities available in the precision instruments industries, particularly in the watchmaking factories, were barely adequate to cover the requirements for fuses needed by the artillery. So far as possible, bomb fuses had to be procured from some other branch of the manufacturing industries. Against the background of the entire branch of ~~industry~~ electro-technical industry specializing in low-voltage instruments, the Type E (Electrical) fuse seemed predestined for the development of aero bombs.

Influenced by the ballistical reverses encountered in the tests with PuW bombs and by failure of experiments at equipping a modern large bomber for their use, the Troops Office of the Defense Ministry in the autumn of 1929 approved a recommendation by Weapons Proving Branch 8 that an immediate start should be made at developing new bombs of the Type C and allocated a special fund of 30,000 Reichsmark out of the current budget for the purpose. With these funds approximately 200 SC-10, 100 SC-50 and 25 SC-250 bombs were produced, together with fuses, which were tested in the field at Lipezk in the summer of 1930. Not a single test drop was allowed within Germany to determine whether they would be stable in falling, and only a few tests could be carried out in wind tunnels. That such a small sum was sufficient for so important a development was due to the fact that the bombs were constructed by

21 the Army Ordnance Office in its own installations.

Two single-engine Junkers W-34 planes were equipped for the 1930 tests. Main emphasis in testing the new type C bombs was on their ballistical properties, for which reason special importance was attached to the powering of these aircraft with high-altitude engines.

At that time the German engine industry had not yet produced an adequately powerful air-cooled engine, for which reason the one ~~xxx~~ plane was powered by an original American Hornet engine while the other was given a Siemens copy of the British Jupiter engine. The latter failed after a few high-altitude flights and was replaced by an original Jupiter engine.

One of the two aircraft previously mentioned was equipped to carry four 110-pound SC bombs suspended under the fuselage and had a horizontal magazine for six 22-pound (10-kilogram) bombs. ~~[illegible] the cabin there was also equipment for the vertical release of one 110-pound SC bomb.~~ The reserve plane was equipped to carry one 550-pound SC bomb under the fuselage and in the cabin had equipment for one vertical 110-pound SC bomb.

The bombings with the horizontally suspended SC-50 bombs at the bombing exercise grounds in Russia were photogrammaterically recorded just as had been done in Sweden 2½ years previously. Since the new bombs were non-rotating

22 the tracer elements were not built into the sides but into the nose, from where the the ray could shine directly into the camera objective. The only tests with the SC-10 and SC-250 served the purpose of determining the forward travel of these bombs in comparison with the SC-50 by dropping the different bombs simultaneously.

The point in the air at which the bombs to be ballistically metered left the aircraft was shown by a vacu-flash (Vakublitz).

23 All SC-10, SC-50 and SC-250 test bombs fell satisfactorily without rotation, ballistically, in fact better than the PuW bombs because the rotation could only be produced by air friction and this resulted in a slower fall and thus in wider dispersion. As previously mentioned, the vertically dropped SC-50 also showed very good ballistic behaviour.

However, some difficulties were encountered with the fuses, both the mechanical nose fuse of the SC-10 and the electrical sidewall fuses of the SC-50 and SC-250.

Most of the bombs were dropped as normal training bombs, with a non-explosive filling, and only a few were dropped with a Trotyl charge towards the end of the test period at Lipezk. These tests showed that the experimental electrical fuses had an undesirable lag and detonated much to deep in the ground. Purely in electro-technical respects the fuses functioned satisfactorily insofar as the charging at bomb release, the adherence to the proper cocking time and the impact contacts were concerned. However, the igniting agent itself took too long to bring about the detonation, the estimated time being 0.1 second, and in that time the bomb had already penetrated to its greatest depth in the ground. As explained in Part B, Chapter III, that point does not correspond to the point at which the best explosive effects are realised. Furthermore, with a fuze of this type it would not be possible to secure undelayed detonation, which is required in certain situations and against certain types of targets to obtain full advantage even with mine-type bombs(as had been shown already in World War I) when better results could be expected from air pressure and fragmentation than from the specific mine-type blast.

At this point it is necessary to draw attention to an erroneous and misleading nomination for bombs which became widespread during the war, in that bombs producing results primarily by air pressure were designated mine-bombs or simply mines. Possible this designation is due to naval mines, which were occasionally dropped by parachute over large area targets and, if landing on firm ground, were exploded by their emergency fuses.

However, the military concept of a "mine" in any event presuppose an enclosing of the explosive charge, whether this

24 is by means of an underground tunnel drilled to an enemy held position, underneath which the explosive charge is placed and then exploded, or by means of the surrounding water in the case of a naval mine.

Mine-type bombs, the effectiveness of which depends on surrounding ground or water pressure, as a rule have delayed action detonation so that they will penetrate deeply into the target before exploding, and are the type of bomb most commonly used. Bombs with a high explosive-charge to overall-weight ratio (the explosive charge making up 70-80% of the total bomb weight) can only be used with non-delayed action fuses, their casing being too thin to permit penetration into the target. They are designated "High Capacity Bombs."

Returning to the 1929-30 tests the essential condition for continued experiments in the following year was that electrical detonating fuses must be further developed to secure accelerated detonation. In the past these devices had been used only in mining and road building and similar activities. For these purposes the slow detonation was adequate, but not for the ignition of shell and/or bomb explosive charges, where differences of even less than one-thousandth of a second were crucially important.

The mechanical nose fuse with its membrane mechanism was admittedly exceedingly sensitive and the artillery shell

24 percussion cap No 26 insured very quick detonation, but its
25 reliability for bombing purposes did not meet the specified
standards. The cocking delay was set by a mechanism and the starting of it permitted such small tolerance limits that these could not be achieved with the horizontal bombing magazine.

4. Continued Tests with Demolition Bombs (1931). In the summer experimental period of 1931 main emphasis was on the SC-250 bomb caliber in horizontal suspension. As had been done with the SC-50 in the previous year, photogrammetric recordings were taken. Tests with the SC-50 in this period were primarily during daylight with bomb release from vertical suspension.

This arrangement of horizontal suspension for the SC-250 and vertical suspension for the SC-50 bombs was regarded as a preliminary for the equipment of the medium night bomber plane which the firm of Dornier, Friedrichshafen, had been instructed to design as the Do-11. This was not a departure from horizontal loading of the SC-50 bomb. Horizontal loading remained important since, in the case of smaller aircraft, these bombs could only be suspended outside, as for example, in the case of the Heinkel-45 reconnaissance plane and the dive-bomber Stuka Heinkel-50. Furthermore, it was not possible to predict how vertical bomb release would function at higher

25 aircraft speeds.

In order to overcome the difficulties encountered in the use of mechanical nose detonators a new rule was established to use 22-pound SC bombs only vertiaclly loaded, namely, in Arado-65 fighter aircraft and in the Heinkel-46 close-range reconnaissance plane. Operations by these types of planes did not call for individual bomb releases, but only for stick releases in series of 5 fragmentation bombs.

To facilitate matters for the aircraft crews, the Vemag-5-C-10 bombing equipment was provided with an automatic mechanism set in motion by a push button and functioning by a Bowden control cable. The fuse was cocked at release by the withdrawal of a plug, 5 centimeters long, longitudinally, and thus in the direction of the drop, from the bomb. During this operation the SC-10 was suspended with its plug in the lock of the vertical magazine and thus with its nose fuse upward.

Prior to loading of the bombs into the aircraft, the No. 3 percussion cap could be set at sensitive or delayed action (3 seconds after impact). The latter was intended for low-altitude attack action, in which fighter aircraft were used at that time. To prevent loss of effectiveness due to penetration of the bomb into the ground, these bombs had no steering tail, so that they bounced off the ground. Here it was admittedly not possible to avert the possibility of bombs

26 "bouncing" over the target, but this also happened in the case of larger caliber bombs.

The electrical impact fuse for Model 1931 mine-type bombs was again too slow in this years tests, the time for detonation of the explosive charge having been specified at 0.003 seconds. A parallel development of a mechanical xxxx sidewall fuse gave satisfactory detonation results but was not adequately safe in handling. Furthermore, it had to be pre-set on the ground at non-delayed action or with-delayed-action, whereas the setting could be selected shortly prior to the bomb release in the case of the electrical fuse. In the matter of safety during transportation, a consideration to which the Air Force attached great importance, the electrical fuse was also far superior. For these reasons the decision on its official adoption as the standard bomb fuse was postponed for another year in the hopes that it would be possible by then to give it accelerated action.

In the early years of development of the German Air Force the use of bombs in low-level attacks had been an exception and, as previously mentioned, the PuW type bombs were not suitable for this type of combat action if the target attacked had a hard surface, as, for example, in the case of concrete roadways or concrete floors in sheds. In 1931, however, the Troops office (later General Staff) stated the requirement

27 that bombing with ~~xxxxxxx~~ large calibers and normal and type bombs ~~xxxxxxxx~~ from flight altitudes of 33 to 330 feet was to be practiced as standard tactics, moreover, if possible even without any change to the fuze timing. At Lipezk, the concrete slab used in the past to determine the hardness of bombs from high altitudes was now also treated to determine the hardness of bombs dropped with a non-explosive filling from low altitudes. Although the new type bombs initially could only be supplied with welded casings, they proved considerably tougher than the old type bombs. This was because of their stocky shape and it was safe to assume that they would bestrong enough to meet all requirements of the times once removal of the secrecy requirements made it possible to manufacture the mine-bomb casings in one piece from drawn metal.

However, it was clear that electricity offered the only possibility to obtain fuses capable of a triple function: non-delay, delayed-action, and extended delayed action (lasting a number of seconds).

5. The End of Bomb Testing in Foreign Countries (1932). 1932 was the last year in which aviation and bombing tests were carried out in foreign countries by the German Air Force being secretly built up. After Hitler's accession to power the research and testing station at Lipezk in Russia was discontinued, that at Tomka having closed down already in 1931.

2 The tank proving station at Kasan also closed down in 1933.

The most important result of the tests carried out abroad was the data obtained on aerial bombing and on the airborne use of chemical warfare agents:

a. A series of modern type bombs in calibers of 22 pounds, 110 pounds, 550 pounds and 1,100 pounds had been developed, besides impact fuses for use in all types of attack and to achieve various effects;

b. Bombing equipment had been successfully tested for the following aircraft types:

Ar-65 fighter; He-46 reconnaissance (close-range);
He-45 reconnaissance (long-range); He-50 dive-bomber;
He-59 naval multi-purpose; Do-11 night bomber;

c. In the field of chemical warfare spray equipment had been developed and was available for the airborne use of diluted mustard gas as well as bombs for use with Blue and Green Cross classes of gases.

In more detail, the following remains to be recorded on activities in 1932:

a. the SC-500 "super" mine type bomb was the old ~~550~~x250-puund bomb enlarged by a pantograph shaped extension and caused no difficulties when used by Do-11 and He-59 planes. It was suspended horizontally under the plane, had two fuses, similar to the SC-250, and initially was available only with welded casings;

In the matter of fuses, the hopes placed in the development of electrical fuses had materialized. The sensitivity was successfully reduced to a lag of a few one-thousandths of a secons, so that there was no longer any obstacle to their introduction as standard equipment;

b. The medium night bomber Do-11 had been fitted with mechanically functioning bomb release equipment, with four SC-250 bombs so suspended under the fuselage that they in no way hindered the release of the twenty SC-50 loaded inside the plane in four type Vemag-5-C-50 magazines.

In place of the 20 SC-50 bombs, the plane could carry an equal weight of 22-pound fragmentation or 2.2-pound incendiary bombs (Electron) without any time-consuming reconstruction and merely by the use of Type Gr-4-C-10 or BSK-36 bomb containers. The plane naturally could also carry any desired mixed load of the bombs mentioned.

The bombing equipment thus installed in the Do-11 made it possible to meet all tactical and supply operation requirements. Unfortunately, however, the flight properties and performances of the Do-11 were so unsatisfactory, and a later development, the Do-23, had such serious defects resulting in wing breakage , that these models were discarded in favor of the Junkers-52 when rearmament commenced in 1933.

In view of the highly diversified purposes for which the Heinkel-59 was to be used, the bombing equipment for this aircraft had been based completely on electrical equipment. Consonant with its use as a normal or torpedo bomber, the plane could carry any one of the following ~~mixed~~ loads:

a. Two SC-500 or five SC-250 bombs suspended underneath the fuselage or twenty SC-50 bombs in horizontal magazines inside the plane.

29 b. One 1,760-pound torpedo bomb suspended under the fuselage.

c. Two 1,100-pound LMA ground mines or one 2,200 LMB ground mine, for remote detonation, suspended under the fuselage.

d. One 2,200-pound anchored mine with contact fuse, which was carried upright inside the plane instead of the bomb magazines.

30 Special equipment outfits were held available for these various purposes, by the use of which the He-59 could be adapted for current purposes. One advantage here was that the different bomb-release mechanisms merely had to be plugged in to the existing contacts.

Although th bombing euqipment of the Do-11 and that of the He-59 palyed no important role in the procurement activities which soon commenced for the new German Air Force, successful work had been done in the fundamental designing and ~~equipment,~~ construction, and it was possible to modify the equipment thus developed for the new types of aircraft which came into use in the rearmament program from 1933 on.

After a buffer had been mounted under the H-50 dive-bomber model to divert the falling bomb outside of the propellor circumference, no difficulties were encountered with the bomb egress from the release equipment when the plane was in vertical flight.

In the matter of bomb sighting devices, the Do-11 had

30 had the Goerz Rl-219 mechanical night bombing sight, while the [illegible]-59 was equipped with the Goerz/Boykow Rl-21d opto-automatic bombing telescope, which proved suitable for its purposes.

In the matter of airborne chemical warfare things had become more quiet once the technical possibility had been properly explored. As previously mentioned, field tests at Tomka had been completed already in 1931. Main emphasis had been on research into the chemical and biological aspects.

Parallel with the development of new demolition bombs a new chemical bomb had been designed. In its outward shape it corresponded to the SC-250 bomb, but was made of 1-mm metal sheeting, and could carry 220 pounds of mustard gas.

31 Tests had also been conducted, based on the Russian pattern, with large spray containers with capacities of 200 and 300 liters (1 liter=1.0567 liquid quart). These were designated S-200 and S-300, but in tactical respects serious problems remained to be clarified, a factor which also contributed towards the decision to discontinue this work.

In summarizing, it must be said of the tests carried out in foreign countries in 1926-1932 that in the field of airborne bombs and bombing equipment these tests had created the possibility to clarify the fundamental problems and to

31 advance the status quite appreciably after World War I.

In addition, a cadre of experts had been trained in Officewho could now be assigned more important missions within the scope of the new rearmament program and the establishment of a separate Air Force. On the basis of the experience they had gathered, these men were well qualified to bring th these plans to realization without remaining dependent on the other branches of the armed forces, from which they had completely separated themselves so far as their views were concerned.

31a

Photo

31b Photo

CHAPTER III

AERIAL BOMB DEVELOPMENT IN WORLD WAR II

1. 1933-1935. During the period preceding Germany's proclamation of her military sovereignty, namely, between 1933 and the spring of 1935, and following Hitler's access to power (in January 1933), the most urgent requirement was not only to activate fighter units for national defense as speedily as possible, but also to give the new German Air Force properly equipped bomber groups so as to be able to counter foreign action in the event of any foreign interference in Germany's internal affairs.

The preceding chapters have described how, in the matter of bombs, the basic data had been developed and made available which would enable the German industries to prepare for mass production.

The former air specialists of Branch 8 of the Army Ordnance Office/Weapons and Equipment Proving Department and of the Procurement Services had meanwhile been transferred to the Technical Office of the newly established Air Ministry.

From the very outset it had been established as aprinciple of the new German Air Force that the proving agencies of the Air Ministry would not engage in designing and construction activities, as was the case with the Army and the Navy, but would confine themselves exclusively to supervising

1 the execution of designing and development contracts they would assign to industrial concerns. Air carried tests were to be conducted at the Rechlin and Travemuende proving stations so far as items of equipment were concerned; bombing tests, however, were to be carried out exclusively at artillery firing ranges under cover of artillery firing practice to be carried out at the same time.

Industrial concerns had designed and developed bomb release and bomb aiming equipment since 1928 and the manufacturing facilities of the firms of Siemens and Zeiss-Ikon were adequate to meet current requirements in these lines for prewar purposes without any factory expansions. Smaller firms participating in the work of designing and development, such as C. Heber, Britz (bomb release equipment) and H. List, Steglitz (automatic bomb release equipment), established factories in provincial areas, generally with State assistance.

The same applied to bomb fuses. The Rheinische Metallwaren Fabrik concern had worked on the development of fuses and for current purposes, at least up to 1939, had adequate manufacturing facilities in Soemmerda, Thuringia.

Conditions were different only in the matter of the bombs as such. These had been planned and designed in the engineering department of the Army Ordnance Office and contracts for manufacture of the relatively small requirements had usually

2 been awarded to small machinery factories. In the past the filling of the bombs with their explosive charge had been done at the filling plants of the Kummersdorf Artillery Firing Range near Berlin.

At the start of rearmament in 1933 firms therefore had to be found which were willing to take into their employment considerable numbers of specialist personnel for the construction of bombs and were prepared to install workshops to manufacture samples, in return for which they were offered prospects of large serial production contracts which were to follow almost immediately.

The firm of Krupp, Essen, had to refuse manufacturing contracts for the new Air Force since its installations were required in full for the Army and the Navy. The Swedish firm of Bofors refused to participate in the development of bombs for Germany.

However, the firm of Rheinmetall declared its willingness to redesign the SC-50, SC-250 and SC-500 bomb casings in its main Dusseldorf works for manufacture in one piece instead of in three sections as they had been manufactured in the past. In this work the firm benefited from its experience in the stamp-and-draw process of Professor Ehrhard, which process it had used since 1929 in the manufacture of artillery ammunition, being the sole licensee for such manufacture in Germany.

3 Consonant with the principle of not allowing itself to become dependent on one firm alone, the Air Force also induced the firm of Vereinigte Oberschlesische Huettenwerke, Gleiwitz, the largest of the World War I bomb manufacturing firms, to install a designing and development office for the development of special type bombs, starting with the SC-10 fragmentation bomb.

The small numbers of Electron incendiary bombs used in pre-1933 tests had been manufactured by the firm of Hagenuk, Kiel, which firm was also taken under consideration for the further development of this type of ammunition.

In the past, bomb sights had been supplied by the optical instrument works of C.P.Goerz, Vienna, after that firm's works at Friedenau had fused with the Zeiss concern and because the only firm allowed to manufacture military equipment of this kind within Germany was that of Karl Zeiss, Jena. Wit the commencement of rearmament the firm of Zeiss also became interested in working for the new Air Force and submitted its automatic sighting telescope Model 6 for testing. This device not only showed optically the correct moment for bomb release, as did the Goerz/Boykow bombing telescope Model Fl-218, but could even operate the electrical release mechenism to release the bomb.

4 Main emphasis in the development and manufacture of aiming

4 devices thus once again shifted back to Germany.

In the matter of bomb testing the great difficulty was encountered initially that there was not a single bombing exercise field in existence within Germany. It was only after the proclamation of German military sovereignty that a large bombing practice area was procured east of the Rechlin Proving Station in Mecklenburg.

In the preceding years of 1933 and 1934 the Air Force had to negotiate with the Army High Command to secure use of the Jutterbog Firing Range (Artillery) for periods of two to three weeks each quarter. Now that rearmament had become an urgent matter, the development of bombs suffered seriously under this lack of continuous testing.

Aircraft procurement plans were hampered after 1933 particularly by the fact that it became increasingly obvious that, in aviation aspects, the Do-23 night bomber was a ~~ixxltyxdaxx xigx~~ failure, so that it was impossible to risk placing contracts for the serial production of any considerable numbers of this model.

However, in response to the German Lufthansa Airways for an economically operating aircraft which could compete with foreign makes in commercial aviation, the firm of Junkers, Dessau, had at this juncture submitted its Ju-52 triple-engine plane, which showed excellent flight properties.

4 Unfortunately, contacts between the technological sections of the Military and the German Lufthansa Airways had been completely severed for some time and the Ju-52 had been developed completelt without regard for its possible future use for military purposes. The reasons for this irreperably harmful circumstance were as follows:

As previously described, the military command in 1931 had planned the activation of a bomber group comprising two squadrons of G-24 auxiliary bombers and one squadron of Roland auxiliary bombers. In order to reduce the time which would be required to adapt commercial planes for military uses, the Defence Ministry's Troops Office had demanded that the necessary reinforcements and other modifications in the aircraft in question for bomb suspension and weapons outfitting were to be carried out by the manufacturing firms, naturally at State expense and with due consideration for the compensation to be allowed for revenue losses due to reduced passenger and cargo space.

In addition to these allowances, however, the Lufthanse Airways had insisted that the Air Ministry should pay milage continuously for the additional weight due to the constructional modifications to the fuselage, an obligation which the Air Ministry refused to take into consideration.

Unfortunately, the military authorities so presented **this**

5 this lack of interest in national defense and the mercenary attitude of the Lufthansa Airways that the view had grown that commercial airplanes under no circumstance were to be considered as aircraft which could be used for military purposes, so that the necessity for timely communication with the Lufthansa Airways had been neglected and data on the constructional measurements for the new Type C bombs had not been passed on, for incorporation in the construction plans.

Furthermore, the thrust of German-manufactured aircraft engines then available was too small to give the Ju-52 plane, which for military purposes would have had to have a turret, only two engines. In 1923 it was also no longer possible to change the between-spar distances in the fuselage to at least allow loading of the 110-pound bombs in horizontal magazines after the Ju-52 had been adopted as the backbone of the "Risk Airfleet" and the decision had been taken to place it in large scale production. 6

Whatwas called the "Thousand and Twenty" prgram was established, under which 1,000 Ju-52 aircraft and a bomb supply for twenty bombing missions were to be stockpiled.

Under this program the bombs still had to be ordered in the three-section casing type and the political crisis was so acute that the highest Government authorities even considered filling compressed air cylinders with explosives, fitting them

6 with makeshift fuzes in order to use them against the forces of any foreign power which might attempt to intervene.

Under these circumstances it must be considered as a wisely foresighted measure that consideration was given from the outset to the possibilities of a vertical release of the Type C bombs.

What could be done with the SC-50 bombs it was thought must also be possible with the SC-250 bomb. To repel attack from the front or from beneath, ~~the~~ Junkers ~~plane had a turret~~ had designed a turret to be placed under the middle section of the fuselage to carry a machine gunner. Suspension of the large (550-pound) bombs under the body and wings would have restricted the line of sight and fire of this weapon. For this reason the large cabin of the airplane was used to load the SC-250 bombs and the SAC-250 vertical suspension unit was constructed, which functioned mechanically, as in the case of the Do-11 and Do-23 aircraft, by means of a pulley and cable operated from the turret.

Special plates were built into the SAC-250 container to make the loading and release of 110-pound bombs, also in single-release, possible. These plates were a standard item of equipment and were carried even when the plane loaded only 550-pound bombs. Special Type Gr-4-C-10 containers with 22-pound fragmentation bombs were held available at the tactical air bases, while the Electron incendiary bombs were delivered directly from the AF ammunition depots ready packed in type BSK-36 bomb containers as had been done formerly for the night-fighter units. The SC-10 and B-1-E bombs were released in salvos of 4 and 36, respectively.

These measures made it possible within a few months and up to the autumn of 1934 to furnish a completely satisfactory--because simple--bombing equipment. This gave the newly created Air Force a good training aircraft and, by 1936, a striking power which was not to be underestimated and which did not fail to create the necessary impression abroad and thus cover the continued military rearmament. It must be admitted that it became evident already in the Spanish Civil War that the Ju-52 could only be considered a makeshift military plane and that with its unprotected gasoline tanks and its inadequate defensive fire was an easy prey for enemy fighters. But by then proper bomber aircraft were already available, which had been developed after 1933 and went into production instead of the Ju-52.

The bombload of a Ju-52 plane thus consisted of

6 SC-250 bombs in 6 vertical bombbays.

Instead of this load the plane could also carry up to 24 SC-50, 96 SC-10 or 864 B-1-E bombs or a combination of these.

Bomb-aiming was from the turret by means of the Fl-219

7 Goerz night-lighting device. The machine gunner served at the same time as the bombardier.

Another swivel-mounted machine gun was on the upper fuselage behind the cabin.

8 Up to 1936 the Ju-52 also served as the most important vehicle for tests in the continued development of new types of bombs.

Ballistic recording of the trajectory of vertically dropped SC-250 bombs was not as difficult as the determination of the optimum delay in detonation of mine-type bombs or as the solution of the incendiary bomb problems.

In the past the effectiveness of mine-type bombs had been judged exclusively by the size of the craters they created when dropped from altitudes of between 3,300 and 4,400 yards over sandy or clayey ground. This system was only correct, however, for the use of such bombs in rendering runways unservicable.

Efforts had to be made to provide one single type of fuse for all three bomb calibers, namely, 110-, 550-, and 1,100-pounds, a fuse which would insure optimum results in dive-bombing or high-altitude bombing of the most widely varied types of targets.

For this purpose large scale tests were essential, in which it would be necessary to determine what penetration

8 depth into an actual target surface corresponded to the normal fuse delay factor for the creation of a crater.

In the Jueterbog Artillery Firing Range south of Berlin a four-storey building was therefore constructed already in the summer of 1933; this target building covered an area of 10 x 40 meters, and was constructed at a cost of 300,000 Mark. The one wing was of reinforced concrete, the other wing was a steel framework structure with wooden shingle roof

Both types of construction corresponded to what was found in factories serving the armament and other industries. However, the target building had no sidewalls, so that
9 the precise detonation point of the practice bombs could be photogrammetrically recorded.

As shown in the discussion of bomb fuse development in Part B, Chapter III, above, the old PuW bombs had a kinetic delay system in which the firing pin spring was compressed at impact. This entailed a certain lag and represented the ideal solution to the problem of obtaining optimum results under any given circumstances. The bomb penetrated deeper into soft targets than into hard surfaces before detonating and detonated immediately at impact on very hard surfaces. Furthermore, the spring lag distances varied in the fuses of the various PuW bombs; in the 110-pound bomb it was 25 millimeters, in the 660-pound bomb only 7 millimeters, since the heavier bomb was

9 retarded less in its penetration than the lighter bomb, given the same target hardness.

The great disadvantage of this delayed detonation system, which could be said to adapt itself automatically to the target, was, however, that for the fuse to function the bomb had to strike in the precise direction of its own vertical axis and that each bomb had to have different nose and base fuses. Experiments with uniform fuses had failed to produce useful results up to 1918, but with the reestablishment of air units this was the target in all development work.

In artillery shells fuse delay on impact is achieved as a rule by means of powder compression, giving the powder a specific burning rate. This is the simplest solution and is used in the fuses of all foreign bombs with the exception of those designed by the Bofors and Skoda Works.

10 It was no easy decision for the experts in the Air Ministry to renounce the advantages of kinetic delay in bomb fuses, but in the case of the centrally placed electrical fuse there would in the foreseeable future be no other possibility than that of securing the necessary delay by means of a powder with a specific rate of combustion, and the point at issue now was to find this powder by means of tests.

Already in World War I the German experts had recognized that the delay factor of 0.1 or more second was too great. The

10 British and Americans only discovered this during x
xIx the second half of World War II, when they intro
lay factors of 0.07 and 0.03 second for their AC and
bombs.

A delay factor of 0.1 second means that, xxxxxxxx
gardless of the nature of the target (except in water) or
bomb release altitude, the bomb will penetrate to its grea
est possible depth (in a house, for example, to a depth of
16.6 to 22 yards) and will detonate after coming to rest
there. However, a mine-type bomb does not produce optimum
results when exploding in the xxxxxxx cellar or on the foundations of a building. It must explode within the ground floor area so that the blast effect will destroy the outer walls and will expand sideways. This presupposes that the caliber of the bomb is suitable to the size of the target: 110-pound caliber for double-storey houses, 550-pound caliber for four-five storey and 1,100-pound caliber only for still larger and more resistant targets.

11 The target building at Jueterbog answered the purpose in all respects and after lengthy series of tests the delay factor for uniform fuses for SC-50
was fixed at 0.08 second.

10 British and Americans only discovered this during ~~Xarlxxxxr xxx~~ the second half of World War II, when they introduced delay factors of 0.07 and 0.03 second for their MC and Demo bombs.

A delay factor of 0.1 second means that, ~~xaxxxxxxr~~ regardless of the nature of the target (except in water) or the bomb release altitude, the bomb will penetrate to its greatest possible depth (in a house, for example, to a depth of 15.6 to 22 yards) and will detonate after coming to rest there. However, a mine-type bomb does not produce optimum results when exploding in the ~~xxilxixx~~ cellar or on the foundations of a building. It must explode within the ground floor area so that the blast effect will destroy the outer walls and will expand sideways. This presupposes that the caliber of the bomb is suitable to the size of the target: 110-pound caliber for double-storey houses, 550-pound caliber for four-five storey and 1,100-pound caliber only for still larger and more resistant targets.

The target building at Jueterbog answered the purpose in all respects and after lengthy series of tests the delay factor for uniform fuses for SC-50, SC-250, and SC-500 bombs 11 was fixed at 0.08 second.

Using this delay factor it was possible around the end of 1934 to commence manufacturing fuses for the Thousand and

11 Twenty Production Program (1000 bomber aircraft and ammunition for twenty bombing missions). In addition to the non-delay and the delay function incorporated in the No. (15) electrical impact fuse, the No. (25) fuse which replaced it later also a retarding factor of 14 seconds. This was for use in low-level bombing, the 5 seconds delay having been found to short when bombs bounced off the ground in the direction of the bombing aircraft.

In the matter of numbers, main emphasis in the manufacture of demolition bombs was on the SC-50 (110-pound) caliber. In view of the type of manufacturing facilities available, however, the larger SC-250 (550-pound) caliber bombs could also only be supplied with welded casings. All bombs from that period, up to the time when the firm of Rheinmetall introduced its one-piece bomb casings manufactured by the stamp-draw process, because of their weak casings were suitable only for the bombing of normal and not especially resistant targets.

Before proceeding to the mass production of incendiary bombs, it had to be determined whether the B-1}E type of World War I, which had remained unchanged, would meet modern requirements. All fire-fighting experts of those times still adhered to the opinion that catastrophically large fires could originate only in the attics of buildings and that fires in the dwelling parts of houses could easily be extinguished by

11 local fire-fighting services. The old 2.2 incendiary bomb had been designed specifically to just penetrate house roofs and burn in the attics. It was known that Britain had developed a "Baby" incendiary bomb weighing only 160 gr [presumably metric grams: 1 metric gram = 15.432 grains averdupois] charged with hardened oil and thermite which emitted a flame approximately 20 inches long for a duration of one minute. It was essential to determine whether a bomb of this type would be more effective than the Electron-type incendiary bomb, which burned only at the point of penetration and emitted very little heat in the surrounding area. Was it actually possible to produce more "starting" fires with the British Baby incendiary bomb than with the same weight of 2.2-pound Electron incendiary bombs?

Propers targets were also needed to determine this question. In order first to test the penetrating power of both types of bombs, a number of single-storey buildings were erected in 1924 around the target building at Jueterbog. The roofs were of tiles and/or metal of all known types and with varying slopes. Later, a few railcars of lumber were brought in from Berlin and distributed in the attics to determine the incendiary effect of the two bomb types.

A departure from the use of Electron could not be taken into consideration, since it was produced in large quantities

12 from waste bases within Germany and was used both for building materials and as fuel. The British baby bomb contained only 50 grams of combustible materials and in ground tests this proved too little, particularly since the flame was in only one directionand did not set the rafters or the wooden floor of the attics on fire.

In order to determine the most appropriate size for Elec-
13 tron type bombs in practical tests, use was made not only of the conventional 2.2-pound B-1-E bombs, but also of bombs weighing only 200 grams (Type B.0.2 E) and as much as 4 kilograms or 8.8 pounds (Type B-4-E). The latter two types were specially manufactured for the purpose and roughly 200 of the larger caliber and approximately 10,000 of the smaller were used in air bombing tests.

The B-4-2 had the same shape as the previously discussed SC-10 fragmentation bomb, had a mechanical Type Mech. AZ Nr. (3) fuse and was released in salvos from Type 4-C-10 bombing equipment unit. 200 B.0.2 E. incendiary bombs were packed into one container and the bomb had a transportation-proof fuse, a considerable advantage over the B-1-E.

In the tests carried out in the spring of 1934 at the Jueterbog Artillery Firing Range, the large-caliber B-4-E bombs were soon discarded: even in densely built up areas the hits scored were too few and it penetrated too deeply, causing

13 no serious conflagrations at all. In these respects the small B.0.2 E produced far better results, also when compared with the old B-1-E. bomb, and the fires produced by these small bombs in attics not cleared of lumber were extinguished only with the utmost difficulty by the firing range fire-fighting units.

Before reaching any farreaching decisions in the matter of incendiary bomb procurement it was necessary, however, to gather more practical experience with targets more similar to actual targets than the roof structures at Sueteroog.

This resolution was stated by the Inspector of Civil Air Defense (Air Inspectorate 14) in an after-action critique, at which it was decided that Air Inspectorate 14 would prepare the next targets in an appropriate manner. The targets selected were the huts and harvest-reaper sheds of the Leppin Estate, which went out of operation at this time because of the expansion of the Rechlin airfield.

Following six months of construction work, tests to compare the effects of the B.0.2 E and XXXXX B-1-E bombs were carried out at Leppin, with the result that not a single building caught fire. Under concept of "corresponding to actual conditions" the Air Defense Inspectorate had turned Leppin into the ideal of an air defense village. In all houses the roof rafters were inpregnated with fire-resistants and the

Photo

Type Bo-2-31 Incendiary Bomb with Steel Nose Fuse

Photo

Incendiary Bomb Testing in the
Schillersdorf Experimental Village

14 wooden floors had been given a concrete coating; doors and windows were kept shut; the attics were empty; the "homes" contained very few pieces of furniture and carpets and curtains were completely missing. Under such circumstances, damage could only have been done with explosive bombs but not even with the heaviest caliber incendiary bombs.

The Civil Air Defense Service was grateful for the magnificent opportunity collaboration with the bomb developing department had provided for the testing of its protective measures, but even after the results obtained in the Leppin tests it was still impossible to to reach a decision in the matter of incendiary bombs.

Fortunately, a larger target became available in 1935 for tests with incendiary bombs, namely Schillersdorf village, situated in the middle of the newly acquired bombing practice terrain east of the Rechlin Proving Station.

This target village comprised thirty to forty houses, including multi-storey brick structures, most of which had been left in their original condition. To clarify various defense or protection problems, Air Inspectorate 14 constructed a number of experimental structures within the village.

Civil Air Defense teams were able to shelter in the cellars of the larger houses during the actual bombings and two

19 modernly equipped fire-fighting teams were held ready outside of the danger zone which were to fight fires when the alert was sounded.

Organization on the ground for the large-scale incendiary bombing test was a responsibility of Civil Air Defense Inspectorate 14, which also furnished field kitchen services for roughly 200 participants.

The incendiary bombing was done by 4 He-111 aircraft operating in formation at an altitude of roughly 4,000 feet. Falling from this altitude both types of incendiary bombs reached their maximum speed of fall, approximately 110 yards per second and therefore struck the target vertically. Roughly 2,000 B-1-E and 4,000 B-0.2-E bombs were released in one strike and were well placed within the target area.

Immediately after the salvos had struck the target area, the observers were able to leave their shelters and closely observe the starting of the fires. However, the "local" fire-fighting units were only allowed to commence fire-fighting operations a few minutes later and then only to preserve objects intended for later tests.

In this highly successful bombing test very specific patterns could be observed:

The small B-0.2-E bombs bounced off steeply inclined tiled or metal roofs and where they had penetrated the roofs

1 had started no fires in attics which had been cleared of lumber.

Only few B-1-E bombs had bounced off roofs; most of them had remained stuck in the attic floors and the fires started were soon spreading throughout the attics even when ~~covered with sand~~ the burning Electron was covered with sand, underneath which it continued burning, to break out again in open flames whenever a draught was blowing and where the flames found timber to feed upon.

~~[illegible] from such a low altitude~~ Since the salvos from the bomb containers were dropped from such a low altitude, 16 some buildings received a number of hits and the smoke was so thick that the professional fire-fighter teams had to be called into the village after about fifteen minutes.

For precisely this juncture, the controlling staff of the Rechlin Proving Station had devised a surprise action designed to lend reality to the whole test and one might say to balance the planned tea party: The four He-111 planes had disappeared beyond the horizon after releasing their incendiary bombs and now returned at a very low altitude over Schillersdorf. About 100 yards outside of the village each ignited ten charges of each approximately 44 pounds of Trotyl in quick succession, giving the impression of faulty bomb releases.

16 The effect on the morale of the onlookers was terrific: all fled head over heels into the air raid shelters, deserting the fires, firefighting apparatus, and field kitchens, with the result that most of the targets were completely burned out before anyone realised what had really happened. This showed already long before the terrorization air attack of World War II that even the best air raid protection equipment and the best training are of no avail against massed air attacks and if the air raid protection forces are required to do their work while exposed to the impressions of continuous bomb hits.

Owing to the inability to provide adequately strong bomber units at the time for massed attacks, however, the German Air Force Operations Staff held the opinion that only incendiary bombs should be used against targets of the type in question. The idea was that demolition bombs of any type would frustrate the whole planning of the attack, since they might prevent full success in the form of very large scale conflagrations.

As a result of the above tests, only the B-1-E incendiary bomb was retained and efforts were made to improve its effectiveness by means of minor modifications. Since the tests had shown that small Electron bombs could easily be extinguished with hand sprays, the plan was taken under consideration of

Photo

A Burning B-1-E Incendiary Bomb

178 including an irritant additive with the incendiary charge in order to compel the firefighting personnel to wear gas masks. To spread the incendiary effect, a small 5-gram charge of black powder was attached to the steering vane in a tin capsule, which xxxxta in exploding was to spread the burning mass of melted magnesium over a wider surface around the penetration point. However, the disadvantage of this method was that the force of the black powder explosion blew out the fire which had started.

The British introduced the idea later, in the war of manufacturing a section of the incendiary bomb as a fragmentation missile to injure the air raid protection personnel, but this measure can also only be regarded as one of the minor measures to improve the effectiveness of the individual incendiary bomb.

What finally broke the morale and resistance of civil air defense personnel and became the cause of the widespread fire catastrophes in German cities was the use of the 50-50% incendiary-demolition bomb of large caliber, with specially large charges and instantaneous detonation.

The conclusion finally reached in testing various calibers of Electron incendiary bombs was thus that the original caliber of 2.2 pounds was the most effective so far as penetration and incendiary results were concerned. It was now possible to commence in earnest the procurement program for

18 incendiary bombs, for the production of which all conditions in respect to raw materials and manufacturing facilities were favorable within Germany whereas this was not the case as yet in 1935 in the matter of large caliber demolition bombs.

No changes occurred in the former construction of the B-1-E bomb, its fuse, or its stabilizing vanes, except that the composition and make-up of the ignition element within the bomb itself were improved. The thermite in the new manufacturing process was forced into a very thin metal container and only inserted inside the bombs when these were readied at the ammunition depots. It was proof against weapons fire and could be stored safely, besides generating greater heat than had been the case in the old bomb.

Later, when Electron became a short-supply commodity because of Army procurements for gun wheels, vehicles and general items of equipment, the casings were made of steel, which increased the overall weight of the bomb to 2.86 pounds (1.3 kilograms). This new bomb was designated B-1.3-E and the added weight gave it a desirable greater penetration power.

However, it was only during the war that an explosive charge was incorporated with the incendiary bomb, when the Royal Air Force introduced its Inc. 4 lb Mk. III. A

18 corresponding change in the German incendiary bomb was the addition of a disintegrator element designated "Z."

The large bombing practice area adjoining the Rechlin Proving Station on the east was unrestrictedly and at all times available after the declaration of German military sovereignty.

2. Bomb Development after the Proclamation of German Military Sovereignty. Up to 1935 all air-carried bombing tests, including those with gas, had been carried out by the same group of personnel, from 1926 to 1932 in foreign countries and after 1933 clandestinely in Germany. These personnel were ~~those~~ the staff members who were responsible within the Defense Ministry and/or Air Ministry for bomb development.

After the proclamation of German military sovereignty in the spring of 1935, special proving personnel were engaged for the purpose and given specialized training at the Rechlin Proving Station (Air Force Section) in Mecklinburg and later also at Travemuende, where seaplanes and their weapons and equipment were tested. At the same time the firms participating in development programs were allocated experimental aircraft and engaged airmen for factory tests of their newly developed models in the matter of weapons and ammunition.

Overall responsibility for the procurement of new types of bombs and bombing installations, as well as all other func-

functions of the newly established Bomb Procurement Branch (Branch LC 7) of the Technical Office of the Air Ministry remained centered in Berlin.

The organization and distribution of functions of the new branch were as follows:

Branch Chief: Field grade officer or engineer with rank
of colonel; Government official

Section 1 : Fuses. [illegible]

The Branch Chief received from the Air Force Operations Staff instructions on the technical-tactical requirements in the field of bomb development and in cooperation with his specialist group chiefs determined the process for execution of such instructions. The appropriate section chiefs awarded the appropriate development contracts to the firms concerned

20 and supervised the firms in the initial and later stages of designing and the construction of pilot models, besides participating in important tests carried out by the firms on the ground and in the air.

When an item was approaching the final stages of development, the Branch Chief convinced himself of the status of development and authorized its acceptance for official testing if it appeared ready. In this he was often assisted by the the technical specialists of the Operations Staff (who were General Staff Corps officers) if doubts existed as to the tactical usability of the item concerned.

The Proving Stations, the personnel of which were kept currently informed on items under development from the early stages on, then received an official proving mission letter. If the proving tests were satisfactory, the item was demonstrated before the Operations Staff, which then authorized its introduction for issue to the troops.

The responsible chief of the Bomb Procurement Branch in the Defense Ministry at an early stage had given instructions to the Manufacturing and Standardisation Section, so that the necessary data for serial production could be made available immediately to the Procurement Branch and serial production could commence.

If an item was found unsatisfactory in the tests, the

20 development firm took it back and improved it.

In 1936 the pace of rearmament was accelerated insofar as the construction of modern aircraft was concerned.

The Messerschmitt Model 109 fighter plane had gained the highest award in the contest of military aircraft in Zuerich and the three biggest German aircraft manufacturing firms, had Junkers, Heinkel, and Dornier, produced prototypes of twin-engine bomber aircraft for the conduct of operational warfare, and the most suitable of these was to be selected for introduction in the German Air Force. In addition the Ju-87 dive-bomber and the Henschel-126 tactical reconnaissance models made their first appearance.

Of the three bomber prototypes, the Ju-86 and the Do-17 had still been designed originally as commercial planes ,with features incorporated for their adaptation as bombers, but the He-111 was designed specifically as a military plane.suitable also for use as a commercial plane, for which reason it found the approval of the Air Force. As a civilian plane the He-111 had not played any important role.

For reasons of space economy, the He-111 still had equipment for the vertical suspension of its bomb load, and could carry at most eight 550-pound bombs. As was the case with the Ju-52, corresponding quantities of smaller calibers were

21 also carried inside the plane. Bomb release was by means of an electrically functioning automatic stick bombing release controlled by optical aiming telescope Lotfe 7, which was mounted in the nose and operated by a prone bombardier. For the first time the turret had all-round windows, so that the pilot and the commander had an unobstructed view in all directions during the target approach.

22. Military tests with the described bombing equipment of the He-111showed very good results. However, when a new model was tried, which was powered by the more powerful Ju-211 instead of the DB-600 engine and had an increased speed of up to 210 miles, it happened that bombs emerging from the bombing chute were jammed by the slipwind. This represented a very serious hazard, since the bombs were armed at release and detonated whan they dropped unexpectedly, for example, at landing.

To prevent this danger, a protective flap was installed, which opened out in the direction of travelas soon as the bomb chute opened sideways and diverted the wind so that the bombs could fall freely. In this standard pattern the He-111 was designated the H-3 and was used unchanged at the beginning of the war in 1939.

In the matter of bombs, the firm of Rheinmetall in 1936 manufactured its first one-piece mine-type bomb casings in for the SD-50 and SD-250 bombs in its experimental workshops at Duesseldorf. Being of one piece, these casings had no weak spots, such as welded joints, but were of uniform strength throughout. The new casings were declared standard types and all manufacturing preparations were to be adapted to their production. This program also included the SC-500, at that time still designated as super-caliber bombs.

However, low-level bombing of the concrete slab at Rechlin could no longer provide adequate proof of the hardness of this bomb. What was now necessary was to test the hardness of the SC-50 (110-pound) and SC-250 (550-pound) bombs when used to penetrate the concrete roofs of buildings and the decks of shipsin high altitude bombing, when the nose of the bomb would the first part to strike the target, the primary purpose in the designing of these bombs. It had to be possible to express bomb-hardness in terms of centimeters of concrete and/or millimeters of steel used in shipbuilding, provided that the bomb casing remained intact during the penetration. Minor deformations of the bomb casing could be accepted as unimportant if only the fuse remained capable of functioning, which was particularly important with long delay fuses, and if none of the explosive ~~skel~~ charge spilled out due to splitting of the bomb casing.

For these tests the firm of Rheinmetall constructed a

23 provin gun [illegible] "[illegible] jector [illegible]" and placed it in position at the Unterlaess firing range (see Part B, Chapter II, 4). This proving installation assumed particular importance later during the development of armor piercing bombs, but also made it possible to make direct comparisons of the hardness of bombs, in terms of target penetration, produced by various manufacturing processes when substitute manufacturing processes had to be found for mine-type bombs at the beginning of the war. In these tests interest centered primarily on the 551-pound bomb, while main emphasis under the "One Thousand and Twenty" program had still been on the procurement of 22- and 110-pound demolition and 2.2-pound indendiary bombs.

The testing of fragmentation bombs will be dealt with later, in Part [illegible], Chapter I, 1. In the detonation grounds known as the "Detonation Garden (Sprenggarten)" it was possible to determine the effectiveness of these bombs precisely and the fragmentation intensity (Splitter dichte) concept permitted practical comparisons of the various bombs one with the other. 24 A new feature of the second phase of rearmament was that fragmentation bombs were tested not only for their effectiveness against live targets but also against aircraft and other light inanimate targets.

If one disregards a few blastin experiments on houses slated for demolition, no objects were available prior to the war on which the effectiveness of mine-type bombs could be tested. Since the house-blasting tests provided no proof of the suitability of bomb and fuse designing and construction the Air Force General Staff had what were called tactical targets constructed in the Lueneberger heathlands near the Fassberg air base. These tactical targets included concrete-roofed buildings, a concrete hangar and a steel xxxxxxxxk trellis bridge on concrete foundations. These targets were taken under bombing attacks continuously by newly activated bomber units during training, so that it was possible finally to analyse a number of hits to determine their effectiveness.

Mutually helpful cooperation also developed during this period between the Civil Air Defense Inspectorate (Luft Inspektion 14) and Bomb Development Branch LC 7. Air Inspectorate 14 constructed a number of multi-storey buildings in the bombing practice terrain near Rechlin and these were used then to test the various bombs, the results being evaluated by both parties.

The Navy Ordnance Office (Marinewaffenamt) for its part was interested in the effectiveness of bombs against ships of all types. Blasting tests on the former battleship Lothringen showed the SC-250 (550-pound) bomb, with its large explosive charge, to be considerably more effective than the 380-mm

High-explosive shell. Practical bombing tests were conducted against a merchant vessel with a displacement of 7,7[illegible]0 tons purchased from Britain and anchored in the Luebeck Bight for firing practice with the 105-mm gun mounted on submarines. The effects of the SC-50 (110-pound) bombs were so negligible that bombing practice with SC-250 (550-pound) bombs was authorized, but the ship sank after the first hit with one of these calibers.

The results obtained at Rechlin, Fassberg and off Travemuende showed the pre-war status to have been as follows as far as the evaluation of bomb effectiveness was concerned:

a. Elektron Incendiary Bomb 1.3 E (with steel nose) (caliber 1.3 kilogram = 2.86 pounds): Incendiary effects, penetration, and spread xxxx pattern of intensity good when dropped in containers Type BSK 36.

b. Fragmentation Bombs SC-10 (22-pound). Disadvantage of bouncing. Effectiveness against personnel good, particularly in high-altitude bombing. However, the fragments on the whole were too small to cause serious damage to aircraft. This bomb remained in production and a start was made at developing a bomb with a caliber between 2.2 and 4.4 pounds for ground-attack aircraft as well as a 110-pound multi-purpose bomb.

c. Mine-Type Bomb SC-50 (110-pounds). Adequately effective only against small buildings. A larger caliber of approximately 220 pounds was needed to destroy militarily important targets on airfields, railway installations and armament factories.

d. Mine-Type Bomb SC-250 (550-pounds), the most important bomb type for demolition purposes. The explosive charge was adequate for a full hit to destroy all suitable targets such as buildings, bridges and transport ships, with the exception of very large shed-type buildings. It was absolutely essential to have one-piece casings, the draw-and-stamp process of manufacture to be given preference over the manufacture from seamless piping. The draw-and-stamp process of manufacture made it possible to produce casings with a wall thickness tapering off towards the rear end, so that the hardness of the bomb was equal at all points. In comparison, bombcasings from widened pipes were easier to produce but their hardness on impact was seriously impaired because of the thinned walling at the point of bomb-head and bomb-casing junction.

e. Mine-Type Bomb SC-500 (1,100 pounds). Suitable only for use against transport ships with a tonnage above 10,000 tons and against large modern aircraft shelters.

f. Fuses. The detonation-delay factor of 0.08 seconds was found generally suitable against targets on land, but had to be doubled for use against waterborne targets. The electrical fuse had proved satisfactory also for use by troops in the field because of its safe handling and the possibility to set it for non-delay impact and for delayed action detonation.

g. New types of armor piercing bombs had to be developed for use against armor plated ships and fortification works.

h. Bomb Release Devices. The bombing equipment of the aircraft types so far tested appeared satisfactory. In view of the increasing aircraft speeds, however, exclusive use was to be made of horizontal bomb suspension and electrical bomb-release equipment.

1. Trends in the Conduct of Air Warfare were considered to be shifting from area bombing to point target attack carried out in a dive operation. It was considered imperative to introduce a highly accelerated program for the development of multi-engine dive-bomber aircraft with appropriate bomb-release installations.

Bombing Sights. Among the aiming devices available, preference was to be given to the development of sights specifically for dive-bombing operations over the development of multi-purpose bomb aiming devices.

At the turn of the year 1938-1939 the conclusions drawn from these experiences was formulated in the "Statement of Technical-Tactical Requirements for 1939 (Technisch-Taktische Forderungen fuer 1939) issued by the Air Force Operations Staff to the Technical Office of the Office of the Chief of Special Supply and Procurement.

Following the proclamation of German military sovereignty in the spring of 1935, the German Army had established ~~a~~ the Muenster Nord Chemical Warfare Agent Testing Station in the Lueneberger Heathlands. Aircraft were also assigned to the station at an early juncture to continue the tests in the airborne use of chemical warfare agents which had been interrupted in 1931. The tactical unit stationed at Muenster Nord was under administrative control by Tactical Headquarters Travemuende and w was staffed by an air staff engineer (Chemistry), two specialists and two air pilots.

Main emphasis among the various chemical warfare agents was still on mustard gas and similar Yellow Cross combinations and in the tactical field, the use of chemical warfare agents in attack now played a larger role than their use in defence.

The incapacitating effect of gas clouds on live targets

was considered

was considered more desirable than terrain contamination, Gas Bomb KC-250 with its filling of normal mustard gas and its eletrical impact fuse having been developed for the latter purpose.

In Army circles, which were in control of tactical and chemical preparations for gas warfare, the view now developed that greater effects could be achieved with a diluted mustard gas filling, which led to the development of gas bomb Type KC-250-I-gr. with the highly sensitive electrical impact fuse known as the e.-A-Z (26). This bomb had an adequately large disintegrator charge so that the contents of the bomb were vaporized and covered a wide area of the field of battle. Very soon, however, doubts arose concerning the advisability of bomb fillings of this type, particularly because a high percentage of the gas filling was burned at detonation.

1938 saw a return to the conventional 1918 designations of the various chemical warfare agents as Yellow Cross, Green Cross, Blue Cross and White Cross, the only differance being that the gas type was now marked on the ammunition by means of colored rings denoting their tactical uses.

such materials after the caliber marking denoted increased effectiveness in the case of newly introduced bomb and filling types.

The rings were painted on the nose and middle section of the bomb and denoted the following:

White Ring: Irritant gas, such as chlorine-acetophenon.
Green Ring: Immediate toxic effect, for example phosgene or diluted mustard gas
Yellow Ring: Lasting contamination, for example, by means of normal or condensed mustard gas.

The fire bombs and incendiary bombs with fluid fillings developed later were marked with red rings.

The former Blue Cross gas filling of Diphenychlorinearsin, and similar gases, suitable only as an additive to the explosive charge of the SC-10 (22-pound) fragmentation bomb, were replaced by the far more effective Chlorineacetophenon irritant gas used in bomb type KC-250-w (550 pounds).

The casing of chemical bomb KC-250-gr-II (550 pounds) was of 1.2-mm sheeting and the bomb had a filling of phosgene, which affected the respiratory organs. Armed with the highly sensitive No. (26) impact fuse and with a powerful disintegrator charge this bomb provided adequate possibilities for the conduct of operations with Green Ring class chemical warfare agents.

An ideal Green Cross class gas was achieved with chemical bomb KC-250-II-gb, which had a filling of viscous

mustard gas (~~[illegible]~~ dichlorinediethylsulphide
thic
thickened with artificial resins) and a time fuse which could be set to detonate the bomb in the air above the terrain sector to be contaminated. The fuse used here was the electrical time fuse No. (9) known as the El.-Z-Nr. (9), used also in the KC-250-w (550-pound Chemical Bomb).

In 1939, however, emphasis in ~~chemical~~ airborne chemical warfare shifted to the use of the ~~XXX~~550-pound KC-250-III-gr chemical bomb filled with the newly developed instantaneously effective nerve poison Alkylfluorophosphonate, known later under the cover designations of Trilon-83, Tabun, and Sarin.

The establishment of tactical air bases for the operational conduct of air warfare created such enormous demands in the field of personnel and equipment that as much of the work as possible had to be done outside of the bases. This work included the final processing of bombs, together with the insertion of the fuses in the bombs, and the packing of incendiary bombs in the various containers.

For these reasons the Air Force Operations Staff decided that the refilling of gas spray-containers could not be taken into consideration under any circumstances and long-distance transportation of these highly sensitive items of equipment in a filled condition was out of the question anyhow. For these reasons, stockpiling against the eventuality of retal-

29 retaliatory gas warfare ~~xxxx~~ and restricted to the stockpiling of standard caliber 551-pound bombs. Because of the impossibility to avoid hydrochlorine contamination of the mustard gas, the gas supplies had to be stored in large-capacity cisterns and gas shells and bombs were only filled at the outbreak of actual war.

A tabulation of the various types of chemical bombs will follow in Part B, Chapter II, 1.

Commencement of the second phase of German rearmament coincided with the outbreak of the Spanish Civil War. Initially, German support to General Franco consisted of the provision of Ju-52 transport aircraft , which carried troops from Morocco to Sevilla, but these planes were soon also used to carry supplies of food to isolated strongpoints. The planes' bombing shafts proved excellent for the air drop of supplies and from this point it was only a short step to the dropping of actual bombs.

Almost all of the bombs used in Spain were manufactured in that country, for which purpose the simple form of the Type C bombs proved suitable.

The bombs were charged with ammonal explosives, which was rammed with makeshift means into the bomb casings made of sections welded together. Only the fuses were supplied from Germany.

The bombs thus produced could only be used against targets a very low resistance; when dropped on vaulted buildings made of natural stone they usually exploded ineffectually, but this applied equally to the Russian mine-type bombs used by the opposing side.

The use of Elektron incendiary bombs against the Red ports of entry along the Mediterranean coast proved a complete failure, which increased the aversion of the German Air Force Operations Staff against the idea of area bombing. This although the failure of the bombs was due not only ~~the~~ to the far too small quantities used and the wide dispersal of the bombs when dropped from altitudes of over 13,000 feet but primarily to the structure of the Spanish houses with their stone ceilings and flat, roofs under which there was little in the way of flammable materials.

A new departure in the Spanish Civil War was the use of fire bombs dropped in dive-bombing and low-altitude attacks against machinegun pockets and other important points in the lines of resistance, particularly in the Cantabrian Mountains.

The makeshift fire bombs used consisted of filled gasolene cannisters, each coupled with a 22-pound explosive bomb and delivered by the light Hs-123 dive-bomber planes using the SC-50 bomb release equipment for SC-50 bombs, suspended under the wings. The fragmentation bomb exploded upon impact and spread the gasoline over a radius of 11 yards. The results obtained were allegedly so great that they led to the demand for development of a 220-pound fire bomb in the spring of [illegible].

As insistent as later claims were that Spain was of the utmost value as a proving ground for the German Air Force, it is necessary to point out that the civil war in that country, with the small forces used on both opposing sides, could not provide an example of what would happen in the event of air warfare between two major air powers, and that the experience gathered in Spain led to conclusions in the field of weapons and bombs which, in most cases, subsequently proved erroneous. The German General Staff watched carefully to ensure that no modern material was delivered to Spain, including items such as the No. (15) electrical bomb fuse, which could also be used in low-altitude attacks. Instead, only outdated equipment, which had meanwhile been replaced in the homeland by improved models, was sent, in spite of the urgent requests made by the Commander of the Condor Legion in the interests of his aircraft crews for more modern equipment.

1

CHAPTER IV

BOMB DEVELOPMENT DURING WORLD WAR II

1. Situation and Measures Taken at Outbreak of War. Shortly prior to the outbreak of war in 1939 it became clear that the German Air Force did not have more bombing ammunition in its depots than had been the case under the "Thousand and Twenty" program.

At the end of the three-weeks campaign in Poland stocks of 110- and 550-pound bombs were almost exhausted and only 2.2+pound Elektron incendiary and 22-pound fragmentation bombs were still on hand in any considerable quantities.

There had been no exceptional targets in Poland and none of those attacked had been particularly resistant, so that the welded bomb casings had given no cause for complaint.

In detail, an analysis of the experiences gained with the various bomb types had shown the following:

a. The B-1-E (2.2-pound) and P-1.3-E (2.86-pound) Elektron incendiary bombs had been dropped very much at random over Warsaw and only in small numbers, as reports had it, sometimes with washing baskets from Ju-52 planes. Thus, no spectacular results were recorded.

b. The 22-pound fragmentation bomb, designated SD-10 because of its thick walling after introduction of the SD-50 bomb had been used in considerable quantities by

1 Do-17-E's specially adapted for the purposes. There had been no intention to destroy the Polish hangars and workshops, so that the German Air Force would be able to resume operations in them immediately after their capture.

The SD-10 bombs had only damaged Polish fighter and
reconnaissance planes on runways, and had bounced off the
2 closed hangar doors as well as off walls harmlessly, since
the fragments from these small caliber bombs were too light
to penetrate such obstacles.

c. The newly introduced SD-50 (110-pound) multipurpose bombs, manufactured primarily of cast steel, had proved satisfactory, since its fragments had proved effective enough to destroy and render unservicable aircraft and vehicles. These bombs were also used in low-altitude attacks, during which many of them bounced through the hangars to explode harmlessly in the open terrain.

d. The SC-50 (110-pound) Mine-Type Bombs had too small a blast effect as results in the field now showed. However, it was too late at this juncture to convert to a 220-pound mine-type bomb since there was no possibility to change all bomb-release and other bombing equipment in the aircraft during the war. A full hit by an SC-50 bomb on a large and modern hangar at the Okecie airfield near Warsaw resulted in complete destruction of the hangar by setting fire to

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2 aircraft fuel tanks.

e. The 550-pound caliber mine-type bomb in general produced the most satisfactory results, and this applied to its used with delayed action fuses against airfield installations and armament factories as well as against railway rolling stock in rail depots and against railroad installations. What proved very profitable here was the ability to select the fuse timing just prior to the bomb release, with the target already in sight and when it was known whether personnel or vehicles were in the target area. The blast and fragmentation effects of this large bomb when used without delayed action were often greater than the mine blast effect achieved by means of the delayed action fuse setting.

f. <u>Bomb Calibers</u>. In order to bring about the total collapse of large shed type structures with a single bomb hit, it appeared essential to use a heavier caliber than the SC-250 (550-pound) bomb. From then on, more emphasis was placed on the production of the 1,100-pound SC-500 mine-type bomb intended in the past primarily for use xgxix against water-borne targets. Since horizontal bomb-suspension was used anyhow in the twin-engine Ju-88 dive-bombers and Do-217 planes as well as in the Me-210 fast bombers, no difficulties were encountered in loading the

8 1,100-pound instead of the 550-pound bomb, the only requirement being the prior construction of the [illegible] bomb release equipment for the heavier caliber bomb.

8. Fire Bombs. These were constructed from a C-250 (550-pound) bomb casing filled with approximately 80 liters of gasoline, and were reported to have a marked effect on troop morale. At impact the bomb burst into a flame of fire about 50 to 66 feet in diameter, which soon subsided. In order to secure a more lasting fire, experiments were carried out with crude oil fillings, but the results were just as unsatisfactory as those obtained by the British with their LC-250-pound chemical bombs containing a liquid incendiary composition, which consisted of gasoline and rags. It was only later in the war, when the idea evolved of mixing the gasoline or benzol with artificial resins or aluminum soaps for thickening, that a new means of warfare, the Napalm bomb, was created, a large fire bomb with a fluid content which splashed over a large area upon impact in the target area. The German Air Force also developed and procured supplies of a ~~500~~ 1,100-pound fire bomb, the Flam-C-500.

The procurement of sufficient quantities of high-explosive bombs in Germany after depletion of the stock-piled supplies suffered from the fact that the installations existing facilities in Germany for the serial production of stamped out one-piece mine-bomb casings were inadequate. The resupply requirements stated by the Chief of Special Supply and Procurement Services in the spring of 1939 only provided for an output of 20,000 SC-250 (550-pound) and SC-500 (1,000-pound) bombs per month by 1941.

In view of the more imminent threat of war, the Chief of Special Supply and Procurement Services suddenly increased requirements to 100,000 SC-250 bombs monthly and in order to remove all difficulties for the other branches of the military and for the industries concerned, the Commander in Chief of the Air Force instructed the Secretary of State and Inspector General to arrange for the greatest possible acceleration of the commencement of bomb manufacturing. This production program was awarded the highest priority in the overall armament program.

It was obvious that the quality of bombs would suffer in the mass production methods thereupon introduced. In the beginning a qualitative retrogression even set in in bomb development, in which the most varied manufacturing methods had to be examined and tried out. Frequently, excessive demands by higher authorities compelled the technical departments to exceed their responsibility in making qualitative concessions in the manufacturing and finishing of bombs in order to

4 [illegible] in order to [illegible] their [illegible], the very

often it was the very persons who stressed only the importance of high output at the time who [illegible] accusations against them for these reasons.

Conditions were most favourable in the case of the
11
110-pound bomb. Here, the tube and pipe manufacturing industry could meet all requirements. After transfer of the roller mills from the frontier areas of the Saarland region this branch of industry was even able to meet a

5 large part of the requirements for SD-50 multi-purpose bombs in addition to all requirements for SC-50 mine-type bombs.

The large roller mills in the Rhineland-Westphalia region were able to supply a small share of the 55-pound bomb casings made from a single piece of piping hammer-treated at both ends to give it the proper shape. This output was increased by development of a special wleding process to fuse two wrought steel head and tail pieces into a single bomb casing. However, firing experiments conducted later showed that even the SC-250 bombs produced by this method had an impact and penetration hardness roughly 20% lower than those made by the Ehrhardt stamp-and-draw process.

However, mass production only got into full stride after it had become necessary to authorize the production

of SC-250 bombs xxxixx made by welding together 3 sections--the bomb head, the casing, and the base. These bombs corresponded approximately to the test mine-bombs used in 1931-1932 and had a penetration hardness equal to only roughly 40% of that of the standard pre-war bombs, meaning that they could penetrate 20 millimeters instead of 50 millimeters of construction steel. The three separate sections of these bombs were manufactured in special workshops by smaller firms and assembled in a newly established assembly plant which, employing only 300 personnel, within a year reached a monthly output of 50,000 SC-250 bombs. This automatization of bomb production was carried out in an exemplary manner by the Bochumer Verein concern in one of its factoriesand provided the most striking proof of how sound it had been to arrange from the outset for a substitute production of C-type bombs in order only then to improve the quality and achieve a production of first-class bombs equal to peacetime qualities.
6

However, the unexpected outbreak of war had interrupted these plans at the most inauspicious juncture; added to this came the excessive demands made by the Chief of Special Supply and Procurement Services under the Air Force General Staff, and this made the introduction of improvisations necessary.

In order to close the supply gap pending the supply of mine-type bombs from current production, use was also made of cement bombs, [illegible] the way [illegible] XXXXXXXXX as late as in 194[illegible] when [illegible]. Cement bombs had been used otherwise for training and cement goods factories had available the forms in which the concrete was pressed around a reinforcing wire framework. These bombs were now given a larger explosive charge and chipped metal was added to the concrete so that these substitute bombs would also have a fragmentation effect, since they could naturally only be used with non-delay fuses.

The fragmentation effect of concrete bombs type SBe-50 is discussed in Part B, Chapter 4, 1. The explosive charge weighed only roughly 13.2 pounds (6 kilograms) and the blast effect was very small. Another disadvantage was that the concrete crumbled when the bombs were dropped in low-altitude attacks and that the cement and sand dust at explosion obscured the target, often as though by a smoke screen, so that follow-up attacking units were unable to detect it.

The SBE-250 concrete bomb was unacceptable. Its roughly 30% of dead weight so reduced the bomb's effectiveness that it corresponded at best to the effectiveness of a 310-pound bomb. This represented such an uneconomical use of an aircraft's loading capabilities that in actual fact, the SBe-250 bomb was hardly ever used.

Production of SBe-50 (110-pound) concrete bombs was also halted as soon as German victory in France was assured.

After conclusion of the campaign in Poland there was such a shortage of the heavier caliber bombs that use had to be made of the stocks captured in Poland and of the stocks of the former Czechoslovakian air forces, for which purposes they had to be provided with holding belts and German suspension hooks. A complete dive-bomber wing flew roughly fifty missions with these adapted captured bombs. In addition there were also available captured French stocks and even stocks of World War I German PuW bombs which had been left behind in depots on the east front in 1918 and were now used on the West front in World War II.

A critical point which hampered increased bomb production was the explosives' supply situation in Germany.

The Trinitrotoluole, generally known as Trotyl, generally used during peace for explosive shells was closely linked with the production of coal, and the output of coal could not be increased as desired. Army stocks were completely inadequate and expansion of the existing nitrating installations had been geared to a relatively slow program of rearmament both in point of time requirements and quantitatively. In this field the Army was the controlling authority and had to provide for the requirements of all military branches.

Owing to the tenfold increase in bomb production, which

7 started in the autumn of 1939, the Air Force had become the greatest military user of explosives.

Plans provided that, in the event of war, trotyl supplies were to be stretched by the addition of ammonium nitrate, adequate supplies of which were available from the large German chemical industries. The resultant "amatole" was also the standard explosive for military purposes in foreign countries.

8 However, another difficulty was that of filling stations, the numbers and capacities of which were suddenly too small, since trotyl first had to be melted in large water-mantel boilers before the ammonium nitrate could be added, after which the compound had to be filled into pre-warmed bomb casings.

The only possibility here was to fill the bomb casings with substitute explosives in powder form, the so-called ammonales, which could be filled cold, and to stamp these explosives into the concrete bomb casings in makeshift installations. The effective explosive charge and the blast effect of these bombs was thus approximately one-third lower than would have been the case with a trotyl filling, whereas the use of amatole would have increased the effect by about 10%.

It was even necessary to use ammonale in a large percentage of the welded-casing SC-250 (550-pound) bombs in 1940 before the "warm" filling process could again be introduced.

In order to adapt the various bomb constructions to the

8 the Air Force Operations Staff authorized the classification of mine-type bombs according to quality, the classification to be marked on the bombs in Roman numerals.

Class I included bombs with stamped, drawn, or rollered casings , two fuses, and standard explosive charges. This classification was given primarily to bombs intended for use against ships as well as the under-water bombs for use against submarines, the latter having a special under-water explosive charge of Trialene.

Class II were the bombs with two-piece casings, which also still had a poured-in explosive charge. Tests showed that the
9 consistency of the explosive filling had a considerable influence on the hardness of the bomb casing.

Class III included all SC-250 (550-pound) bombs with three-piece casings produced by the old or newer processes. As previously mentioned most of these bombs had a charge of substitute explosives. Regulations prescribed that they were to be used only against low-resistance targets. Unfortunately, it was ~~xxx~~ rarely possible to adhere to this requirement,since usually only Class III bombs from 1940 output were available for attacks against important armament industry targets in England. When the output of Class I bombs increased in 1941, most of these new bombs were dispatched to the Russian front, where most of the targets were less resistant.

These bombs were recognizable by their protective coat of green paint and were to be used exclusively against personnel and grounded aircraft.

Whereas bomb procurement planning up to 1938 was governed exclusively by the requirement for use against a possible enemy on the Continent, the technical-tactical requirements stated for 1939 with their demand for armor-piercing bombs were directed against Britain. In contrast, almost all British incendiary bombs in use as late as 1942 still showed by their factory stamp that they had been produced in 1936-1937, proof that Britain already at that early stage was aiming for a war on the Continent of Europe.

Fullest utilization of all personnel in the designing office and experimental workshops of the Rheinmetall concern in Duesseldorf made it possible shortly before the outbreak of the war to demonstrate in firing and bombing tests the PC-500 (1,100-pound) armor-piercing bomb and the PC-500-RS (1,100-pound armor-piercing bomb, both designed for use in dive-bombing at- 10 tacks by the newly introduced twin-engine Ju-88 dive-bomber aircraft.

However, the relatively small explosive charge of these armor-piercing bombs was considered inadequate by the Air Force Operations Staff, which therefore demanded development of a 2,200-pound armor-piercing bomb, the size of which was to be [illegible] to the [illegible] of the newly introduced [illegible] fast bomber.

After rejection of Hitler's offer of peace negotiations in the autumn of 1939, the Chief of Special Supply and Procurement Services submitted to the Air Force General Staff for approval a very comprehensive bomb development program for 1940, which included provisions for the development of mine-type and armor-piercing bombs up to calibers of 4,000 pounds, corresponding to the maximum bomb payload of He-111-H-4 aircraft. In this latest version of the tried and tested He-111 plane, all bombs were suspended underneath the fuselage, so that no restrictions had to be placed on on the diameter or length of the bombs it was to carry. The aerodynamic disadvantages attendant upon outside suspension of the bombs had to be accepted, since the space used inside the [illegible] version of the plane for the vertical suspension of 8 550-pound bombs was now taken up by fuel tanks in order to increase the plane's striking range.

The Air Force Operations Staff placed special hopes in the use of heavy mine-type bombs of 2,200- and 4,000-pound caliber with an explosive charge making up 50% of the total bomb weight. It was hoped that these bombs would compensate for the lack of air torpedos and that even in the case of near hits the blast effect of their large explosive charge

10 would destroy the under-water protection of large armor-plated ships.

11 However, weapons specialists placed greater hopes in direct hits, in which it was essential to penetrate the horizontal armor plating. On the one hand, it was possible with high-precision aiming devices to score direct hits and on the other hand an armor-piercing bomb of [illegible],000 pounds could carry a 660-pound explosive charge through a 150-mm thick armor-plated deck and, according to naval artillerymen this charge was sufficient to sink even modern battleships with a displacement of 35,000 tons. To meet the demands of the numerous proponents of dive-bombing tactics, however, a 2,200-pound armor-piercing bomb was also designed and constructed. This bomb was released at an altitude of 3,300 feet and by means of rocket propulsion attained such an impact speed that it could even penetrate 18[illegible]-mm armor plating. However, this latter armor-piercing bomb carried such a small explosive charge that it would have required a direct hit in the ammunition chambers to sink a large warship.

Inititally, the penetrating capabilities of these bombs were only calculated in theory, but after cobstruction of the Missile Propeller 66 described previously in this study, these calculated capabilities were fully substantiated in actual tests. The Navy provided information, for the accuracy

11 of which it gave the responsibility, on the blast effect of explosive charges inside ships and underwater.

The following bombs were thus available for use against modern warships:

Summer 1940: The SC-1800 (4,000-pound) mine-type bomb with
an explosive charge of 2,200 pounds

The PC-1400 (3,000-pound) armor-piercing
bomb with an explosive charge of 660 pounds.

Spring 1941: The PC-100-RS (2,200-pound) rocket-propelled
bomb with an explosive charge of 140 pounds.

A special mine-type bomb was also developed for use against aircraft carriers and older class warships which were less heavily armored. This was the SD-1700 (3,340-pound) bomb with an improved penetration capability. Carrying an explosive charge of 1,540 pounds it could penetrate 60-mm

12 of armor plating and thus could be used effectively against larger areas of the classes of ships just mentioned than could the thin-walled mine-type bombs or the armor-piercing bombs.

Of all these large-caliber German bombs only one, the rocket-propelled PC-1400-X with certainty actually sank a battleship, namely the Italian battleship Roma while it was trying to escape to the western Allies in 1943. The Roma sank ~~XXXX~~ within a few minutes after a direct hit midships.

Another armor-piercing bomb was introduced in the summer of 1942. This was the PC-1800-RS (4,000-pounds). With its special high-explosive charge of 504 pounds it was to have

12 a blast effect equal to that of the [illegible] [illegible] its [illegible] was to pierce decks protected by [illegible]-mm armor plating.

A few of these large caliber armor-piercing bombs having been used at Scapa Flow and Malta, English sources have stated that already during the first years of the war the German Air Force had introduced most exceptional innovations in armor-piercing bombs. The very fact that the British ~~Navy~~ Navy, fearing the German bombs, usually stayed outside the range of German aircraft, constituted an important strategic advantage for the German military forces.

However, one tactical disadvantage was that, because of the reequipment of bomber aircraft to carry the large-caliber bombs of 2,200 pounds and more, not enough use was made of the medium-caliber bombs of 550 and 1,100 pounds, or of incendiary bombs in the Battle of Britain.

13 The most striking example here is the He-111 bomber, the most important bomber aircraft used in German operations from 1940 to 1942. The H-3 version of this plane could still carry eight SC-250 (550-pound) explosive or 1,152 B-1-E (2.2-pound) or B-1.3E (2.86-pound) incendiary bombs, which were the most effective types for use against most of the targets involved. The H-4 version of the plane, however, was only equipped to carry one SC-1800 (4,000-pound) or one PC-1400 (3,000-pound) bomb, or two SC-1000 (2,200-pound) or four SC-500 (1,100-pound)

explosive bombs, while new [illegible] suitable for outside suspension had to be constructed for the use of elektron incendiary bombs.

In spite of these concentrated efforts in the development of conventional type bombs, hopes had not been abandoned of developing an air torpedo. The reasons for failure of the German Navy in this field have been discussed elsewhere; the inadequate Horten torpedo was to be replaced by the Italian Whitehead air torpedo, for the deliveries of which an agreement had been concluded as far back as in the autumn of 1938. The Air Force made appropriate arrangements for a comprehensive airborne test and in order to emphasize matters activated a special naval mine and air torpedo ~~group~~ section within the LC-7 Bomb Development Branch. This section also assumed responsibility for the development of new types of naval mines which, in contrast with the Navy's system of dropping mines by parachute, were to be laid by aimed drop from high altitudes (see Part B, Chapter II).

2. Experience and New Developments during the First Years World War II. In the case of the newly developed large-caliber bombs only functional tests were carried out at the training grounds. The effectiveness of the new bombs was to be tested in actual use against enemy targets.

However, the field forces were too much occupied with their own problems to find time for reports in detail on the [illegible] attacks. [illegible]lly, they merely reported good results and [illegible], complained about difficulties in the handling of their ammunition and/or equipment, which difficulties were immediately remedied.

To determine the effectiveness of the various types of bombs it would have been necessary to examine the impact areas on the spot. Following the German advance in the west, commissions were therefore formed immediately of representatives from the Bomb Development Inspectorate (Inspectorate 2), the Technical Office of the Air Ministry, and from armament industry concerns and dispatched to important points of combat.

Experimental use was made of a few large caliber bombs in the attack on the Liege fortresses in May 1940. It was found that the rocket-propelled PC-500-RS (1,100-pound) bombs had failed to pierce the several yards thickness of concrete covering the fortification works, and the subterranean installations of the more modern fortification works were about 66 yards underground, so that even the PC-1,400 (3,000-pound) armor-piercing and the SC-1800 (4,000-pound) mine-type bombs had fauled to damage them. However, the shock of the large bombs detonating at a depth of between 11 and 16.5 yards had so demoralized the garrisons of two forts on the eastern perimeter of the fortress area that they soon capitulated.

A spectacular success was achieved with fire bombs dropped on

14 dropped on a fort west of the Meuse River. Here type Flam-C-250 bombs were dropped, intentionally without ignition. The gasoline from the bombs sickered through the crevices and cracks in the armored turrets and exploded inside when set on fire by bombs detonating later.

15 The main work of softening up the French Maginot Line and the Belgian Mur Dévèze prior to the assault by ground forces was done by dive-bomber units using normal SC-250 (550-pound) and SC-500 (1,100-pound) bombs, which in many parts created breaches in the concrete surrounding walls, through which the infantry and engineer units were able to approach the inner fortification works to blast the turrets.

The S-Be-50 (110-pound) concrete bombs were also used from the first day of the offensive on, primarily against enemy airfields, in order to gather experience on their use and effectiveness. Results showed that the demolition bombs caused numerous fires in settlements and in factory installations containing easily flammable materials. The French air forces had evacuated their major air bases, so that not much damage was caused there.

In the air attacks against Britain in the summer and autumn of 1940 use was again made primarily of the conventional type of bombs in calibers from 110 to 1,100 pounds. Although large numbers of Elektron incendiary bombs were

15 also dropped, there was no clearly defined area of main effort, as would have been necessary to gain an impression of their effectiveness when used in large masses. Furthermore, the poor possibilities for aimed bombing and the inadequate intensity of the bombing complicated efforts to arrive at a logical evaluation of the value of the incendiary bombs.

Large numbers of the newly developed mine-type and armor-piercing bombs were also delivered on targets in England, although they had been developed specifically for use against point targets and had delayed action fuses which insured good results when used against ships but were set at too long a delay for use against targets on land. 16

It was also during this period that the use of naval mines, suspended from parachutes and set for detonation by their self-disintegrators 30 seconds after impact on the ground, was introduced. Aiming with these was even more erratic than with the Elektron incendiary bombs, but the brilliant flame of the exploding charge with its additive of aluminum (guncotton 18) was regarded by the aircraft crews as a sign of good results, for which reason the effectiveness of these "air mines" was overestimated.

In efforts to improve aiming, a super-charge bomb, the SB-2500 (5,500 pounds) was made in the late autumn of 1940 by combining three LMB naval mines stabilized by a normal bomb

16 steering unit. The explosive used in these bombs was Trialen 105, which exploded instantaneously on impact. A few hundred of these, the largest bombs ever used by the German Air Force, were dropped over London in the winter of 1940-1941. There can be no doubt that their blast effect must have been impressive, for which reason they served as a pattern for the High Capacity Bomb 4,000 pounds and High Capacity Bomb 8,000 pounds used later by the British.

The development of these superheavy bombs was symptomatic of all further bomb designing and construction during the war. It resulted from demands made by the field forces, which the German Air Force Operations Staff later approved.

There was no longer any long-range planning, nor was any bomb development program established with due regard to the form in which warfare would develop within the coming six or twelve months. Interrogated on this subject the Chief of the Air Force General Staff himself could only reply that the

17 branch chief responsible for bomb development had to have a sixth sense for this purpose.

Top-level command problems and General Staff plans were classified material to which only only the appropriate ~~branch~~ department chiefs, in this case the Chief of Special Supply and Procurement Services, had access, so that they did not penetrate to lower levels.

All the chief of the Bomb Development Branch could do, therefore, was to always maintain very close contact with the field forces in order to become aware immediately of their current needs and their desires for the immediate future. He therefore went personally in search of his missions and after his return from the front line headquarters and troop units discussed matters with his colleagues in the Air Ministry and at the proving stations, which then initiated the necessary work by the industrial concerns and supervised its completion.

It was only in the last year of the war that some semblance of development planning again came about in preparation for an attack with drift mines against large hydroelectric stations in Russia, a plan which was not put into execution. During the decisive years of the war, and thus up to 1942, the only new means of warfare introduced were those planned shortly prior to and immediately after the outbreak of war; strictly speaking, all other innovations were more or less noth nothing but improvements and modifications of existing constructions.

After the turn of the year 1940-1941 the bombing attacks against Britain decreased in intensity and took the form of individual operations as a rule carried out at low altitudes because of weather conditions and described as harassing attacks.

17 What was a matter of grave concern in the field of bomb technology in these attacks was that the targets in many cases were highly resistant, while a large percentage of the bombs
18 used against them were still of the welded SC-250 (55 -pounds) type of qualitative class III. In low-altitude attacks so far only the thick-walled 22-pound and 110-pound SD-10 and SD-50 bombs had been used and then only to achieve fragmentation results against light inanimate targets such as aircraft and transport columns. Now, however, the targets under attack were heavy tooling machinery in armament factories of massive construction.

Against such targets it could not even be expected of Class I mine-type bombs, which had single-piece drawn casings, that they would outlast repeated bouncing and rochocheting before detonation, since, although they appeared compact superficially, the SC-250 (550-pound) bombs were only designed for penetration when striking first with the nose and their casing had a thickness of only a few millimeters in order to permit a 50% explosive charge. If the bomb'sxx side struck a sharp edge it could happen that the casing would be torn and the explosive charge spilled before it was detonated by the 14-second delay fuse.

As soon as it became known that such cases had occurred, for example in attacks against the French Schneider Works at

11 [illegible] near Le Havre, [illegible] a multi-purpose SD-250 (550-pound) bomb with a thick-wall casing, which would not only be harder for use in low-altitude attacks than the SC-250 but would also have larger fragments which would perhaps do more damage to machinery used in the heavy industries than could be done by the blast effect of mine-type bombs.

The Langendreer factory of the Bochumer Verein concern, which was installed originally for the manufacture of SC-250-III bombs was successfully converted for the manufacture of
19 the new SD-250 bombs, the casing of which was no longer to be cylindrical but biogivale and was to be of two thick-walled stamped pieces welded together. The explosive charge had to be reduced to 30% of the overall bomb weight, but in test bombings carried out at the semi-destroyed gun workshop of the previously mentioned armament factory near Le Havre, the new SD-250 proved very satisfactory in point of hardness when compared with the SC-250 bomb. An even heavier multi-purpose bomb, the SD-500-A (1,100-pound) bomb with a single-piece cast steel casing was produced in the appropriate workshops of the Rhine-Westphalian industrial region.

However, both of these two bomb types were introduced too late for the purposes for which they were intended. Regarded critically, they complicated storage and supply operations

19 and their target effect was smaller than that of mine-type bombs of the same caliber. It was only from the production viewpoint that it was a sound policy to manufacture the SD-250 and SD-500-A bombs from 1941 on in place of the excess requirements of SC-250 and SC-500, which could not be manufactured with single-piece casings, the time having now passed in which the German Air Force could attack area targets and the necessity having arisen to select carefully the appropriate type of bomb to be used against each circumscribed target.

A counterpart to these circumstances was to be found in the circumstances ruling in the British armament industry.

The Royal Air Force prior to the war had introduced as its standard general purpose bombs the GP-250-pound, GP-500-pound and GP-1000-pound bombs, whereas the German Air Force had the mine-type SC-25 and SC-500 bombs. The superior effectiveness of these latter during the Battle of Britain influenced the British Ministry of Supply to also develop mine-type bombs with an approximately 50% explosive charge ratio , which were therefore designated "Medium Capacity Bombs," and to give the production of these bombs the highest priority. Practically every suitable factory manufactured its own special bomb type designated from Mk 1 to Mk 12, most of them with welded casings, even with longthwise welding. At the same time, however, 20 however, the British heavy industry, in which the workshops as a rule were installed for cast steel working, continued to manufacture the existing type of General Purpose bomb. In the second half of the war the British received a large share of their HC and GP bombs, with stamped out casings, from the United States.

The US Army Air Forces, in contrast, had no reason to depart from the 50% explosive charge ratio mine-type bombs, designated as demolition bombs, which, consonant with ruling conditions in the United States were roller produced from tubing. The only modifications they introduced during the war in their bombs had to do with the safety factor of their fuses and a slight reduction in their fuse delay factor, after the delay of 0.1 second had proved too long. The Americans realized that their demolition bombs did not fully meet hardness requirements, but to compensate for this defect, they used in their "saturation bombing" twice or three times the quantity of bombs calculated as necessary to achieve destruction of the target.

From the technological viewpoint, the US Bomber Command was a gigantic ~~transport and distributing system~~ explosives and incendiaries transporting and distributing agency, in which the quality of the individual bomb played only a small role as long as it remained possible to produce the bombs in

20 sufficient quantities. The German Air Force, in contrast, was at no time able to afford such a policy and the German Air Force Command at all times emphasized that the weight of
21 the enemy mass must be countered by the superior quality of the German side, both in materiel and pxxxxxx in performances of the personnel.

There is no room for doubt that the whole idea of dive-bombing and of point target attack evolved already prior to the war out of consideration for the fact of German numerical inferiority, but in the end, in the air as well as elsewhere, God remained on the side of the strongest air flxxxsx wings.

As previously mentioned, the German Air Force Operations had already before thewar rejected the 22½pound SD-10 fragmentation bomb. From the outset this bomb had been intended only for use against personnel, for which purpose it had an exceptionally dense fragmentation pattern, which is dealt with in more detail in Part B, Chapter 1, 1. It was less suitable for action against inanimate targets, however, because the weight and force of the individual fragment were inadequate
w
to seriously damage even light types of targets. In place of the SD-10 the multi-purpose SD-50 (110-pound) bomb was introduced already in the spring of 1939 specifically for use against air units on the ground, and it could be used in high-altitude, dive-bombing, and low-altitude attacks. The

21 Air Force Operations Staff had called for a special fragmentation bomb with a caliber between 2.2 and 4.4 pounds, later produced as the SD-2-t (4.4-pound) ground-attack fragmentation bomb for use against personnel and other live targets. This bomb was no intended for use by the Ju-87 dive-bomber units, which ere to use larger caliber bombs in their point target attacks, but for the Henschel-129 ground-attack plane still under development.

It has already been mentioned that shortly before the campaign in Poland a few Do-17-E squadrons had been equipped with magazines to hold SD-10 bombs without steering tails. The omission of steering tails was to prevent the bombs penetrating
22 into the ground and they were detonated by a 5-second delay fuse to prevent the bombing planes being hit bt fragments from their own bombs. The results achieved in tests at the Krakau airfield and also in actual attacks against moving columns were only very moderate, however, due primarily to the fact that the bombs often bounced right over the target but also to the fact that when a bomb explodes on the ground roughly one-third of the fragments strike downwards, into the ground, and the fragmentation spread is very irregular. These defects were known prior to the outbreak of war and in the case of fighter aircraft carrying out an occasional low-level attack--which could carry 5 SD-10 bombs without steering tails-- were accept-

22 accepted as an unavoidable disadvantage. The new 22-pound bomb was intended primarily for use with a stabilizing tailpiece and a highly sensitive fuse in high-altitude attacks, and an He-46 or Hs-26 tactical reconnaissance plane could load ten SD-10 (22-pound) bombs of this type while an Hs-45 strategic daylight reconnaissance plane could carry twentyfive.

The disadvantages of the SD-10 in low-level attack were to be avoided in designing the new type of SD-2-t. Owing to numerous failures, development of this new bomb took almost two years, but in the autumn of 1940 it was in use by a bomber unit in Northern Africa and had been placed in serial mass production.

After the decision had been taken to attack Russia, the Air Force Operations Staff unexpectedly ordered reequipment of a number of He-111-H-3 wings with interchangable fittings to take SD-2-t bombs in the standard bomb magazines. The present author is unable to explain what tactical considerations prompted the order to use heavy bomber aircraft in low-altitude attack operations. 23

The ground-attack bomb was designed exclusively for use against live targets and had a regular fragmentation spread pattern in all directions, especially when set to esplode in the air.

However, its main use on 22 June 1941 was against forward

23 Russian airfields in Lithuania and eastern Poland. The light German dive-bomber units prepared the way for the German ground forces, while the heavier bomber forces, most of them equipped with Ju-88 aircraft, attacked targets farther in the enemy rear, such as rail centers and unit headquarters. The mission of the fighter forces was to repel the expected counter attack by Russian bomber forces.

Using such small caliber bombs as the SD-2-t (4.4-pound) fragmentation bomb aircraft can only be seriously damaged by direct hits. In the operations under discussion, however, all hopes were placed on the element of surprise and the clumsy bomber units were sent in to within range of hand weapons fire, a mission which should only have been assigned to armor-protected ground-attack units.

Such targets as aircraft parked at the edge of an airfield, the Americans on principle always took under high-altitude attack in mass bombing with 90-pound fragmentation bombs, while the German side had for this purpose their specially suitable SD-50 (110-pound) bombs.

However, the attack against the near-front Russian airfields was carried out in such heavy concentration that it succeeded on the first day in putting practically all enemy planes out of action.

These results could be regarded as proof that tactics

23 are always more important than technical considerations, but the question remains open whether even better results could not have been secured at a smaller expenditure and at a smaller

24 er cost in losses.

The fact must be mentioned, namely, that many of the German bomber aircraft employed in this brutal mission ~~ixxx xxxxxd~~ received so numerous hits from small weapons that they were out of action at a juncture which could not have been more unfavorable.

Combined with the availability of a usable ground-attack plane, or for use in harassing attacks, for which purpose it was used later and is still in use by the US Air Force, the SD-2-t bomb might still be considered a suitable weapon, but to regard it as a major means of attack at a decisively important moment in the conduct of a war was an absolute fallacy, particularly in view of the fact that its effectiveness against aircraft had never been tested.

The most important calibers used in the war against Russia were the tried and tested SD-50 (110-pound) and the SC-250 (550-pound) bombs, use of the SC-500 (1,100-pound) bomb becoming necessary only for attacks against industrial installations. All larger calibers were merely waste.

The fire bombs which had still proved so effective in the West had no marked impact on the combat morale of the

24 the Russian troops; little use was made of incendiary bombs, but the wooden houses immediately caught fire when stricken by normal explosive bombs without delayed fuse action.

The bombing attacks against Britain were brought almost to asstandstill by the gigantic effort of the German Air Force against Russia. Projects to use against Britain what was called a concentrated charge (Geballte Ladung), the SA-4000 with a charge of 4 tons of explosives, were relinquished in favor of the use of a superbomb, the SC-1000 (2,200-pound) containing 1,617 pounds of high-explosives, after it had been realized that four bombs of this kind would do more damage in a densly built up city than a single giant bomb. The SB-1000 was even produced later in a special version for the Me-410 25 plane. In place of the normal stabilizers it had a stabilizing parachute so as to fit into the bomb bay of the Me-410.

3. Bomb Development from 1942 On. In the spring of 1942 a sudden demand arose for large masses of small fragmentation bombs, initially for use in the war of movement in North Africa and then for use in Russia, when the Air Force was called upon increasingly to support the Army in repelling mass attacks on the ground. This suddenly again brought the underestimated SD-10 (22-pound) fragmentation bomb into prominence, namely for use by the Ju-87 dive-bomber units which were not equipped for its use. To avoid the necessity to install magazines in the planes for this purpose, which

25 would have required considerable modifications to the plane's fuselage, four SD-10 bombs were combined to form the B-4-B-10, which was fitted into the bomb release equipment for 110-pound bombs under the wings of Ju-87 aircraft (see photo).

These casings for the four bombs opened soon after release from the plane. Opening was by means of an electrically ignited powder cartridge which simultaneously allowed the arming plug of the No. (3) mechanical impact detonator to spring forward into position. The impact of these bombs was similar to that of a battery salvo of four shells falling at intervals of about 66 to 99 feet, covering this area with about 2,000 fragments.

It was not possible at this juncture to resume manufacture of the former 22-pound bombs from pressed steel or cast steel since all workshops equipped for this purpose had long ago been pressed into service manufacturing 105-mm howitzer shells which were urgently needed by the Army and had a higher priority. 26

A substitute, the SD-10-dw (see photo) which had been designed already before the war consisted of two thinwalled concentric steel mantles, the space between these walls being filled with several hundred iron missiles. The explosive charge consisted of a compressed filling. This was placed in the bomb at the readying stage and thus dispensed with the

25a

Photo

Double-Walled SD-10-dw (22-pound)
Fragmentation Bomb

necessity for "hot filling," at the filling stations. However, in 1942-1943 the greatest difficulty was not that the turning lathes had to be made available for the production of artillery shells but rather the lack of high-quality steel to produce the bomb casings by the draw process, since these high-quality steels had in the meanwhile been required for more urgent armament purposes and were no longer available for the production of these bombs.

The difficulties encountered in the procurement of manufacturing materials for the mine-bomb casings and which threatened to reduce penetration hardness of these bombs at this juncture are related in Part B, Chapter 1, 2.

In the end, even the heavy bomber units of the German Air Force had to use fragmentation bombs of all calibers to intervene in the battles on the ground, so that the bomb-drop containers used in the past only for Elektron incendiary bombs were now also packed with small fragmentation bombs. Supply requirements in these bombs assumed such vast proportions that the Armaments and War Production Ministry launched a "Special Mass Bombing" project under men who were furnished exceptionally wide authorities.

So far as the matter of the 22-pound caliber as such was concerned, it was of course possible to produce ~~larger~~ larger numbers of SD-10-B bombs than mortar shells for the Army from a given amount

26 of the same type of special steel. The bombs could also be charged with ammonite. However, the supply requirements stated by the Air Force General Staff through the Air Force Chief of Special Supply and Procurement Services were numerically so high that completely new methods had to be adopted to meet them.

Attention was also drawn to the fact that the Russian aircraft operating in direct support of the Russian ground forces usually carried fragmentation bombs made from 76- to 123-mm artillery shells. In 1941 this Russian usage had been ridiculed, but in 1943 it became obvious how greatly a wartime economy could profit if shell casings which did not meet the restrictive tolerance allowances for acceptance by the Army did not have to be regarded as scrap metal but could be used without disadvantage as fragmentation bombs after further processing.

It goes without saying that a mass production of artillery ammunition would be essential if from that production adequate supplies of fragmentation bombs are to be made available to the air force, but any difficulties encountered here with any xxx one caliber would be offset, quantitatively, by other calibers. One point to be borne in mind is that shell casings rejected by the Army can definitely serve as bomb casings, since the bombs are not subjected to firing stresses in the

27 gun barrel, need not be an air or gas-tight fit, and since minor dimensional and center-of-gravity differences play no role at all.

It was chiefly the 105-mm howitzer shells which proved excellent as fragmentation bombs after pilot models had first been made and they had been introduced as bomb SD-15. Less use was made of 88-mm reject shells, used as SD-bombs, but large numbers of 50-mm and 80-mm howitzer shells were rejected by the Army and served the Air Force excellently as SD-1 and SD-3 bombs.

All of these small fragmentation bombs were used with the previously described bomb drop containers, which were available in the dimensions of the 110-, 550-, and 1,100 and 2,200-pound bombs and consequently were designated Bomb Container AB-50, AB-250 /AB = <u>Abwurfbehälter</u> = drop container/ etc. The size marking was followed by the content marking, 28 namely, 50-SD-1 or -4, SD10 A, and so forth.

The bomb drop containers were in two halves of sheet metal. They were fastened by an eye in the bomb release equipment and were opened after release by the action of a powder fuse. The fuses were available with various burn periods and were electrically ignited. When opened the bontainers emptied their contents over the target area.

A special type of impact detonator had to be designed

26 for fragmentation bombs used with containers in order to insure safety during transport and in the event of a plane making an emergency landing. The fuse developed for this purpose was that described later in this study as the "electromagnetic impact fuse No (66)," which was armed by the action of a propellor after the bomb left the container and was highly sensitive. These fuses were standard for all fragmentation bombs in calibers from 6.6 to 33 pounds and was also used with the SD-10 bomb, the original No (3) fuse of which could not be used when these bombs were packed in containers.

The smallest of all German air bombs, the SD-1 (2.2-pound) had an integrating impact fuse copied from the French 2.2-pound fragmentation bomb. It had no special safety device of any kind, as was the case with the German Elektro incendiary bombs, but proved just as satisfactory as this latter in use.

The result of the measures and new developments just described was that from then on the units on line received satisfactory supplies of fragmentation bombs.

During the latter years of World War II the German Air Force Command gave clear evidence that it had not only lost confidence in the solution of operational and tactical problems but that it also entertained doubts concerning the effectiveness of the bombs and other weapons used by the German Air Force.

59 An overall comparative study of German and enemy bombs and other weapons showed that there was no reason to doubt the efficacy of the German bombs and weapons and that the successes achieved by the enemy were due to the mass commitment of aircraft, which the enemy with their xxpxxx numerical superiority in manpower and materiel could afford.

However, the failures suffered with the Me-210 and He-177 bomber aircraft produced fateful consequences, for which even the outstanding performances of the German aircraft industry in placing the first jet aircraft in front line service were unable to compensate, since these came too late. The main defect in the two bomber types was due to their designing specifically for dive-bombing operations.

Concerning the other developments of new types of bombs described in this study it must also be said that they came too late, but in retrospect it is hard to find justification for the sporadic nature of these developments. The impression is that the German Command, after the tide had turned against Germany in Africa and Russia, in the air and at sea, still hoped by means of some miracle weapon or other to bring about a favorable turn in the course the war was taking.

Developments in the "miracle weapons" category during the latter years of the war will be discussed in Part B concurrently with the development of conventional bombs and mines, 29 among which they technologically belong. This study deals exclusively with bombs and mines, in the strict sense of these terms, and thus with bombs and mines designed to have a destructive effect. It does not deal with flare, smoke, or signal bombs, etc., although these were also used with bomb release equipment. Illustrations of bombs etc. in this latter category are offered only in the case of the LC-50-F Parachute Flare Bomb and the NC-250-S Smoke Bomb.

Detail sketches of all types of bombs are included at the end of the Appendix, with the exception of those which were special type designs which were not introduced for use by front line units.

APPENDIX A IV/1

[illegible] EXPLOSIVES USED IN BOMBS
[illegible] EFFECT**

Code	Military Designation	Year Bomb type	Composition in % of weight: Trotyl	Amnitrate	Hexogen	Aluminum	Effects* cub.meter
113A	Ammonal J 1	1940 SB-50	10	85	–	5	57
111	Ammonal J 1	1940 SC-250-111	20	60	(Sawdust 5)	15	65
14	(Trotyl FP 02 /trinitro-toluol/	1938 SC-50x	100	–	–	–	81.5
13 A	FP 50/50	1944 SC-50x	50	50	–	–	8[illegible]
52	Amatol 52	1941 Hs 293, V 1	50 Dini-trobenzol	35	15	–	86
13	FP 60/40	1939 SC 50x	60	40	–	–	88.5
X 1	T/H 55/45	Experimental	55	–	45	–	91.5
X 2	FP 60/30/10	Experimental	60	30	–	10	93
SW 18	Guncotton 18	1939 LM	60	(Hexanitrodi-phenylamin 24)	–	16	103.5
105	Trialen /trichlorethylene/	1941 BM,SC ~~250/X~~ 250/S	70	–	15	15	106.7
SW 36	Guncotton 36	1940 LT	67	(Hexanitrodi-phenylamin)8)	--	25	113.4
X3	Tri/Al 75/25	Experimental	75	–	–	25	114.2
X 4	Trialen 60/20/20	"	60	–	20	20	121
107	Trialen 107	"	50	–	20	30	124.2
106	Trialen 106	1942 SC 250/J	50	–	25	25	126

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* The effect is given in terms of the number of cubic meters of sand displaced in the crater formed by an SC-250 (550-pound) bomb dropped from a medium altitude with short fuse delay action.

** The German term used here is "Minenwirkung=Mine Effect."

APPENDIX A IV/1--SUPPLEMENTARY

OTHER EXPLOSIVES USED BY THE GERMAN AIR FORCE

Code	Military Designation	Year Bomb Type	Composition in % of Weight Trotyl	Ammitrat	Hexogen	Aluminium	Miscellaneous
101	Phlegmatic Trotyl	1940 PC, PD	85	-	-	-	Wax: 15
102	Phlegmatic Trotyl 60/40	1942 PC, PD	55	35	-	-	Wax: 10
32	Nitropenta -- [pentaerytritol-tetranitrate]	1941 2cm M	(Nitropenta: 90)	-	-	-	" 10
92	Hexogen*	1942 2cm M	-	-	90	-	" 10
95	T/H 1/1	1943 3cm M	38	-	60	-	" 2
104/106	"E"-Mischung	1943 SB 1000	20	-	70	(Hexogen* 10 60 Tr. 106 40)	
109 P	PMF (AP Ammo)	1940 PC/Rs	(Nitroguanidin:100)	-	-	-	(Optimum charge)
			(" 54)	-	36	XX	(Center Charge Wax:10)
			(" 57)	-	38	-	(Base Charge Wax:5)
			(" 25 Trotyl: 42)	-	27	-	(Wax:6)
148	Trotyl Compound	1944 SD 15	50				Rock Salt: 50
24	Shell filling	38	(100 Trinitrophenol) solely as prime charge				
56	Ammonit	1942 SD 1, SD 3	12	80	(4 nitroglycerine, 4 meal)		
Xyrol	Myrol*	1945 "Mistel"xx	(NC-powder: 50; Methylnitrate:35; Methanol: 15)				

Remark: The marking "tp" signified proof against tropical conditions

* Code for type of mongerol containing methylnitrate

** Codx for composite aircraft, Ju-268.

APPENDIX IV/I--SUPPLEMENTARY (2)

Illustration

Flam C250C (Fire Bomb)

APPENDIX IV/I--SUPPLEMENTARY (3)

Illustration

FlamC250C (Fire Bomb)

DEVELOPMENT OF BOMBS (1925-1945)

Bombs used by Germany, Britain, USA, Soviet Russia

<u>Legend:</u>

Stand:1.7.1943/Ergaenzt:1945 = Status:19Jul.43/suppl. 1945.

Wirkungsbereich = Category

unter 50 kg = Calibers less than 50 kilogarms (110 pounds)

50 kg, 100 kg. etc. = Caliber 50, 100 kilograms etc (110, 220 pounds etc)

Staat = Country

Deutschland, Grossbritannien, USA Sovjet Union = Germany, Britain, USA, Soviet Russia

Dtschl., GB, USA, SU = Germany, Britain, US., Soviet Russia

Brandbomben = Incendiary bombs

Aufbau, kennzeichnungen = Structural features

Windrad Entsicherung = Fuse arming propeller

Zuender = Fuse

Uebertragungsladung = Prime charge

Aufhaengung = Suspension

Brandladung = Incendiary charge

Sprengladung = Explosive charge

Durchschlag (Stahl) = Penetrating point (Steel)

N=Normalsprengstoff = N=Normal explosive

HHochleistungssprengstoff = Special high-power explosives

wH=wirksamster H.

Tri=trinitroluol = Trinitroluol

Am.=Ammonsalpeter = Ammonsalpeter

Abwurf aus Behaelter zu: 178 Stueck oder 112 oder AB500 610 Stueck oder AB1000 238B2 248 BT = Dropped in containers of 178 AB500 or 112 or 610 AB1000 or approximately 238 B2 or 248 BT

Zerleger = Self-destroyer

Elektron = Elektron

Term. = Thermite

Abwurf aus Behaeltern zu 90 Stueck = Dropped in containers of 90

8 Stueck = 8 only

Treibladung = Propelling charge

Continued--

Steuerfinnen = Steering or stabilizing vanes

USA INC 100 lb) = USA incendiary 100 lbs
17 l. Benzin) 17 liters gasoline
350 g Schw P.) 350 gram black powder

Treibladung = Propelling charge

Stabbrandbombe = Stick-type incendiary bomb

Bezeichnung = Code number

o. Zerleger = without self-destroyer

m. " = with " "

mit Sprengkopf = with warhead

Phosphorbrandbombe = Phorphorus incendiary bomb

Brand = Incendiary

Spreng-brand = Explosive+incendiary bomb

Flam = Fire or Oil bomb

Streubrand = Fire scatter bomb

Gewicht (Kaliber) Kg = Weight (Caliber) in kilograms

Brandladung) = Incendiary charge
Sprengladung) Explosive charge

~~XXXXX~~ Benzol,Kunstharz) Benzol+artificial/~~XXX~~ resin+phosphorus
und Phosphor) =

Benzin Kunststoff in) = Gasoline + plastic in bag
Beutel)

15 l Brandoel m.Phosphor = 15 liters burning oil+phosphorus

73 ElBrandbomben = 73 Elektron fire bombs

55 l Benzol u.Kautschuk = 55 liters benzol & caoutchouc

~~XXX(XXXXXXXXXXXXXXXXX)XXX~~
~~3XXXX(SprengstoffXXXXXXX)XXX~~

145 Thermit-Kugeln je) = 145 Thermit balls each 300 gram
200 gr.)

8-10 Thermit Brandbomben) = 8-10 Thermite fire bombs + 30 kilo-
30 kg Sprengstoff) grams explosives

75 l. Brandoel m. Phosphor = 75 liters burning oil+phosphorus

75 l Oel-Benzin = 75 liters Oil+gasoline

1200 Branddosen (selbst-)) = 1200 self-igniting fire canisters
entzuendlich)

Leistung) = Target effect
Brandflaeche m Ø) Fire area Ø
(Brennzeit)) (burning duration)
Durchschlag) Penetration (in millimeters of
(mm Eisenbeton)) ferroconcrete)

mehrere Stockwerke = Several floors of a building

4 min. 10-20 min.etc = 4 minutes, 10-20 minutes etc.

Sprenw. w. SC 50 = Blast effect equivalent to that of SC-50 (110-pound) bomb

12 qkm. = 12 square kilometers
[1 sq.kilometer = 247.104 acres]

Bildmassstab
1:10 8 1:40 = Scale of drawings:
under 50 kilograms (110-pound) caliber = 1:10
50 kilograms and over = 1:40

Bemerkungen = Remarks

Magn.Kopf = Magnesium head

Stahl Kopf = Steel head

Gebuendelt zu 51 od.34 oder 192/128 Stueck = In clusters of 51 or 34 or 192/128 bombs

mit und ohne Zerleger = with and without self-destroyer

Sprengbomben	= (High) explosive bombs or demolition bombs
a) Minenbomben	= mine-bomb or high-explosive bomb
Aufbau Kennzeichnungen	= Structural features
Zuender	= Fuse or detonator
Windred Entsicherung	= Fuse or detonator arming propeller
Uebertragungsladung	= Prime charge
Brandladung	= Burning charge
Sprengladung	= Explosive charge
Durchschlag	= Penetrating point
Aufhaengung	= Suspension
N=Normalsprengstoff	= N=Normal explosives
H=Hochleistungssprengstoff	= High explosive charge
Wirksamster H.	= /Probably=Wirksamster Haertegrad= /probably denotes most suitable or effective degree of hardness/
Tri=Trinitroluol	= Tri=Trinitroluou
Am=Ammonsalpeter	= Am=Ammonsalpeter
Abwurf aus Behaeltern zu: 4 x 10 Stueck	= Dropped in containers of 4 x 10 bombs
GB Formaehnlich MAB 100	= Structurally similar to MAB 100
Bedeichnung	= Code number
Gewicht (Kaliber)	= Caliber in weight (5, 4 etc. kilograms)
Sprengladung Gewicht kg (% v. Kal.)	= Explosive charge in kilograms (% of caliber weight)
Art	Type
Ngl. Pl.	= Nitroglycerine-Plastic
Leistung, Durchschlag mm Schiffsbaustahl	= Target effect = Penetration performance in millimeters of shipbuilding steel
U-Boot Jagd	= Anitsubmarine operations
Wirkung wie geballte Ladung 3 kg	= Target effect equivalent to 3-kilogram (6.6-pound)concentrated charge
Bemerkungen	= Remarks
Fliegerbombe AT=Antitank	= Airborne underwater bomb = AT = Antitank
wird ersetzt durch SP-70	= Replaced by SP-70 bomb

Continued from p. 171

Einzelheiten z.Zt. nicht bekannt = Details at present unknown

Abwurf mit u ohne Fallschirm = Dropped with and/or without parachute

Leitwerk oder Fallschirm - = Steering vanes or parachute

<u>Sketch Scale:</u> under 50 kilograms (110-pound caliber)= 1:10
50 kilograms and over = 1:40

Sprengbomben = Explosive bombs

b) Splitter- und Mehrzweckebomben = b) Fragmentation and multipurpose bombs

Aufbau Kennzeichnungen = Structurel features

Windrad Entsicherung = Fuse or detonator arming propeller

Zuender = Fuse

Uebetragungsladung = Prime charge

Brandladung = Burning charge

Sprengladung = Explosive charge

N=Normalsprengstoff = N=Normal explosives

H=Hochleistungssprengstoff = High explosive charge

Aufhaengung = Suspension

Durchschlag (Stahl) = Penetrating point (Steel)

wH=Wirksanster H. = /Probably wirksamster Haertegrad = most suitable degree of hardness/

Abwurf aus Behaeltern zu 50 Stueck oder 224 oder 392 = Dropped in containers of 50, 224, or 392 bombs

Abwurf aus Behaelter zu.... = Dropped in containers of.......

Abwurf einzeln oder aus Behaeltern zu..... = Dropped individually or in containers of....

Abwurf im Buendel zu 16 Stueck = Dropped in clusters of 16

Aufhaengung an Gleitschienen = Suspended on slide rail

Treibsatz = Propelling charge

Abwurf aus Schuettkaesten zu 2x5 Stueck = Dropped in containers of 2x5 bombs

Bezeichnung = Code number

~~Panzer-Raketenbomben~~ = ~~Rocket-propelled armor piercing bombs~~

gep.Stabilisierungsschirm = Armor-protected stabilizer vane

~~Windhaube (Metall oder plastischer Stoff)~~ ~~Windscreen (metal or plastic)~~

Form aehnlich GP bomben = Structurally similar to GP bombs

Gewicht (Kaliber kg) = Weight (Caliber in kilograms)

Sprengladung Gewicht kg (% v.Kal) Art = Explosive charge. Weight in kilograms (% of caliber weight) Type

Leistung Durchschlag im Panzerstahl vom = Performance (Penetration capability in steel armor of..)

(Winkel 30° zur Horiz.) = (Angle of 30° from horizontal)

174--Continued from p. 173

Leistung (Splitterzahl --ueber 5 g) = Target effect (fragmentation count--fragments above 5 g in weight)

Durchschlag- mm Panzer = Penetrating capability in mm of armor

(ueber 1 g. 130) = (fragments larger than 1 g 130)

Splitterwirkung geringer als bei SC 10 = Fragmentation effect less that that of SC-10 bomb

Umkreis der Splitterwirkung m: = Fragmentation covered area: radiusin meters

Bemerkungen = Remarks

Hochangriff = High-altitude bombing

Tiefangriff = Low-altitude attack

Bestaende werden umgebaut in SD 10 A = Stocks being modified as SD-10-A bombs

Aus sprenggr. 10,5 cm = From 105-mm explosive shell casings

wird ersetzt durch SD 70 = Being replaced by SD-70 bomb

Geballte Ladung = Concentrated charge

<u>Sketch Scale</u>: under 50 kilograms (110-pound caliber) = 1:10

50 kilograms and over = 1:40

DEVELOPMENT OF BOMBS--(1925-1945)--Continued

Sprengbomben = Explosive Bombs--Continued

c) Panzerbomben = Armor-Piercing Bombs

Aufbau Kennzeichnungen = Structural features

Windrad-Entsicherung = Fuse or detonator arming propeller

Zuender = Fuse

Uebertragungsladung = Prime charge

Brennladung = Burning charge

Sprengladung = Explosive charge

N=Normalsprengstoff = N=Normal explosives

H=Hochleistungssprengstoff = High explosives

Aufhaengung = Suspension

Durchschlag (Stahl) = Penetrating point (Steel)

wH= wirksamster H. = /probably wirksamster Haertegrad= most effective degree of hardness/

Panzer-Raketenbombe = Rocket-Propelled armor-piercing bomb

Windhaube (Metall oder plastischer Stoff) = Windscreen (metal or plastic)

Sprengladung/Gewicht kg (% v.Kal.) Art = Explosive charge Weight in kilograms (% of caliber weight) Type

Gewicht (Kaliber) kg = Weight (caliber) in kilograms

Leistung/Durchschlag im Panzerstahl vom = Performance/Penetrating capability in steel armor of thickness (in millimeter)

Winkel 30° zur Horiz. = Angle of 30° from horizontal

Bemerkungen = Remarks

Beton = Concrete

Stahl = Steel

1 m Beton = 1 meter concrete

Hochangriff = High-altitude bombing

Sturzangriff = Dive-bombing attack

Nicht mehr in Fertigung = No longer in production

<u>Sketch Scale:</u> under 50 kilograms (110-pound) caliber = 1:10

50 kilograms and over = 1:40

Photo

SD-10 (22-pound) bomb fragments

Photo

SD "d.w." [double-walled] bomb fragments

Photo

Size-Breakdown of SD Stg Bomb Fragments

over 30 g. 15-30 gr. 10-15 gr. 5-10 gr. under 1gr.

PART B

CHAPTER 1

TESTING OF EXPLOSIVE BOMBS

1. Fragmentation Effect. In Germany, the fragmentation effect of an artillery shell or of a bomb was stated in four factors:

Fragment count in test explosions
The concept of fragmentation pattern density
The fragmentation pattern
The average weight of the individual fragments.

To determine the fragment count the bomb in question was exploded in a wooden box within a blast trench, after which the fragments were sorted according to size, so that a size and count pattern could be compiled as shown on pages 176 and 177.

However, the digging and later the closing of the trench required considerable manual labor, for which reason this system was only practicable for the testing of specifically fragmentation type bombs, meaning bombs not exceeding a maximum caliber of 44 pounds overall weight. For the SD-50 (110-pound) multi-purpose bomb a shelter of Peiner sheet piling was constructed at the Air Force Proving Station Rechlin , in which the bomb was exploded. The previously mentioned size and count pattern provides no cause to assume that the fragments were further fragmented by impact with the steel walls of the shelter.

1 When the need arose to determine the fragment count of British
and American bombs and of the newly developed German multi-pur-
pose 550- and 1,100-pound bombs, these were exploded under water,
hanging in an air-filled barrel, and the fragments were recover-
ed from the ground by means of a ground sheet. This method pro-
2 vided satisfactory factors for comparisons.

The target effectiveness of a specific type of fragmentation bomb cannot be assessed satisfactorily on the basis of data procured by detonating the bomb in a blast trench alone. This will provide data on the size and average weight of the average fragmentsbut not on their direction and force of penetration. To obtain a more complete assessment, use was therefore made in Germany of the fragmentation test circle (<u>Sprenggarten</u>) to ascertain the effective xan fragmentation range.

For this purpose, the bomb was placed standing on its point and touching the surface of the ground. The concept of fragmentation pattern density was taken as anxx effectiveness coefficient and the number of fragments penetrating through a 20-mm thickness of pine planking per square meter was ascertained for this purpose.

By means of interpolation this makes it possible to compute the distance in meters at which the fragment spread density will have a value of one per square meter. In establishing this area unit for determining the effective fragmentation range it was

2 assumed that a soldier standing upright had a surface area of 1 square meter. Generally speaking, the purpose of fragmentation artillery shells and bombs is to incapacitate live targets, for which purpose a fragmentation weight of 5 grams is as a rule adequate. A penetrating force sufficient to pierce through 20 millimeters of dry pine wood would at least enable a fragment of this size to inflict serious injuries. According to C.Cranz, French authorities consider a projectile force of 4 meter-kilogram necessary to incapacitate a soldier and 19 meter-kilogram to incapacitate a horse. In Germany the assumed necessary force was 8 meter-kilogram, which in the case of a 5-gram fragment would be equivalent to a velocity of 180 meter-seconds. Since 3 a shell or bomb fragment, also according to C. Cranz, has an initial velocity of between 400 and 2,000 meters per second, it is to be assumed that these fragments will still have sufficient force at a distance greater than that corresponding to a fragment spread density of 1 per square meter.

It was customary, when comparing the fragmentation effect of one bomb with that of another to express matters in a more abbreviated form, for example: the SD-10 bomb has a fragment density pattern of 28 and the SD-15 bomb a fragment density pattern of 40, these being the optimum factors for shell casings made of pressed steel.

The concept of fragment density pattern (<u>Splitterdichte</u>)

APPENDIX B 1 1

to Part B, Chapter 1, p.2.

FRAGMENTATION TEST CIRCLE
FOR DETERMINATION OF FRAGMENT SPREAD DENSITY PATTERN

<u>Legend</u>:

Grundriss = Plan view

15-, 20-, 30 m = 15, 20, 30 meters

Sprengpunkt = Bomb detonation position

Wahlweise = As desired

Schnitt A-B in Richtung C = Sectional view in direction C

Brettstaerke 20 mm (Kiefer) = Plank thickness: 20 millimeter (pinewood)

Legend:

Ermittlung der "Splitterdichte der Splitterbombe SD 10 = Determining the fragment spread density pattern of the SD-10 fragmentation bomb

Mittelwerte von 20 Sprengungen. = Mean values obtained in the detonation of 20 bombs

Bomben mit der Spitze auf dem Boden stehend gesprengt = Bombs detonated standing upright ~~on ground~~ with point touching ground

Anzahl Splitter je Qm = Number of fragments per square meter of area

Splittordichte = Fragment spread density pattern

Abstand vom Sprengpunkt = Distance from bomb detonation point

3 thus included both the probability of a hit and the effect of that hit. In the fragmentation test circle it is observed, however, that there are zones with varying fragment impact, in other words that the fragment intensity of one fragment per square yard is found at varying distances, since the fragments, as far as area is concerned, depart from the exploding bomb in an irregular pattern.

If one enters the fragment penetrations on a grid sheet one obtains a fragment spread pattern. This should be regarded as a cross-section of a body of rotation (<u>Rotationskoerper</u>), the axis of which is identical with the axis of the bomb, and its greatest diameter represents the position of the zone of greatest fragment density.

By calvulating the fragment count per square meter for each grid and entering the result over the point of bomb detonation one obtains a target-effect-pattern. Using this factor, it is possible to compute any bomb impact angle, from which the fragment density is obtained for the height of the target.

The average weight of the fragments of a specific bomb is calculated by dividing the fragment count into the
4 overall weight of all fragments of effective size; from this it is possible to determine the suitability or otherwise of a fragmentation or multi-purpose bomb for action against

APPENDIX B 1, 1

to Part B, Chapter 1, p. 3.

<u>Legend</u>:

Splitter- u. Wirkungsbild von SD 10 = Fragment density and effect pattern of SD-10 bomb

Laengsachse der Bombe = Longitudinal axis of the bomb

Splitterbild = Fragment density pattern

1 cm.= 2 Spl. = Per sq.centimeter 2 fragments

Wirkungsbild = Fragment effect pattern

1 cm = 2,50 qm = 1 centimeter = 2.5 sq. meter.

4 targets of greater or lesser resistance. In the case of the SD-10 bomb the average fragment weight was 6 grams, in that of the SD-50 bomb roughly 17 grams. The mean average fragment weight here represents the fragment halfway between the heaviest and lightest of all fragments considered effective, in the case of the SD-50 bomb, for example, roughly 10 grams for fragment no. 710. However, this is less informative than the more commonly used ordinary average weight.

The results obtained with twenty different types pf explosive bombs are shown in the attacked chart, in which the highest factors are given. Instructions to the troops included the average fragment values.

In the case of the smallest types of fragmentation bombs, SD-1 (2.2 pounds) and SD-3 (6.6 pounds) fragments weighing only 1 gram were also included in the count, because brittle cast iron usually produces a large count of small fragments. An effective force of 6 meter-kilogram is obtained with a fragment weight of 1 gram at an impact velocity of 900 meters per second. Given a fragment density of one per square meter, such small fragments are thus adequate within very short ranges to incapacitate a live target.

For better intelligibility the testing of fragmentation bombs is also presented in the form of graphs.

Only bombs of calibers up to 15 kilograms (33 pounds) can

4 strictly speaking, be considered specifically as fragmentation bombs; at that caliber begins the category of so-called multi-purpose bombs in which the aim was xxxxixx to obtain a combined blast-fragmentation effect. Introduction of the S-Be-50 (110-pound) concrete bomb during the first phase of the war must be

5 considered only as a measure of extreme emergency.

On the matter of the graph curves, the following should be noted:

In the case of the smallest caliber bombs of from 2.2-to 6.6-pound bombs the xurvaxiorxirxgxxnx count curve for fragments over 1 gram in weight is almost perpendicular, a sign of the equivalent value of these bombs when compared one with the other.

In the case of fragmentation bombs in the 8.8-to 33-pound class, however, deviations become evident:

Consideration must be given to the fact that the SD-4 Hl (SD 8.8-pound hollow charge) bomb was designed as an antitank missile and was only given a supplementary fragmentation effect because the Russian tanks usually carried infantry or were followed up by infantry (see Chapter II, 4, for discussion of the development of hollow-charge bombs).

For the above reason the SD-4-Hl hollow-charge bomb can not be considered specifically as a fragmentation bomb; its 350 gram charge of Hexagon shattered the steel casing, approximately 4.4 pounds in weight, of the bomb into relatively small fragments. From the fragment density curve the SD-4-Hl bomb can be assumed to have corresponded in its fragmentation effect more or less to a proper fragmentation bomb weighing approximately 3.5 pounds.

APPENDIX

to PART 3, Chapter 1, page 4

Legend:

Ergebnisse von Sprengungen in der Grube zur Ermittlung der Splitterzahl = Results obtained in blast trench tests to ascertain fragmentation counts

Werkstoff = Material

Bombenmuster = Bomb type

Gewichte in kg = Weights in kilograms

Gesamt = Overall

Sprengladung = Explosive charge

~~[illegible]~~

Zdr., Leitwerk = Fuse, stabilizer

Gew. Verlust = Weight loss

Spl. 5 g = Fragments of 5 grams

~~[illegible]~~

Spr.Ldg. % Gesamt Gewicht = Explosive charge % of overall weight

"Wirksame" Splitter = Effective fragments

Anzahl = Count

kg = Kilogram

d/schnitt = Average

Splittergewicht = Fragment weight

Temp. = Tempered cast steel

Stg. = Cast steel

Pr. = Pressed steel

ca. = About, approximately

Remarks

a. In tye case of the smaller caliber SD 1 (2.2 pounds) to SD 4 Hl (8.8 pounds) bombs all fragents over 1 gram are included in the count given and the number above 5 grams is given in parentheses. For SD 10 (22-pound)bombs and the larger German and British General Purpose bombs, the count includes only fragments over 5 grams; for SD-10 (22-pound) bombs, the number ~~andarx~~ above 1 but under 5 grams is given in parentheses.

c. Only 4.4 pounds of the Atlantic SD-4-Hl bomb has been counted as a fragmentation component. This bomb had an explosive charge of pure hexogen

Appendix

to Part B, Chapter I, 1, page 4--Continued

Remarks--Continued

d. In the case of the American fragmentation and demolition bombs the figures have been taken from manuals and include all fragments with a striking force of at least 8 meter-kilogram.

e. The average fragmentation weight represents the total weight of all effective fragments. The average fragment weight represents the weight of that fragment which is halfway between th heaviest and lightest of the effective fragments.

APPENDIX

TO Part B, Chapter 1, 1, page 4

Legend:

Splitterzahl und Splitterdichte von Splitter und Mehrzweckbomben SD 10 to SD 500 A, GP 40 lb to GP 1000 lb = Fragment count and density of fragmentation and multi-purpose SD-10 (22-pound) to SD 500 A (1100-pound) bombs and British GP 40-lb to GP 1100-lb bombs.

Splitterzahl > 5 gr = Total Fragment Count 5 grams & over

Stueck = Count

Splitterdichte = Density

Sprengung = Detonation on ground

Abwurf = Air dropped

(Splitterdichte engl. Bomben wurde nicht ermittelt) = Fragment density of British bombs not ascertained)

Splitterzahl (engl) = Fragment count (British)

Splitterzahl (dtsch) = " " (German bombs)

Splitterdichte $1/m^2$ = Fragment density one p. sq. meter

APPENDIX

to Part B, Chapter I, 1, page 4

Legend:

Splitterzahl und Splitterdichte der Splitterbomben SD 1 - SD 15 = Fragment density of fragmentation bombs calibers SD 1 (2.2 pounds) to SD 15 (3.3 pounds)

Splitterzahl = Fragment count

Splitterdichte = Fragment density

Splitterzahl 5 gr = Fragment count - 5 grams and over

Bombengewicht = Weight of bomb

Splitterdichte ______1/qm = Fragment density one per sq ~~yard~~ meter

The extended curve for fragments weighing 5 grams and over therefore creates a false impression; it would probably be more correct to place the SD 4 HL bomb fragments of 13, in relation to the fragment density ~~axx~~ corresponding to a 3.25-pound bomb, and to extend the fragment count curve II from that point, as indicated by the broken line extended with the curves for larger caliber bombs.

SD-9, which was an antiaircraft 88-mm shell converted to serve as an air bomb is on the unfavorable side of the 6 fragment curves; it had a relatively low explosive charge. Designed originally for high muzzle velocities it had to have a high barrel safety coefficient with a corresponding decrease of target effect.

In contrast, the SD 10 fragmentation bomb is on the favorable side, ~~afxthx~~ insofar as the effective fragment count is concerned. The fragment effects of the SD-15, made from 105-mm howitzer shells (the ammunition used by the large bulk of all field artillery units), were in every respect satisfactory, whereas the 105-mm antiaircraft shell was useless as an air bomb. Even in the matter of fragment density the SD-15 showed relatively more favorable results than the SD-10. This was probably to its higher explosive charge ratio, which insured the fragments adequate penetration velocity at greater distances.

The fact that all pre-war bombs in the 22-pound to 1,100-pound range had the same fall trajectory and were aimed by the same ballistic table, which in general was an advantage in point of ballistic considerations, had an adverse effect on effectiveness in this case, because the SD-10 bomb had too thick walling and only 9% explosives to achieve the highest possible cross section strains.

In spite of its all-round fragmentation spread, the ground-attack aerial bomb SD-2-t shows up well in both the fragmentation count and density curves. This is probably

6 due to its well balanced explosive charge ratio of 12% Trotyl and the high-quality cast steel used for the almost spherical bomb casing.

Far more difficult than the technical testing of fragmentation bombs was the problem of ascertaining their effect of the various types on actual enemy targets. In a number of cases this was achieved by trained ordnance officers attached to the air corps as liaison officers. The annihilating effects of the SD-2-t bomb in operations to drive the Soviet masses out of the eastern parts of the Crimea in April 1942 in itself had been a point in favor of the smaller caliber fragmentation bombs in place of the until then preferred SD-50 multi-purpose bomb. However, it also proved possible already in 1943 to determine and even to prove by close-range photographs some less clearly defined differences, such as the difference between the effects of an AB-50 container packed with SD-1 (2.2-pound) bombs on the one hand and those of a cluster of four SD-10 (10-pound) bombs on the other hand. In the case of a captured battery in field-type emplacements it was found that the casualties which had been caused by the smaller caliber bombs were a multiple of those inflicted by 22-pound bombs under otherwise equal conditions. In the case of each of these types it was found that each bomb release covered an area of roughly 100 x 100 meters with fragments. Whereas fifty SD-1 bombs produced 50 x 130 = 6,500 fragments, over 1 gram in size, the 4 SD-10 bombs produced only 3,600.

6 Apart from the fact that the packing space in the containers is exploited better with small caliber bombs than with large, the only other explanation which can be~~xxa~~ offered for better the results obtained with small caliber bombs than with large is that the smaller calibers (SD-1) struck considerably closer to the actual targets aimed at than the larger calibers (SD-10), so that even the smaller fragments had an adequate velocity impact to incapacitate live targets.

Computing the fragmentation effect pattern it was found that 50 SD-1 (2.2-pound) bombs provided a fragment density of one fragment per square meter within an area of 7,350 square meters, whereas the area so covered by the fragments of four SD-10 (22-pound) bombs was only 2,100 square meters, which provided mathematical confirmation of the results observed at the fighting fronts.

8 The ratio of effectiveness between the SD-3 (6.6-pound) and the SD-15 (33-pound) bombs was probably similar. However, it should be noted that when the target attacked was columns of vehicles or parking aircraft, the larger and more jagged fragments of ~~SDx9x(9x8)xSDx10x)xandxparticularlyx~~ SD-9 (19.8-), SD-10 (22-pound), and particularly of SD-15 (33-pound) bombs did more damage to materiel than the smaller fragments from the SD-1 (2.2-pounds) and SD-3 (6.6-pound) bombs. Form the practical viewpoint, the highly diversified nature of targets thus makes it impossible to do without the smaller or the larger caliber fragmentation bombs.

8 calibers.

The use of artillery and mortar reject shell casings as aerial bombs should therefore not be considered merely as an emergency measure but as an armament industry requiremment of the first order. The results obtained with such ammunition are in no way inferior to those obtained with standard fragemntation bombs of similar calibers, so tha no justification exists for the separate manufacture of fragmentation bombs of calibers under 44 pounds. Instead, every air force must already during peace prepare for the use of suitable Army and Navy ammunition as bombs.

In this way the separate branches of the Armed Forces very favorably complement each other. Objections raised by the Air Force against the use of rejected artillery ammunition should be countered by emphasis on the fact that far more comprehensive preparations are made for the mass production of artillery ammunition and that such ammunition is usually more thoroughly tested, because the artillery is a major arm of the military forces, then fragmentation bombs, these latter not being the chief weapons in air warfare.

In Germany it was necessary for psychological reasons, when introducing such ammunition to mark it from the outset as air force ammunition, for example SD-1 and not Wgr [mortar shell] 50-mm apt. [adapted], etc. An interesting point is that the French Air

8 Force already prior to World War II had adopted the 50-mm
8 mortar shell for use as a fragmentation bomb and in 110-
pound composite containers used it in a way similar to that of the Elektron incendiary bomb. German interest was only roused later in the war in the large stocks of these small-caliber bombs among the captured French materiel, which met initial requirements at the eastern front.

Only the Russians used small caliber bimbs for individual or stick bombing; all other air forces used them in salvoes--the French, as previously mentioned, in composite containers, the USAAF in a Cluster Adapter, the German Air Force in vertically suspended fastenings and in bomb containers, and the Royal Air Force in their "small Bombs Containers." Owing to the unfavorable ballistic properties of the small caliber bombs, better results were achieved by salvo than by individual bomb releases, and the smallest bomb suspension systems in aircraft as a rule were for 110- or 220-pound bombs. If we disregard use of the SD-2-1 (4.4-pound) bombs, the German Air Force only started using small-caliber fragmentation bombs in the autumn of 1942, when the German ground forces in the east requested direct air support to repel Russian counteroffensives. Owing to the excessively wide frontages, it was always exceedingly difficult to bring about artillery fire concentrations at critically endangered points.

9 The SD-10 bombs stockpiled prior to the war, of which only few had been used by specially adapted Do-17-E planes in the Polish campaign and by Ju-87 planes in North Africa, undoubtedly would have sufficed for a while, but there was no possibility to resume their production, since the factory spaces originally allocated for the purpose had meanwhile been taken into use for the production of artillery shells.

10 A program put into effect immediately to manufacture a substitute, the SD-10-E bomb, from special gray cast iron with an ammonit explosive charge failed to produce the required quantities.

The Armaments Ministry initiated a special program under the title "Mass Bombing = Massenabwurf" to produce adequate supplies of fragmentation bombs and drop containers. Similarly to the Soviets, who had done so already prior to the war, the German Air Force commenced processing artillery and mortar ammunition for adaptation as aerial bombs. Very considerable quantities of these were available, which could not be used for firing by gun owing to minor structural defects, such as imperfect barrel fits of off-balance point of gravity, but could serve without any disadvantage as bombs.

The proper allocation of the fragmentation bomb types, enumerated on the attached table, for use with 110-, 550-, and 1,100-pound bomb containers, and the adaptation of the fuse system for these bombs, as well as the adaptation of the containers for the various attack tactics, created

10 very special problems of designing and testing.

In the matter of tactics, consideration had to be given to the fact that every type of aircraft, regardless of whether it was equipped for small-caliber or large-caliber ~~fragmentation~~ explosive bombs could be committed against all types of targetsrequiring the use of SD-1 or SD-3 bombs with their small fragments or SD-9, SD-10, and SD-15 bombs with their large fragments. In order to avoid the necessity to pack all eight fragmentation bomb types into each container of all three container types, which would have meant that the supply services would have had to handle 24 different composite ammunition types, a system was worked out to insure that only eight types would be in supply, namely,

Container	Number of fragmentation bombs packed
AB-50	50 SD-1; 24 SD-2-t; 4 SD-9 with container-opening-fuse-arming device (69)
AB-250	224 SD-1; 17 SD-10; as above (79)
AB-500	84 SD-3; 78 SD-4; 24 SD-14 as above (69)&(9)

The proper testing of these standard container packings, to which the special "Mass Bombing" production program was adapted, included determination of the proper container-opening timing for each type of bombing in order to insure the optimum spread of fragments at the target.

The types of container opening-fuse arming devices used were as follows:

10 For high-altitude bombing with Container Type AB-500: remote-control electrical firing fuse (9);

For smaller container types: Powder burning fuses Nos. (69) and (79) with fixed burning times of 7 or 2 seconds or (for low-altitude and dive-bombing attacks) 10 seconds.

If a wider fragment spread was desired, the AB-500 container could be opened by the (69) remote-control fuse.

No detail tests were carried out by the German side with the American Frag 20 lb fragmentation bomb, since the methods used in its construction could not be taken into consideration. It consisted of a steel casing with an explosive filling and bound with a square profile steel xxxx hoop. Presumably, the purpose was to exploit the American steel-producing industries and to reserve the available machinery in these calibers for the production of artillery ammunition.

The target effect coefficient of the Frag 20 lb can be described as good, which was due primarily to the fact that i it had the proper explosive ratio of 12% for fragmentation bombs. Structurally, however, it was in no way superior to

12 the fragmentation bombs made of cast or pressed steel. It was dropped in clusters of sixteen, using the suspension equipment for a 500-pound bomb, which must be considered a poor exploitation of weight capability.

In the graph for large-caliber fragmentation bombs, consideration of the fragment count curve for German bombs shows

Appendix to page 10.

Legend:

Beladungsmoeglichkeit der Abwurfbehaelter	Holding capacity of bomb containers
Behaelter	Container type
Bomben	Bombs of type
Stk	Only
Brand	Fire or other incendiary
Zuender	Fuse, detonator
bzw.	and/or

upp as steep in comparison with the curve for English bombs. This can be accepted as proving that up to calibers of x33 1,100 pounds the fragment count can be influenced as desired by a correct choice of casing and explosive charge, although the curve for the large caliber bombs is steeper, meaning less favorable, than the curve for the fragmentation count of the smaller calibers. The fragment density curve also shows that the smaller calibers of fragmentation bombs are more effective than the multi-purpose bombs in use against easily vulnerable targets.

In detail, the following merits attention: The British GP 40-pound bomb with its 16 percent xaxghx of weight explosive charge apparently had a too powerful blast effect to secure an~~d~~ effective fragment count of fragments over 5 grams in weight commensurate with its caliber; on the other hand a charge of only 6.6 pounds of explosives would produce only negligible demolition results. The British also seem to have realised this, since the GP 40 pound bomb was soon withdrawn from use.

The only British multi-purpose bomb with a favourable fragment count ration was the GP 250 pound. The GP 500 pound bomb, on the other hand, apparently was designed more for demolition purposes, since the factors for its fragment effect appear on the minus side of the curve. The GP 1000

12 however, appears on the plus side of the curve, which becomes steeper at this point; the more favorable fragmentation ratio is probably due to the higher content of Trotyl in the explosive charge (40% Trotyl instead of the 20% used in the smaller caliber GP bombs). For this same reason the German multi-purpose bombs ~~xxpxxx~~ (with the exception of the SD-250) appear in a more favorable area left of the curve of the British GP bombs.

Of the German bombs, the SD-50 and SD-250 appear on the minus side of the curve; the SD-50 was not a sound design and was soon replaced by the SD-70. SD-250 was definitely a substitute design, due to the demand for larger caliber bombs for use in low-altitude bombing: As was to be expected, 550- and 1,100-pound mine type bombs had not proved quite satisfactory in low-altitude attacks against industrial targets in the 1940 campaign in France. Because of ~~its~~ their massive point section and ~~its~~ their shortened tailpiece as well as ~~its~~ their well placed ~~fxxx~~ central fuse (with a few seconds delay) in the middle of the bomb, SC-250 and SC-500 (550 and 1,100-pound) bombs of the first quality, Class 1, withstood the initial impact on hard targets well when released in a descending angle at low altitudes. However, when bouncing off because of their flat impact and then struck against vertical objects such as tooling machinery or girders they often

28213 burst and spilled their explosive filling before detonating. At the time when this defect was recognized in mass production of Class III SC-250-K bombs, with 3-piece-welded casings, was halted because The output in 1- and 2-section (Class I and II) SC-250 bombs was gradually increasing and current requirements could be met from current output in these two classes.

In order to accelerate production of a thick-walled 550-pound bomb, the nose piece of the 3-section SC-250-III mine type bomb was retained and the thin-walled middle section ~~was replaced by a thick-walled~~ and tempered-steel base were replaced by a thick-walled base piece of pressed steel welded to the nose section. The new SD-250 multi-purpose bomb was thus considerably shorter and more resistant to side impact than the SC-250 mine-type bomb had been.

Conversion to production of the new bomb type at Langendreer was carried out in the winter of 1940-1941 without any considerable loss in output. The SD-250 admittedly had about 88 pounds less explosives than the SC-250 but met all requirements in the harassing attacks just beginning against the British armament industry, most of which were carried out at low altitudes. Their suitability for this purpose was proved in field tests in which field units bombed the disused gun factory of the firm of Schneider in Harfleur, 14 near Le Havre. Furthermore, the destruction caused to heavy manufacturing machinery by the SD-250 proved far greater, because of the high average weight of the individual fragments, than could have been caused by the blast effect alone of a mine-type bomb of the same size. In judging an emergency construction such as this, it would naturally be wrong to apply the strict standards applied in assessing the effectiveness of standard fragmentation or multi-purpose bombs.

In contrast, the SD-500 (1,100-pound) multi-purpose bomb was a thoroughly developed design except in the one point that its weight had to be increased to 1,100 pounds. Far over on the favorable, or plus, side of the fragmentation factor curve appear the S-Be-50 and SD-250-Tel bombs, both "single-purpose" bomb types, the former being a concrete bomb and an emergency solution produced during the initial stages of the war, the latter a "telescope bomb" developed towards the end of the war.

15 In order to increase the production of fragmentation bombs to a monthly output of 100,000 within the shortest space of time without having to rely on the facilities available for pressed and cast steel processing, the S-Be-50 was manufactured in cement goods factories using ~~the~~ a centrifugal and rocking process, in which 2,000 fragments of 5 gram each were added to the concrete aggregate. Owing to high dead-weight ratio caused by the use of concrete, these bombs could only be given a 13.2-pound explosive

16 charge which, moreover, consisted of the substitute explosive Ammonal tamped into the casing. In tests on the ground, in the fragmentation testing circle, these bombs had a higher fragment density coefficient than the SD-50 bomb, but in bombing tests from aircraft the factors were less favorable because the impact velocity when the bomb was released at any appreciable altitude gave the fragments a too low horizontal velocity, which resulted in a too great vertical component and thus restricted the effective striking range.

The above example serves to show that theoretical factors, such as fragment count and density alone do not make a sound assessment possible and that actual bombing tests at all times are more reliable than tests made on the ground.

The production of concrete fragmentation bombs was discontinued already in the early summer of 1940, at a time when the unfavorable results obtainable in actual bombing had not even been determined, because the bomb had served its purpose as a stopgap.

The design of the telescop or nose-spike fragmentation bomb, SD-250-Tel, was based on experience gained prior to the war with what were called ~~ground-stand~~ nose-spike fuses (<u>Bodenabstandszuendern</u>) (see Chapter III, 1). Armed with their electrical side fuse No. (37), SD-50 multi-purpose bombs detonated before contact with the target while still 16 to 40 inches above

16 the ground regardless of the release altitude, speed, and altitude above sea level. It was found that the bomb's fragment density in such cases was between 25 and 30% higher than when used with an impact fuse without delay action.

Unfortunately, the necessity to reduce the existing number of types necessitated discontinuation of the final development of this promising type of fuse at the beginning of the war. Instead, the SD-70 bomb was designed to replace the SD-50, increased fragmentation effect being achieved in this bomb by an increased use of material in ist construction At the same time, the SD-70 replaced the SC-50 for demolition purposes.

The unfavorable fragment count of multi-purpose bombs for use against live targets made improvements necessary The capacitive detonation system used with the nose-spike fuse No. (37) did not permit of a bomb burst point appreciably higher than 40 inches from the ground and the height from the ground for a 550-pound bomb had to be about 10 feet from the ground for optimum fragmentation effect. The 55-pound SD-250 bomb was therefore provided with a spike embodying the membrane contact of the (55)-A electrical contact fuse built into the tip. The entire spike column was placed longitudinally within the bomb and after bomb release was projected forward by means of a slow-burning powder charge.

16 Even in high altitude bombing the projecting nose spike which was 9 feet in length, had no noticeable unfavorable ballistic influences. These bombs were intended primarily for use by fighter-bomber units. The membrane contact also functioned on impact with water, so that good results were anticipated in use against seacraft which might be used in any attempt at invasion.

The reason for the cylindircal shape of the SD-250-Tel nose-spike fragmentation bomb was that a better fragment spread parallel with the ground was obtained with this shape than with bi-convex shaped bombs. The highest fragment density coefficient ever obtained was obtained with the SD-250-Tel spike-nose fragmentation bomb.

Although the SD-250 bomb had a fragment count 30% higher then that of the nose-spike bomb, tests in the fragmentation test circle showed that the area effectively covered by the latter was 40% larger, a point in which the spike-nose bomb proved even better than the SD-500-A with its very high fragment count.

A will be seen from the above account the higher expenditure incurred in the manufacture of the SD-250-Tel spike-nose bomb was worth while in every respect. Unfortunately, however, it was taken into use too late to play any role in the winter campaigns in the eastern theater.

17 In snow deeper than 40 inches the smaller caliber fragmentation bombs proved a complete failure, so far as target effects were concerned. A usable solution was found for the mechanical Type (3) impact fuse of the SD-10 by providing it with a collapsible nose spike or spokes, to the tip of which a snow-plate was attached. These bombs could be packed into the Type 250 bomb container and exploded above the snow surface.

Following suggestions from the front line forces, SD-50, SD-70 multi-purpose and SD-250 normal bombs were provided with a 40 inch or 9 foot rigididly mounted nose-spike. A disadvantage here was that these bombs could only be suspended outside the aircraft.

Shock effect and the inability to find cover by lying prone on the ground against the SD-250-Tel spike-nose bomb played a very important role, as had been the case with the
18 results obtained with the SD-2-t ground attack bomb with its fuse Type (41), which could be set as desired for impact or time-delay detonation.

The relatively heavy weight of its fragments also made it possible to use SD-250-Tel bombs against vehicular columns and railway rolling stock and its high burst point gave just cause to hope that it could also destroy aircraft protected by sheltering walls and within hangars.

TELESCOPIC SPIKE FRAGMENTATION BOMB SD-250-Tel

Supplementary to p. 203 (p. 15 of German text).

Legend:

M. 1:10	= Scale 1:10
hochempfindlicher AZ	= Superquick contact fuse
Zeitzuender f.Tel.Rohr	= Time fuse for telescopic spike
Membrankontakt	= Membrane contact
3 f. Tel.Rohr	= 3-section telescopic spike
ca. 900 mm	= Appriximately 100 millimeters
Gesamtgewicht ca 350kg	= Total weight approximately 770 lbs
Sprengladung 100 kg	= Explosive charge 220 pounds
Splitterdichte 1 bei 100 m	= Fragment density 1 fragment per meter at distance of 100 meters
[illegible]	=
Splitterzahl ca 5000 5 gr	= Fragment count approximately 5000 of 5 grams and over
M. 1:25	= Scale 1:25
ca 2.70 m	= Approximately 2.70 meters
Teleskoprohr schiebt sich nach dem Abwurf heraus und leitet die Zuendding beim Aufschlag ein	= Telescopic spike projects after bomb release and initiates bomb detonation at impact

Supplementary to p. 206 (p. 17 of German text)

Legend:

Distanzstab fuer SC-10 und Distanzrohre fuer SD-50 und SD-250	= nose spike for SC-10 bomb and nose spikes for SD-50 and SD-250 bombs

SD-10

Anschlagteller	= Striking plate
2 mm Stahldraht	= 2-mm steel wire
Distanzstab klappt beim Abwurf nach vorn	= Nose spike springs forward into position at bomb release
AZ (3)	= impact fuse (3)

SD-50

el. AZ 55	= Electrical impact fuse 55
Stahlrohr	= Steel tube
ca 1 m	= Approximately 1 meter

SD-250

el. AZ 55	= Electrical impact fuse 55
Stahlrohr	= Steel tube
ca 1,70 m	= Approximately 1.7 meters
Anschlagteller	= Striking plate or disc.

16 The Shr-500 shrapnell bomb was also specifically a fragmentation bomb and its origin is due to the tactical air situation over Germany from the summer of 1943 on. In efforts to exploit all means of attack against the American bomber formations, German fighters also dropped time fuse bombs amongst the enemy squadrons flying in close formation.

For this purpose they initially used both the SC-500 (1,100-pound) mine-type and the SD-500-A multi-purpose bombs since there was no clarity as to whether the blast effect of the exploding mine-type bombs or the fragments of the multi-purpose bombs would produce the best results when used against airborne targets. Experience had shown that even an ~~direct hit~~ 88-mm AA shell exploding in direct proximity to a Flying Fortress did not always bring its target down, unless it struck the pilot's cupola, the engines, the petrol tanks or the steering system. The view that the blast pressure of larger caliber bombs was more likely to destroy an aircraft than fragment damage seemed confirmed by tests carried out with the wings of an He-111 plane. It was found that an SC-500 mine type bomb exploding 20 meters away caused wing fractures, whereas the damage done by the fragments of an SD-500 bomb held out no promise of immediate success.

For the above reasons the General Commanding Fighter Forces continued the important front line experiments with

18a Supplementary to p. 209 (p.18 of German text)

Legend:

Schrapnellbombe Shr 500 = Shr-500 shrapnell bomb

1650 = 1.65 meters

E..zt.zdr. M (9) = Electrical time fuse M (9)

SC 250 mot eingeschweisster Innenhuelse = SC-250 bomb with welded-in inner casing

Sprengladung 80 kg = Explosive charge 176 pounds

3500 Splitter zu 10 gr eingelagert und mit Pech vergossen = 3,000 10-gram fragments enclosed with a filling of melter pitch

3 gepresste Uebertragungsladungen aus Trinitrophenol = 3 compressed primer charges of trinitrophenol

19 both of these two bomb types. The time fuses used were the (69) and (79) powder train fuses, set to detonate at seven or at 10 seconds after bomb release.

It was only after a whole year of bombing airborne targets that indisputable experience data became available, which led to the deduction that the fragment damage effect was greater than the results obtained by blast effect alone. Under the existing tactical conditions it was the large number of fragments striking the B-17 and B-19 bombers which caused such serious damage that the crews had to bail out or come down in an emergency landing.

Measures were thereupon introduced for the accelerated production of a special fragmentation bomb, the Shr-500, for use against airborne targets. By placing a cylindircal explosive chargewith a thickness of roughly 25 centimeters longitudinally in a normal SC-250 mine type bomb casing. This explosive column weighed approximately 176 pounds, or 16 percent of the entire charge of the bomb. The space between the outer shell casing and the inner explosive column was filled with several thiusand jagged steel fragments weighing roughly 100 grams each.

Using these "shrapnell" bombs fighters repeatedly brought down whole series of enemy bombers in a single day, when the bombers lacked adequate fighter escorts, as was the case over

19 Southern Europe in the autumn of 1944. Eyewitnesses spoke of these missiles as "stratosphare ~~XXXXX~~ mines" which was just as inappropriate as the designation of "shrapnell bombs."

Owing to the numerical superiority of enemy fighters in the western theater there was little opportunity for German fighters to use the Shr-500 bombs there.

As was the case with British GP bombs, the fragment density of the shrapnell bomb was not tested. The reason was that bombs of larger caliber usually completely destoryed the fragmentation testing circle, so that no reliable information became available in the tests.

In summarizing it can be said that when speaking of fragmentation bombs one must differentiate between two categories:

Small-caliber bombs of from 2.2 to 11-pound caliber
and normal fragmentation bombs in the approximate caliber
range of from 17.6 to 33 pounds.

In the case of both categories an explosive charge of 12 to 15 percent of the overall weight was found a sound ratio.

Bombs of the first category are best made from unprocessed handgrenades with a caliber of 5-8 centimeters, the casings of which are of special gray cast iron or malleable cast iron while the explosive charge consists of ammonites.

The larger caliber category, above, is made from reprocessed artillery shells in calibers between 75 and 105

20 millimeters and the most favorable explosive charge is one of trotyl or a 60/40 trotyl-ammonnitrate compound. It was found that the most suitable steel for these purposes was that normally used in the manufacture of artillery shells with additives in the following maximum ratios:

> Manganese: less than 1 percent; carbon: 0.5 percent; phosphorus: 0.05 percent; sulphur: 0.05 percent; silicon: 0.15 percent.

20a SUPPLEMENTARY TO P. 205 (p.20 of German text).

Legend:

Bremsschirmbombe SD-500-Br und ihre Anwendung	= The SD-500-Br brake parachute bomb and its use
M. 1:10	= Scale 1:10
hochempfindlicher AZ Nr (55a)	= Superquick impact fuse (55a)
Aufhaengeoese	= Suspension eye
Ausloeseleitung	= Bomb release line
Zuendkabel	= Ignition cable
Membrankontakt	= Membrane contact
ca 1,50 m	= Approximately 1.5 meters
Gesamt-Gewicht: 550 kg	= Total weight 1,210 pounds
Sprengladung: 180 kg	= Explosive charge: 400 pounds
Splitterdichte: 1 bei 90 m.	= Fragment density: 1 per square meter at 90 yards distance
Splitterzahl: ca 7000 St 5 gr	= Fragment count: Approximately 7,000 at 5 grams and over
ca. 3 qm. grosser Bremsschirm aus Perlonbaendern	= Brake robbin parachute of Perlon, approximately 3 sq.meters
M. 1:1000	= Scale 1:;,000
V = 600 km/std	= Velocity 600 kilometers (roughly 360 miles)
Ausloesung	= Bomb release point
Flugzeug mind. 500 m. entfernt	= Aircraft at least 500 meters distant
Bombenbahn	= Bomb trajectory
Flughoehe ca 50 m	= Flight altitude approximately 50 meters (165 feet)

21 2. Bomb Casing Impact Resistence Capability. On the German side, the impact resistence of mine type bombs had been determined as far back as 1926 by the use of bombs with inert fillings. In place of the normal explosive charge, the test bombs were given a filling of pitch and heavy spar and were released from the normal bombing test altitude of 13,200 feet, which gave them an impact velocity of approximately 250 meters per second when striking the concrete slabs of roughly 88 x 110 yards constructed for the purpose at the test bombing ranges. The use of the inert bomb filling protected the concrete slabs, which would have been rendered useless after a few hits by live bombs.

This testing system had been adopted from the USA, where experts regarded a thickness of one foot of concrete over a bed of ballast two feet deep as the maximum resistence a demolition type bomb with delayed fuse action or a mine type bomb would have to penetrate under normal conditions without bursting prior to detonation.

In Germany this bomb hardness specification was increased, the standard penetration thickness being established at 0.5 meter stamped concrete over a 0.5 meter thick bed of coarse ballast which the SC-250 (550-pound) bomb was required to penetrate without bursting prior to detonation.

For the 1,100-pound armor piercing bomb developed

21 Shortly before World War II the firm of Rheinmetall evolved a testing system in which standard or test model bombs, fitted with stabilizing vanes similar to those used on artillery shells were fired from smooth bore guns, with velocities appropriate to the various methods of attack, against vertical ferroconcrete slabs or steel armor plates at a range of 330 feet (see Chapter I, 4). These smooth-bore guns were also used later to test mine-type and multi-purpose bombs and determine their penetration capability, as given in the tables and regulations governing the use of such bombs.

However, neither this system, nor the system of bombing tests against specially erected targets were adequate to cope with the requirements of the mass testings becoming necessary at the outbreak of war because of expanding bomb development activities and the need for serial tests. Furthermore, it also appeared essential to use real live bombs in tests with hard surface targets because of the reciprocal influences of casing and filling and because the inert fillings did not have the same consistence as the live explosive charges.

From the beginning of the war on the system of testing with smooth-bore guns was used exclusively to test bomb models under development until higher headquarters prohibited the use of the factors thus determined to express the penetration capability of bombs introduced for use by the field forces.

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22 The system was also far too complicated to permit the testing of large numbers of test bombs within the short time available.

The reerection of the heavy armor plates, which became necessary after each round fired because the impact tore loose even the strongest supports, made it impossible to fire more than three or four round per gun and day. Furthermore, the necessity to wait for the cement used in replacing the targets to set restricted the number of tests which could be carried out to ten or twelve per month.

A mobile bomb testing gun, Missile Projector 66 (*Koerperwerfer 66*), designed in 1940 and capable of the highest velocities required for the largest German-produced bombs, was only completed in 1943. 23

Both Missile Projector 38 and the new gun just mentioned were used during the war primarily to determine the extreme limits at which bombs could withstand impact or penetration without bursting before detonation.

The calcerous ground at the Muensingen maneuver area in the Schwaebische Alp region, because of its uniformity appeared ~~suitability~~ suitable to test the hardness of mine-type bombs in high-altitude bombing, particularly when the need for mass production made necessary the introduction of welded casing bombs in addition to the originally used casings manufactured

23 by the press and draw processes. Here, it was possible to evolve a sound method of combined data obtained with gun-fired and air-dropped bombs based on an empirical comparison of the penetration hardness and the bomb release altitude when used against a practically unlimited substrate.

It was found, for example, that whereas the SC-250 mine-type bomb of Quality Category I at an impact velocit of 250 meters per second could penetrate a 50-millimeter thickness of shipbuilding steel with a tensile strength of kz=54 millimeter/kilogram and remain intact, the SC-250 bomb of Quality Category III only had a degree of hardness adequate to pierce a 20 millimeter thickness of steel, and thus only a hardness equal to 40 percent of that of the one-piece-casing bomb. It was also found that the ammonal explosive charge, which was only loosely tamped in, subjected the bomb casing walls to additional strains, and that moreover precisely at the point at which, in the three-part SC-250-K bomb, the nose part was welded to the middle section.

When striking the Muensinger Jurassic limestone surface, which has a pressure resistance coefficient of 400 kilograms per square centimeter, the SC-250 Class I bomb withstood the force of impact when dropped from an altitude of 17,400 feet, equivalent to an impact velocity of 265 meters per second; in contrast, the SC-250 Class III bomb already showed cracks and tears, from which the Ammonal explosive charge spilled, when dropped from an altitude of only 6,600 feet, equivalent to an impact velocity of 270 meters per second.

In all structurally sound bombs, including those of other calibers than the 555-pound bomb, the "maximum altitude" was very sharply defined, meaning that the breaking point was reached quite suddenly at a certain altitude. Structural substitutes, in contrast, and bombs made of lower quality materials, varied widely in their degree of hardness. These variations were due not only to the various methods of manufacture, but considerable differences were found even within one and the same delivery batch. For these reasons, the Ammunition Accepting Branch, an independently acting authority between the developing branches on the one hand and manufacturers on the other hand, only carried out a few test bombings before acceptance instead of their normal procedure of testing five bombs per delivery of 5,000.

From 1942 on only Class I bombs were delivered. Instead of the thickness penetrated by the bomb when fired from a gun, the altitude factor was then introduced as the standard of quality for bombs, and the specification was that 100 percent of the bombs dropped had to withstand the impact.

However, the limestone surface of Muensingen proved too soft already for the SD-500 multi-purpose bombs with their slightly thicker casings, so that these bombs withstood the

24 the impact shock even when dropped from the highest practicable altitudes. A harder surface thus had to be found to use this method in testing armor-piercing bombs. In this matter the National Soil Research Office submitted recommendations. Factors taken into consideration here were, besides the hardness and uniformity of the surface, favorable climatic conditions and the proximity of airfields.

25 A test bombing area was finally selected near Mandal, in southern Norway, where the Wexio granite ground appeared suitable for the testing of armor-piercing bombs. This ground had a pressure-resistance coefficient of 3,000 kilograms per square centimeter and the main time for test bombings was during the summer months.

For bombs requiring a lesser degree of impact hardness a suitable area was found in the hilly terrain of Monte Gargano, east of Foggia in southern Italy (Apulia), where large surfaces of so-called Eocene limestone were found with a penetration resistance coefficient of 1,000 kilograms per square centimeter. In meteorological respects, also, southern Italy was ideal for the purpose, in particular these conditions permitted bombings from high altitudes throughout the winter with a regularity of 80 to 90 percent. The remote-control PC-1400-X armor-piercing bomb, which required a minimum release altitude of 20,000 feet, was also tested

25 from Foggia; other experiments conducted there included "maximum release altitudes" for SC-500, SD-500-A, PC-500, and PD-500, tests in which a Ju-86-P plane released these bombs from altitudes between 40,000 and 46,000 feet to ascertain their stability at supersonic velocities.

However, developments during the following year of warfare made the movement of test materials increasingly difficult over the crowded Brenner Pass route. For this reason the test activities moved to Millau, Central France, in the summer of 1943. Here, however, conditions were considerably less favorable, so that very few results were obtained.

The Muensingen testing range was abandoned as soon as operations commenced at Foggia and Mandal, in order to concentrate all testing activities to ascertain the hardness of bombs.

Long negotiations with the Air Force Operations Staff 26 were necessary to secure approval for the conduct of important tests in foreign countries. Finally, however, it was the Commander in Chief of the Air Force himself who refused to recognize the data secured in gun-fired bomb tests and made the introduction of any new type of bomb contingent upon actual bombing tests, in which the conditions of hardness were to be as realistic as possible.

In spite of utmost efforts it proved impossible to find

26 suitable terrain within Germany, with its dense population. The Zugspitze plateau, for example, had to be rejected because the steel cables of the cableway would have been within the range of flying fragments and any damage done could not have been repaired during the war. Other bombing areas with a hard to medium-hard surface, with the necessary uniformity and as level as possible were to inaccessible.

In Norway there was no real safety against the activities of the British Intelligence Service, while in Foggia the head of the testing activities had to endeavor to prevent the Italians finding out about the tests with the PC-1400-X bomb. The German Commander in Chief South did everything possible to promote the testing activities within his theater of command, stipulating only one condition, namely, that the German civilians essential to the work were to be restricted to military rations and were not to receive per diem allowances which would have enabled them to make purchases in the Italian market. Unfortunately, it was not permitted to employ Italian labor for preparation of the ground and other such work, since the Italians were more interested in German rations than in cash payments. The paradox situation thus developed that German workers had to be released from Army service to work in Italy, while that country was simply crawling with young men for whom there was allegedly no military equipment and who thus

26 could not be inducted for military service and remained idly at home.

27 Nevertheless, cooperation ~~withxthexItalianxauthorities~~ functioned smoothly with the Italian authorities, who tactfully curbed their curiosity concerning technological innovations until officially invited to final demonstrations, as was the case with PC-1800-Rs rocket-propelled armor-piercing bomb. However, they were never shown the PC-1400-X bomb.

The maximum altitudes to test the fracturing of mine-type bombs at Foggia were within the easily attainable range of 8,250 feet, whereas proper armor-piercing bombs ~~hxxd~~ had a hardness proof against the local Eocene limestone formation when dropped from any altitude and therefore had to be tested in impact on Norwegian granite.

The attached graph gives a presentation of the results obtained in tests with the more important German bomb types at the three most important testing stations of Muensingen, ~~xaxx~~ Foggia, and Mandal to determine their behavior at impact. If one places the bomb release scale over the various test stations with an inverse proportion to the hardness of the ground it is possible in a diagram to fit the data factors obtained in practice quite well in relation one to the other. However, it must be borne in mind that the various bomb types have different fall velocities according to their shape and cross

27 their ballistic coefficient, as mentioned previously in Chapter I, 3. Furthermore, the data available on bomb releases from altitudes below 3,300 feet in Mandal can not be used in any appraisal of the impact hardness of the mine-type bombs, because, owing to the flat impact angle when dropped from low altitudes the bombs were subject to considerable sectional strains at impact. Experiments at braking the bombs by the use of brake-plates at the end of the steering tail, in order to achieve a perpendicular impact, proved ballistically impracticable.

Another factor which had to be taken into account was the risk to aircraft and crew, due to the high sensitivity of the explosive charge to shock: with a normal explosive filling, the SC-1000 bomb, for example, detonated at impact when
28 dropped even from altitudes below 3,300 feet, subjecting the releasing He-111 to considerable air pressure. The safe burst limit would have been at an altitude of 990 feet.

As a rule the bombs were released from the ~~maximum safe~~ minimum safe altitude, so that it would be possible to check the material and the manufacturing process by the shell casing fragments collected. Too great altitudes and too hard ground caused too great destruction to the bombs and were only used in tests to determine "detonation altitudes."

The data in Diagram 1 therefore only to Mine-type

APPENDIX TO p. 20: Chart.

Legend:

Verpuffung	Deflagration
keine Detonation	No explosion
lebh. Verpuffung	Fierce deflagration
Detonation ohne Uebergang	Immediate detonation
auf 2 m. dicker Beton (V_z 700 m/s)	at impact on 2 meter thickness of concrete (impact velocity 700 meters per second)
bleibt ganz aus allen Hoehen	Remained intact at all release altitudes
bleibt intact	Remained intact
Abwurfhoegen in km	Release altitudes in kilometers
(Jura Kalk ca 400 kg/qcm Druckfestigkeit)	Jurassic formation limestone with hardness of approximately 400 kilograms per square centimeter
Eocänkalk von ca 900 kg/qcm)	Eocene formation limestone with hardness of approximately 900 kilograms per square centimeter
Granit von ca 2900 kg/qcm	Granite with hardness of approximately 2900 kilograms per square centimeter
M. 1:125,000 etc.	Scale 1:125,000 etc.
Festigkeit deutscher Sprengbomben auf gewachsenem Boden verschiedener Haerte	Impact hardness of German explosive bombs on natural surfaces of various degrees of hardness
Bemerkung: Das Diagram gilt	Remark: The diagram applies
in Muensingen nur fuer SC-Bomben	In case of Muensingen only to SC type bombs
in Foggia fuer SC- und SD-Bomben	In case of Foggia to SC and SD type bombs
in Mandal fuer alle Panzerbomben)	In case of Mandal to all armor-piercing bombs.

28 For the above reasons, in Diagram 1 the data offered for Muensingen applies only to mine-type bombs, that for Foggia to mine-type and multi-purpose bombs, that for Mandal to all types of armor-piercing bombs. Individual drops of SC-250 mine-type and SD-500 multi-purpose bombs were carried out at Mandal in order to also determine the self-detonation of the explosive charges in the case of impact on granite.

The bombs used in the tests had their normal filling of explosives, but no fuses, and therefore in many cases served simultaneously to test the shock safety of the explosive charges. When the question arose as to how far the premature detonation might be due to sharp-edge fragments of the bomb casing when it shattered at impact, a few bombs were given an inert filling of pitch and heavy spar in place of their explosive charge, in order to test the hardness of the casings; in order to test the shock safety of Trialen (which was to be used in all bombs by order of the State Secretary through the 29 Chief of Air Force Special Supply and Procurement Services) PC-500 bombs were given trial fillings of this explosive in place of their normal filling of phlegmatized Trotyl.

In the case of most bombs there is a clearly defined moment of transition between the shattering of the bomb casing and the reaction of the explosive charge, and prior to self-detonation of the explosive charge various form of deflagration are usually noticable.

Even in the case of the SD-500-A multi-purpose bomb which, according to the diagram on p. 225 detonated immediately on impact, the Foggia records show a bomb dropped from an altitude of 16,500 feet which at impact commenced burning with a small flame and only ceased burning after several hours. Closer examination revealed that the suspension lug had torn the bomb casing at impact, causing such heat that the filling began burning through the crack and finally burned out completely.

All bomb impacts were filmed and seismographically recorded. The data thus procured showed a clear difference between the moment of impact and that of detonation and made a check of the fuse functioning possible.

In Mandal (Norway) the training terrain was so uneven and patchy that only approximately 1/3 of all bombs dropped provided usable data. Data on the reaction of bombs ricocheting from sloping surfaces or which bounced too far were not used. In contrast, only approximately one-quarter of all bombs dropped in the Foggia grounds had to be disregarded, namely those which fell onto too soft surfaces in the bauxite crevices separating the patches of limestone.

If we consider the data offered in the diagram for mine-type bombs of calibers from SC-50 to SC-1800, we find that their impact hardness decreased as their size increased

30 also that the critical moment between shattering of the bomb casing and reaction of the explosive charge becomes steadily narrower, the one exception being that of the SC-1000 bomb, which was a faulty construction.

It is also clearly discernible that not only the type of explosive used but also the size of the charge influenced the shock detonation. In Foggia it was not possible to bring about self-detonation of the SC-50 bomb at all, while the SC-1800 bomb exploded immediately, without a deflagration interval, when the necessary mass-delay occurred.

SC-250 deflagrated at Foggia with considerably less delay than the SC-50 bomb, because of its ~~greater~~ bigger explosive charge.

SC-1000 must be considered as a special case: out of weight and point of gravity consideration only the front half of its explosive charge consisted of the normal fluid-filled explosive while the other half was tamped-in ammonal. This latter was, as is known, more shock proof and the great altitude of 17,200 feet required for its self-detonation at Foggia was probably due to this fact.

As a rule, wide intervals can be taken as an indication of some flaw in the bomb structure; in the case of SC-1000 and PC-1000 this was known from the outset since these two bomb types had to be constructed tu suit the stowage space in ceralso that the critical moment between shattering of the bomb casing and reaction of the explosive charge becomes steadily narrower, the one exception being that of the SC-1000 bomb, which was a faulty construction.

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As a rule, wide intervals can be taken as an indication of some flaw in the bomb structure; in the case of SC-1000 and PC-1000 this was known from the outset since these two bomb types had to be constructed to suit the stowage space in cer-

certain types of aircraft and not in accordance with the requirements to obtain optimum results.

In the case of the rocket-propelled PC-1000 armor-piercing bomb, however, the flaw as in respect to its hardness on impact came as a surprise, which was also the case with the discovery of the self-detonating character of the PMF-109 armor-piercing bomb explosive charge, which had until then been recommended as unconditionally shockproof. It was for these reasons that production of this type of bomb was halted. From an examination of fragments of these bombs it was deduced that the screw-in base of the bomb was tooheavy in relation to the thickness of the casing wall, for which reason the bomb burst at this point on impact on a hard surface. According to specifications by the manufacturing firm, the 484-pound (220-kilogram) filling of PMF-109 had a blast effect equivalent to that of the 660-pound Trotyl explosive charge of the PC-1400 bomb.

In spite of its heavier explosive charge, the PC-1400 armor-piercing bomb thus showed better impact results than the PC-1000-RS rocket propelled armor-piercing bomb; although it admittedly also always detonated when released on the testing ground in Norway from altitudes above 11,220 feet, probably because of the shock-caused contraction of the relatively long explosive charge column, there was a certain interval at releases from an altitude of 10,120 feet.

31 Apparently, pre-deflagration no longer occurs in the case of such heavy explosive charges.

In the Army the self-detonation of 420-mm explosive shell with a 220-pound Trotyl explosive charge and a total weight of 1,760 pounds when impacting on a fortification wall of more than 2 meter thickness of concrete was a known fact and since shells with an inert filling also shattered in such cases, this feature was explained as splintering (Splitterinitiierung). However, 420-mm armor-piercing shells with a phlegmatized explosive filling penetrated through the concrete.

What has been said concerning the 420-mm explosive shell must also have been the case with the SD-500 multi-purpose bomb, since this bomb in tests at Foggia exploded without
32 any deflagration interval when released from altitudes of 16,500 feet although this was not to be expected from the size and type of its explosive charge. Apparently the strength of the casing wall and the sharpness of the fragments also played a role here.

Field units had reported occasionally that fierce deflagration occurred when SC-500 bombs with Trialen explosive charges impacted on concrete runways--as could occur during transportation, with serious consequences to personnel and materiel. An examination of what was left of such bombs

32 showed that due to the fall the welding seams had burst and that the sharp edges had cut into the highly sensitive aluminum-containing explosive and initiated the deflagration, since these edges had become blued through the heat engendered. Instructions were therefore given that Trialen was only to be used in one-piece mine-type bombs, since experience had shown that no sharp edges resulted when these burst.

In low-altitude attack exercises carried out by a number of Air Force units against a large Belgian padsenger ship aground near La Rochelle on the Atlantic coast it was also noticed that SC-250 one-piece mine-type bombs with a Trialen explosive charge deflagrated fiercely when striking the ship decks, while this did not happen with bombs having a normal explosive filling. The cause was found to be that the bombs struck hard objects, such as steel belaying pins, bollards, etc., which initiated deflagration of the Trialen.

However, such occurrences represented no hazard to attacking planes, even when bombing at extremely low levels; Trialen-filled bombs were therefore retained for attacks against seaborne targets because of their more powerful blast effect, particularly when exploding under water. 33

However, heavier explosive charges soon approach the detonation-tolerance limits, as the unsuccessful attack with the BM-1000 mine-type bomb against the Stalin Canal in June

33 1941. The 1,496-pound charges of these bombs exploded completely on striking the concrete bottom of the canal, destroying the attacking aircraft and their crews.

As previously mentioned, the use of Trialen as an explosive charge in armor-piercing bombs had to be discontinued after its sensitivity to shock had been demonstrated by test bombings in Norway, since the PC-500 bombs with a Trialen filling detonated already when released from altitudes of 10,560 feet, while bombs of the same type held when dropped with an inert filling up to altitudes of 13,200 feet and with a filling of phlegmatized Trotyl only exploded when dropped from altitudes of 15,840 feet and higher. These findings served as an excellent proof of the value of the procedures adopted in the experiments.

SB-2500 bombs with a heavy filling of Trialen exploded at impact on the surface of water even when dropped from such low altitudes as 3,300 feet, and the cause could not have been the casings, since these were of aluminum. To permit the use of bombs with super-heavy explosive charges against water-borne targets, these bombs, designated SB-2300, were later reconstructed with casings of sheet steel and given a reduced filling of Trotyl.

It has been mentioned that the SC-1000 mine-type bomb was considered the least satisfactory in this series. The need to keep down its length for stowage in certain types of aircraft resulted in a too big diameter, which gave it an inadequate cross-sectional resistance to impact when penetrating into the ground.

Circumstances were similar with the PC-1000 armor-piercing bomb, the length of which was not to exceed 2 meters so that it would fit into the bomb bays of the Me-210 fast bombers, considered highly important aircraft at the time. To enable it to penetrate 100-mm of shipbuilding steel, a stipulation, still unclarified, which had been fixed by the Air Force Operations Staff in the spring of 1939 for hostile ships, designs for the PC-1000 had to allow for a lot of weight in the bomb's nose section. Owing to the steadily decreasing percentage of alloys used in its manufacture as the war drew on, however, it was no longer possible to temper the metal in the nose section right through to the core, which explains the relatively wide ~~interval~~ critical interval between non-fracturing of the casing and the detonation of the explosive charge.

The behavior of the 420-mm explosive shell is entered in the diagram with reference to the PC-1400 armor-piercing bomb, which had approximately the same cross-sectional impact resistance coefficient and, in the case of concrete, ~~the same penetration power as the 420-mm shell~~ with an impact velocity of 335 meters per second had the same

34 penetration coefficient as the 420-mm shell at an impact-velocity of 500 meters per second.

The PC-1000-RS rocket-propelled and the PD-1000 armor-piercing bombs remained intact when dropped from altitudes of 16,500 feet at Mandal, Norway, which was proof of the excellent structure of these bombs, the steel used in their manufacture, and the processing of the explosives used. The PC-1000-RS rocket-propelled bomb had a PMF-109 explosive filling, the PD-1000 bomb a filling of phlegmatized Trotyl because its use in 1942-43 was simpler than that of the multi-part explosive filling of the firm of Rheinmetall.

In contrast with the Navy, which had its armor-piercing ammunition manufactured from chrome-nickel-steel, the
35 Air Force from the outset had to adapt its development of armor-piercing bombs to the use of only weakly alloyed chrome-molybdene-steel. When these alloys also became scarce, a chrome-vanadium alloy was used for the PC-1400-X bomb (the remote control version of the armor-piercing bomb) and a manganese-silicium alloy for the PD-1000 bomb.

Appropriate manufacturing processes and subsequent treatment of the unfinished bomb~~s~~ casings made it possible to maintain the former standards of quality, but the new installations required for these purposes were very extensive and expensive and ~~although~~ calculations had to be based

35 on the assumption of a 50 percent wastage in xxxxxxxxxxx rejects.

However, in the 1942 year of warfare the materials used in the production of ordinary bombs declined in quality because of the general trend in the production of steel. The inquiry addressed by the Armaments and War Production Ministry to the Air Ministry in this respect whether the phosphorus content of SM steel could be trebled or quadrupled was tantamount to an order to bring about this increase.

In order to determine what influence use of the poorer qualities of steel would have on the impact hardness of the bombs most commonly used, a few hundred SC-250 bombs were produced from the new steel and used in test bombings at Foggia for comparison with bombs made from the old SM steel. Surprisingly enough, the tests showed that the envisaged increased phosphorus content improved the impact hardness of the test bombs, the altitude tolerance rising from 8,200 to 9,240 feet. Taking into consideration the large number of test bombs used, this represented a considerable gain in impact hardness.

The results obtained in these tests provided renewed confirmation that bombs had to be regarded as something different from artillery shells: they are not intended for firing from a gun but have to be designed exclusively for

36 impact hardness, or penetration capability, and their impact velocity is considerably less than that of artillery shells. If the release altitude is increased from above the 13,200 feet level in the case of mine-type bombs, this does not increase their penetration capability; on the contrary, the casing will shatter at impact on the same test target slab which it would have penetrated if released from a lower altitude. De Marre's formula for armor-piercing projectiles can be applied only in the case of armor-piercing bombs and not in that of normal demolition bombs of the SC and SD categories, the purpose of which is to place the greatest possible load of explosives on the target and which have a degree of impact hardness just sufficient for this purpose.

However, the quality of steel used in the production of ammunition continued to deteriorate in 1943 and the Armaments and War Production Ministry gave notice that the phosphorus content of SM steel would again have to be increased and requested that tests be carried out to determine whether Thomas steel could be used for ammunition in place of SM steel. However, tests with the SC-250 mine type bomb, the bomb most commonly in use and therefore used as the standard model in tests, showed that use of these types of steel so far reduced the impact hardness of the bombs that the Air Force had to reject their use in bomb manufacture. However, in

36 the final phase of the war, the addition of aluminum made it possible to use "stabilized (beruhigter) Thomas steel. When used for artillery ammunition Thomas steel in some cases produced catastrophic results. Thus, during the last massed Allied air attacks against Berlin, the heavy AA batteries mounted on concrete towers remained silent because ~~practically~~ defective shells had caused barrel bursts in practically all of their guns.

With the data available, it is worth while to examine the causes for the self-detonation of bombs. Here, it must be borne in mind, however, that the main purpose of the tests
37 so far described was to ascertain the durability of the entire bomb as it was used against the enemy.

For the clarification of the more academical problem of the shock-proof qualities of various explosives it was only possible to carry out a few test bombings within the current impact-hardness testing program, particularly since the data obtained was not thoroughly processed during the war.

The table on p. 238 reflects the more important cases of bomb self-detonation and the appropriate bomb-release conditions for each case. From the manifest kinetic energy and the penetration depth the "mean force" has been computed and from this factor the mean negative acceleration expressed in multiples of the gravitational acceleration "g;" the last column gives the probable cause of detonation.

37 The second diagram in this chapter is an attempt to express the shock effect contingent upon the type of explosive and the quantity involved.

Similarly to the nomogram in the following chapter, in which each type of soil gives a line below the 45 degree, is what happens here in the case of the explosives. The quantity of the explosives are entered as X-coordinates, the negative accelerations as ordinates, which lead to the self-detonation of the quantities of explosives involved. Here, the position of the normal to the straight or conjugate line, must provide a measure for the shock sensitivity of the explosive itself, and actually if the intervals are logarithmically interpolated between the conjugate lines of the explosives it will be found that the sensitivity results obtained correspond very closely to those obtained in the 2-kilogram hammer method of testing explosives.

According to Stettbacher Trotyl, for example, detonates under a hammer drop of 110 centimeters. According to the diagram, the explosive charge of the SC-1000 mine-type bomb, consisting of 50 percent Ammatol (60%Trotyl,40% Ammonnitrate) and 50 percent Ammonal (20% Trotyl, 60% Amnitrate, 15% Aluminumpowder, 5% sawdust), is the least sensitivity to shock, requiring a 180-centimeter drop of the hammer to detonate. Next comes the phlegmatized Trotyl charge used in PC-500 and

37a Appendix to p. 238.

Legend:

Entwicklung von Bomben = Development of bombs

Zusammenstellung ueber Eigendetonation von Sprengbomben = Compilation of data on self-detonation of explosive bombs

Nr. = No.

Muster = Type

Gew/kg = Weight in kilograms

Spr.Stoff = Explosive

Kennz. = Reference number

Ziel = Target

Granit = Granite

harter Kalk = hard limestone

Beton = Concrete

Wasser = Water

Detonation a. = Detonation from altitude of

Hoehe/m. = Altitude in meters

V_z: m/s = Velocity in meters per second

Kin. Energie kgm = Kinetic energy in kilogram/meter

Eindringweg m = Penetration depth in meters

Kraft kg = Force in kilograms

Verm.Det. Grund = Probable cause of detonation

Schock = Shock

Splitterinitiierung = Initiated by fragments

Grenzfall = Uncertain

Bemerkung: B = Beschleunigungs-Zuender (28B) = Remark: B = Acceleration fuze (28B)

37b Appendix to p. 238

Legend:

Zusammenhang zwischen Ladungsgewicht & Ladungsart und der Verzoegerung bei Eigendetonation = Interrelation between weight & type of explosive charge and retardation of detonation

(g=9.81 m/sek^2) = (g = 9.81 meters p. sec.^{2})

96,5; 119 etc. cm Fallhammer-Probe mit 2 kg = 96.5, 119 etc centimeter drop in tests with 2-kilogram hammer

Mischung = Composite

phlegm. Trotyl = phlegmatized Trotyl

Verzoegerung in "g" bei m. Aufschlag = Retardation in "g" at meter/impact

Gewicht der Sprengladung in kg. = Weight of explosive charge in kilograms

Bemerkung: Die unterstrichenen Geschossmuster z.B. die 42cm Granate detonierten vermutlich infolge "Splitterinitiierung," da das Geschoss zerbrach, bevor die Grenze der Schockempfindlichkeit der betr. Schockladung erreicht. =

Remark: Detonation of the underlined missile types, for example the 420-millimeter artillery shell was probably due to fragment initiation, since the missile shattered before the shock tolerance limit of the explosive charge involved was reached.

SD 500 A ist ein Grenzfall = SD-500-A is uncertain.

30 and PC-1400 with a hammer drop of 135 centimeters and the Amatol used in SC-250 and SC1800 with a hammer drop of 113 centimeters.

As was to be expected, Trialen 105, with a hammer fall of 96.5 centimeters headed the list insofar as the sensitivity of the explosive charges tested was concerned. Judging by the results with the PC-1800-RS bomb, PMF-109 explosive was more sensitive than Amatol and in the 420-mm explosive shell Trotyl would be also almost as sensitive as Trialen 105.

However, there can be no doubt that the causes here were the previously mentioned detonation of the explosive charge by sharp-edged fragments, so that the factors thus arrived at cannot be used in assessing the sensitivity of the explosive charge to shock.

Remarkably enough, Bomb No. 3 on the list, namely, the SD-500-A bomb with a 400-pound explosive charge which detonated completely from an altitude of 5,940 feet at impact on granite, appears exactly on the conjugate line for self-detonation of the Amatol explosive charge, whereas in the past its detonation at impact on hard limestone from an altitude of 16,500 feet had been considered due to fragment initiation. Apparently this is a border case.

However, Bomb No. 9, the PC-1000, must be considered as a genuine case of fragment initiation due to the poor structure of this bomb, since in the other armor-piercing bombs--PC-500 and PC-1400, the phlegmatized trotyl explosive charge had proved highly proof against shock and there was no cause for it to approach Trialen in point of shock sensitivity.

The large SC-1000 and SC-1800 normally had an accelerator fuse (Fuse 283), which detonated the bomb before it sn shattered at impact on hard surfaces. In the described tests, which were carried out without fuses it was found that the "g" factors chosen for the accelerated detonation in reference to the shock stability of the explosive charge were correct, since in the SC-1000 the fuse would have withstood approximately 2,000 "g" before detonating, and in actual fact the Amatol + Ammonal charge only exploded at 9,200 "g", the total weight of the charge being 1,144 pounds. In the SC-1800 with its 2,200-pound charge of Amatol, the fuse was set for 800 "g" and self-detonation at Foggia occurred at 1,165 "g" corresponding to impact from an altitide of 3,300 feet.

In order to prevent incomplete explosion effects resulting from shock or fragment-initiated detonation, the SB-1000 and SB-2300 super-charge bombs were provided with No. 24 fuses, the so-called fragmentation fuses. Through an initial and prime charge, this fuse brought about proper de-

39 detonation, initiated by commencing deformation of the bomb point, at a moment when movement of the whole explosive charge column had not yet been arrested by impact. In the case of bombs with relatively thin casings, this insured that acceleration or deformation detonation of the explosive charge would secure full blast effect.

3. Nomogram of Penetration Depth In compiling the attached nomogram (p. 244) the point of departure chosen is a lineal initial point of the penetration direction as stated by Zaleski: in the mathematical formula:

S = q. v. a, q being the cross-sectional resistence of the bomb, v the impact velocity of the bomb and a the coefficient for the target material.

In contrast with the penetration formula stated by de Marre the impact velocity is thus not squared but instead its first power is used. In the case of the impact velocities of freely falling aerial bombs, which are relatively low in comparison with the impact velocity of artillery shells, it appears that the determining factors are dynamic rather than static rules

Use of the formula stated above also produced results corresponding very well to the results obtained in practical tests with bombs to ascertain their impact hardness, as described in the preceding section.

40 So far as the penetration depths in steel armor and in fortifications+type concrete are concerned, the values obtained with bombs obtained in firing tests, as described in the nect chapter, are entered in dash lines on the nomogram. The data for the 420-mm explosive artillery shell are also entered for comparison.

Assuming the same steel and pointed form to be used in all bombs, the factor "a" is thus the identifying symbol for the target material.

The numerical factors for "a" have been computed from the actual results in the test bombings. Entered on the right hand part of the logarithmically graduated sheet of the nomogram, each target material shows a conjugate line at an angle of less than 45°.

The nromal~~s~~ for the "a" conjugate line~~s~~ provides a standard for the pressure resistance (of the target material (k_d) in kilograms per square centimeter) and has the modulus 142 if the bi-logarithmically graduated paper has a modulus of 100.

On a separate sheet "a" as a function of k_d is presented on logarithmicall~~y~~ graduated paper, providing the following equation:

$$a = \frac{2.82 \cdot 10^{-3}}{k_d^{1.169}} \quad \text{or Log } a = 0.5825 - 3 - 1.169 \log k_d.$$

For a mathematical pre-calculation of the penetrating capability of a specific bomb in a type of soil of known

Appendix to p. 244

Legend:

Nomogramm ueber Eindringtiefe = Nomogram of penetration depth

Muster = Type

Entriittswinkel = Impact or initial penetration angle

Sprldg. = Explosive charge

Mittl.Fallzeit in sec. = Mean time of fall in seconds

Fallgeschwindigkeit m/s = Fall speed in meters per second

Querschnittsbelastung = Cross-section resistance

Granit = Granite

Beton = Concrete

harter Kalk = Hard limestone

gew. Kalk = Virgin limestone

weich.Kalk = Soft limestone

Grobsand = Coarse sand

Feinsand = Fine sand

Lehm = Clay

Lehm + Sand = Clay + sand

Eindirngweg = Penetration channel

41 resistance or hardness the formula is adequate:

$$S = \frac{3.82}{10^3} \cdot \frac{P}{R^2} \cdot \frac{1}{\mathrm{pi}} \cdot \frac{v}{k_d} \cdot \frac{\sin \mathrm{psi}}{1.169} \quad \text{in meters}$$

The following is an explanation of the factors used in the foregoing text and nomogram:

S = Penetration channel in meters

S' = Penetration depth in meters

P = Weight of bomb in kilograms

H = Release altitude in kilometers

Z = Penetrating capability in kilograms/meter's

2 R = Diameter of bomb in meters

f = Function of ( )

v = Impact velocity in meter/second

a = Identifying symbol for target material

K_d = Pressure resistance coefficient of target material in kilograms per square centimeter

q = Ballistic coefficient of missile in kilograms per square meter

pi = 3.14

psi = Angle of impact.

The falling speed of bombs being contingent upon their shape and ballistic coefficients, the left upper part of the nomogram shows five different curves for comparison with the dash lines showing the theoretical falling xxxxx velocety of the following German types of bombs, v being equal to f(H)

Type SC Mine-type bomb with cylindrical middle section

SD multi+purpose bomb with biogivale bombshape

PC/RC rocket-propelled bombs dropped without propulsion

Armor-piercing bombs (PD) with very high ballistic coefficient.

The left lower part of the nomogram shows the penetrating capability XXX (Z) according to Zaleski as the product of q . v, while the right part shows the penetration channel (S) as the product of $Z \cdot a$ or $S = Z \cdot f(k_d)$.

Instructions for use of the nomogram.

To precalculate the penetration channel ~~XI~~ (S) of a bomb released at altitude H, follow the horizontal altitude line (in kilometers) in the left upper part of the nomogram as far as the fall velocity (expressed in meters per second) of the bomb type in question and then follow the vertical line downward to point of interception of interpolation with or between the curves for ballistic coefficients expressed in kilograms per square meter.

The ballistic and other coeeficients of characteristic types of bombs are given on an attached table.

The penetrating capability (Z), expressed in kilograms per meter . s can be read of from the side scale in the lower left part of the nomogram.

However, it will be necessary from the point found to trace horizontally in the right-hand and proper part of the nomogram to as far as the point of intersection (or an intermediate point) with the slanting conjugate line for the appropriate type of soil (clay, sand, weathered or hard limestone,or granite), vertically underneath which the desired penetration channel (S) can be read off from the scale graduated in meters. To obtain the vertical penetration [illegible] 7

Legend:

Char. Form deutscher Bomben = Characteristic shapes of German bombs

Form A, B, etc. = Shape A, B, etc.

42b **Appendix to p. 247**

Legend:

Technische Angaben ueber characteristische deutsche Sprengbomben = Technical data on characteristic German explosive bombs

Nr. = Number

Muster = Type

Kal = Caliber

Gew. kg = Weight in kilograms

Spr. Kg = Explosive charge in kilograms

D mm = Diameter in millimeters

L mm = Length in millimeters

Kal Laenge = Caliber/lengths

Durchschlag mm = Penetrating capabilita in millimeters

Bemerkung: = **Remarks:**

\+ Schiffbaustahl II k_z = 54 kg/mm^2 = Shipbuilding steel II k_z = 54 kilograms per square meter

++ wolframleg. Panzerstahl k_z = 100kg/mm^2 = Wolfram alloyed steel k_z = 110 kilograms per square meter

+++ Raketengetriebene Panzerbombe V_z = 280 m/s = Rocket-propelled armor-piercing bomb Impact velocity 280 meters per second

++++ Auftreffgeschwindigkeit der Moersergranate ca 500 m/s = Impact velocity of mortar shell approximately 500 meters per second

60° = Auftreffwinkel 60° im Sturzangriff V_z = 180-200 m/s = 60° = impact angle in dive attack = 60° Impact velocity = 180-200 meters per second

90° = Auftreffwinkel 90° im Hochangriff V_z = 250-300 m/s = 90° = impact angle of 90° in high-altitude attack Impact velocity 260-300 meter per second.

capability it is necessary to multiply S by the sinus of the impact angle, as in the upper right hand part.

Examples of the Use of the Nomogram

Question: How deep will an SD-500-A bomb released from an altitude of 9,900 feet penetrate into weathered soft limestone?

Answer: The horizontal altitude (H) line ~~xtx~~ for 9,900 feet (3 kilometers intersects the curve for SD bombs at 215 meters per second and directly below this point will be found the curve for a ballistic coefficient of 9,540 kilograms per square meter. From this point a line is traced to the oblique conjugate line for weathered and soft limestone (corresponding to the Jurassic formation as found, for example, in the Schwaebische Alb region), showing a pressure resistance coefficient of approximately 400 kilograms per square centimeter (the soil factor in this case is $3.38 \cdot 10^{-6}$).

The penetration distance can be read off directly underneath this point as 2.48 meters. Given an impact angle of 68° the sinus psi = 0.925, so that the actual penetration depth ~~of~~ S' of the SD-500-A bomb, if released at an altitude of 9,900 feet (3 kilometers) is $2.48 \cdot 0.925 = 2.3$ meters, generally taken to refer to the nose of the bomb.

Using the formula stated above the penetration depth would be

43 $$S' = \frac{2.82}{10^3} \cdot \frac{540}{0.2235^2} \cdot \frac{215}{pi} \cdot \frac{0.925}{400^{1.169}} = 2.23 \text{ meters.}$$

The difference between the penetration depth computed from the graph and that computed by the mathematical formula is thus 0.07 meter or 3%.

<u>Example 2</u>

<u>Question</u>: Given a vertical impact and an impact velocity of 500 meters per second how deep would a 420-mm mortar shell penetrate into armor steel plating with a resistance coefficient of 100 kilograms per square millimeter?

<u>Answer</u>: S'N = 0.229 centimeter, S'R = 0.233 centimeter; difference = 2%. The maximum penetration when gun-fired was 320 mm of armor steel plating, meaning that after penetrating 25 centimeters, the 420-mm shell pierced another 7 centimeters of steel (see missiles lodged in target material in following chapter).

In order to provide indications for use of the nomogram for other than German bombs, technical data on a number of Russian, British, and American ~~xxxxx~~ explosive bombs are also given in the attached table.

For example: to determine how far a British GP 1000 lbs bomb would penetrate in sand from an altitude of 20,000 feet (6,000 meters) it will be found ~~XXXX~~ in the last column that this British bomb most closely approximates the German SD-500-A bomb. However, the weight and ballistic coefficient are

45 10% below the German, so that, moving downwards from the SD curve v= 296 meters per second one comes to the horizontal $Z = 1.05 \cdot 10^6$ kilogram/meter and s. In the right hand part of the nomogram this line intersects the conjugate line for sand as the target material, with a pressure resistance coefficient of approximately S = 8.0 meters. In view of the great release altitude, of 20,000 feet, the penetration distance can be considered equal to the penetration depth without any wide margin of error.

The mathematical computation would be as follows:

$$S = S' = \frac{3.82 \cdot 450 \cdot 296 \cdot 1.0}{10^3 \cdot 0.22^2 \cdot pi \cdot 200^{1.169}} = 7.6 \text{ meters}$$

(Difference: 5%).

For an American 500-pound demolition bomb under the same conditions (the structure of the American bomb being similar to the German SC-250 but with a ballistic coefficient 6.6 % higher) the SC curve would show v = 272 meters per second and $Z = 7.2 \cdot 10^5$, and the penetration depth would be 5.6 meters in sand, whereas the mathematical computation would give the penetration depth as 5.4 meters.

A corresponding examination of the Russian rocket-propelled bomb constructed from the 203-mm heavy artillery shell, provides the following

BETAB 150 DS = (Betonobojnaja aviabombe s deponitelnij skorostju or Concrete-piercing aerial bomb 150 kilograms with

Accelerated velocity).

According to Russian claims a rocket attachment with a burning duration of 2.6 seconds accelerated the velocity of this bomb by 210 meters per second, enabling the bomb to pierce a 1.59 meter thickness of concrete. Assuming an aircraft speed of 500 kilometers per hour, the missile velocity would thus be 140 + 210 = 350 meters per second. With a ballistical factor of q = 4.920 kilograms per square meter Z would equal $1.8 \cdot 10^6$ and in an indefinite thickness of concrete the penetrating capability would be S = 0.98 meters.

Russian claims that the bomb could pierce a 1.59 meter thickness of concrete appear perfectly credible when compared with the performances of the German rocket-propelled bomb PC-500-RS. Delivered in dive attack and released at an altitude of 3,900 feet, the propelling rocket having a burning duration of 2.5 seconds, the German bomb had an impact velocity of 310 meters per second, giving a penetration capability of 1.2 meters in concrete. This penetration capability was confirmed under practical conditions in combat action against the firtifications of Liege in May 1940. However, the forts under attack had a concrete covering 4 meters thick. The PC-500-RS bombs therefore could not pierce through the covers; when gun-fired the bombs could pierce a 2 meter thickness of fortification type concrete in order then to explode on the inside of the fortification wall.

On the basis of the above, the following empirical hypothesis can be stated:

> When considering the results obtained with the 420-mm explosive bomb (23 centimeter penetration distance: 30 centimeter breaching capability) the ratios for the bomb can be assumed as 1:1.6 in the case of concrete and 1:3 in that of steel.

Using graph data the point of the FC-500-RS would penetrate 165 mm into steel, corresponding roughly to the claims of the manufacturers, which were based on gun fired tests showing a breaching capability of 190 mm at an impact angle of at least 60°; calculated by the de Marre formula the breaching capability would be 194 centimeters at vertical impact.

BRAB 200 DS. (Bronjebojnij = armor-piercing) . Using the factors of q=6.620 kilograms per square meter, v = 140 + 180 = 320 meters per second, $Z = 2.0 \cdot 10^6$ this rocket-propelled Russian bomb had a penetrationdepth capability of S = 150 mm in steel. The Rüssians claimed a breaching capability of 162, calculated by the de Marre formula the capability would be 170 mm.

The greater difference between penetration depth and breaching capability in the case of concrete must be ascribed to the fact that in concrete the tensile strength is smaller pressure resistance coefficient, which resulted in an earlier fracturing of the concrete on the far side of the concrete slab. In the case of high quality homogenic armor steel plating k_z is almost equal to k_d, so that the missile would remain lodged in the plating until the hole pierced is as wide as the caliber of the missile.

It is necessary to emphasize here, however, that the nomogram has only been compiled to predetermine the penetration distance of explosive bombs in target materials of indefinite thickness and on the basis of bombs actually dropped, while the formula for calculating the penetration depth S' mathematically is also based on factual factors.

To pre-calculate breaching capabilities it is better to use to appropriate formula developed for artillery missiles. In these formulae use is made of the powers of impact velocities, since in the case of high impact velocities these provide more precise values than the recalculation of the penetration formula.

An interesting application of the nomogram is presented on the attacked sheet, showing the penetration depth capability contingent upon the ballistical factors of bombs.

The British periodical <u>Engineering</u> (No. 4225, Vol. 163 of 6 January 1947) contains information on the penetration distance of German bombs dropped on targets in England

47a

Supplementary to p. 255

Legend:

Eindringtiefe deutscher Sprengbomben nach engl. Angaben, in Aghaengigkeit von ihrer Querschnittsbelastung	Penetration depth of German explosive bombs, according to British information, contingent upon their ballistical factors.
Druckfestigkeit des Bodens in London ca 120 kg/qcm	Pressure resistance coecficient of soil in London approximately 120 kilograms per square meter
(nach engl. Angaben)	According to British informatio
vermutlicher Verlauf der Kurve	Probable direction of the curve
(nach deutschen Erfahrungen)	According to German experience
Querschnittsbelastung	Ballistical factors

47 during attacks in the autumn of 1940 and up to the spring of 1941.

During that period a total of 17,630 explosive bombs were counted in the region of London, of which 1,461 (8.3%) failed to explode and were excavated in the course of time for disarming. During these operations the lateral and longitudinal direction of the penetrations were measured and are analyzed according to calibers on the attached sheet (p.256). Using these figures it is possible with the nomogram to determine the pressure resistance coefficient of the soil.

Since all 550-pound (250-kilogram) and 1,100-pound (500-kilogram) bombs used against land targets were dropped without point bands, while all larger calibers had nose bands (and consequently a lesser penetration depth), calculations show that London soil has a pressure resistance coefficient of roughly 120 kilograms per square meter, similar to that of a sandy clay soil, findings substantiated by official measurements in England.

Owing to its verry narrow point, the PC-1400 bomb had a very winding passage from its point of initial penetration to the place where it came to rest. Its direction of penetration is shown in a dash-line curve in the diagram and with its penetration depth of 19 meters, appropriate to its high ballistic coefficient, corresponds more closely to the

43 data obtained at Liege than the values shown by the solid line curve.

49 4. <u>Breaching Capabilities.</u> (<u>Durchschlagleistung</u>). Repeated mention has been made in the foregoing chapters of the gun-firing method used in testing bombs on the ground to determine their penetration capabilities, and this method will now be described more fully here.

As previously described it was thought sufficient during the years of development of the newly designed cylindrically shaped bombs to test their hardness in high and low altitude bombing by means of a horizontally placed concrete slab with a thickness of 0.5 meter. It has also been described how it became necessary during the war to extend the test and pre-acceptance bombings to natural limestone and granite surfaces in order to check the suitability of the materials and manufacturing methods the use of which became necessary under war conditions.

Mine-type bombs are not required to have any appreciable penetrating capability, since deep penetration would not be appropriate to the purposes for which they are intended. All that is needed is a casing strong enough to insure penetration through covers over industrial installations with a pressure resistance coefficient of 200 kilograms per square meter, so that their explosive charge could detonate effectively inside buildings; the same applies to ships, such as freighters and transport ships, not protected by armor

49 plating, when these bombs are used against them.

Development of the armor-piercing bombs, which commenced around the end of 1938, made determination of the penetrating or breaching capability of bombs a matter or urgent importance.

Armor-piercing bombs must be capable of breaching the horizontal armor plating of large warships. As a rule the horizontal protection of such ships consists of a system of armor-plated decks at least 2 meters above each other, the

50 strongest being the lowest deck, appriximately at the ship's waterline. American battleships usually have another protective deck, generally somewhht weaker, beneath this waterline deck.

An especially complicated problem in the bombing of large battleships is that of so arranging the fuses of armor-piercing bombs that they will detonate immediately below the armor-plated deck in order to explode the ammunition stored in the ammunition chambers.

In constructing armor-piercing bombs, consideration had to be given to the various types of ships involved and the various tactics of attack which would be employed.

At the time when armor-piercing bombs were being developed, dive-bombing was strongly advocated in the German Air Force.

For use against less resistant armor plating, as used at

50 the time in the construction of aircraft carriers and cruisers, which had only approximately 2" armor plating plus several upper decks of normal ship construction steel, there were prospects that the penetrating capabilities of armor-piercing bombs with a relatively high (20%) explosive charge ratio would be sufficient. Calculations showed, however, that if bomb calibers were to remain within reasonable caliber limits bombs released in dive-bombing attacks would have to have rocket propulsion to pierce 6 inch armor plating. Prior to World War II German bomber aircraft had a maximum pay load of 2,200 pounds (1,000 kilograms); after the outbreak of the war this maximum increased to 3,740 pounds (1,700 kilograms); at the beginning of 1940 a maximum of 4,000 pound was authorized and during the attacks against London the largest bomb caliber used was that of the super-charge SB 2500 bomb, with a weight of 5,500 pounds, which was possible because German aircraft could take off from airfields in northern France.

51 Credit is due to the firm of Rheinmetall, Duesseldorf, for having made available within a relatively short time in the spring of 1939 apparatus which made it possible to gun fire bombs against armor plating and concrete walls.

The 380-mm missile projector used (see illustration) was a smooth-bore inner tube of a 380-mm cannon with a 210-mm liner. The latter was used to test fire 110-pound

91 bombs while the larger was used to fire 550-pound bombs.

Instead of using the standard PC-500 armor-piercing bombs, which had a diameter of 400-mm, special model bombs were constructed for tests with the missile projector. These model bombs were approximately 10% lighter, fitted into the 380-mm barrel and were constructed of the same steel and in the same way as the standard bombs.

All firing tests were carried out at ranges of 88-110 yards between the projector and the target. The armor plating and concrete walls used as targets were placed upright. In the case of armor plating tests were based on an impact angle of 60°, corresponding to the angle in dive bombing. In the case of the concrete walls, the impact was vertical, which corresponded to the impact angle of bombs released in high-altitude attack.

Instead of armor plating, normal ship sonstruction steel was used in testing mine-type bombs. Since the decks to be pierced by such bombs were relatively thin, the quality of the target material was of less importance than the impact angle so far as the total impact force was concerned.

When bombs pierced the armor plates at an angle the lateral stresses affecting the wall strength of the cylindrical bomb casings were greater than the stresses to which the massive nose section of the mine-type bombs were subjected.

51a

Photo

380-mm Missile Projector with
200-mm Inner Tube

52 In spite of these facts the established testing conditions were retained and events in the war served to prove how wise it had been to increase the test requirements, since the various inside installations of transport ships subjected bomb casings to far greater stresses than those caused by the decks and superstructures.

The targets to represent ship construction steel were made of normal construction steel, Quality II, with a tensile strength of 54 kilograms per square millimeter. Homogenio (nor surface-hardened) steel with a tensile strength of 110 kilograms per square millimeter was used to represent the armor plating to be pierced. This steel was known as Quality W,h (Wolfram alloyed} hardened).

The vertically placed concrete slabs were of what was called fortification concrete, which had what was called "cubic armoring (kubische Bewehrung)" consisting of 10-mm iron bars, and with a weight of 110 pounds per cubic meter of concrete. A maximum pressure resistance of 2,000 kilograms per square centimeter can be assumed.

For each round fired the barrel was precisely aligned with the "target line tester to secure repeated use of the armor plates and concrete slabs. The missile projector had a field of dispersion of approximately 50 centimeters at a range of 100 meters. However, it proved necessary to

52 re-erect the steel plates after each round, since the force of missile impact tore the from their supports. This caused considerable intervals between the individual rounds.

As is usual with test guns, the Boulangé apparatus xxx and compression measuring instruments (*Stauchzeug-Messeinrichtungen*) were used for the continuous measurement of gas pressure and muzzle velocities.

The impact velocities selected were 180 meters per second for armor-piercing bombs and 300 meters per second for armor breaching bombs, which corresponded to the impact velocities of bombs released in dive attack from an altitude of 7,200 feet, the former without and the latter with rocket propulsion. The impact velocity for mine-type bombs was 250 meter per second, corresponding to the impact velocity of bombs released in horizontal flight at an altitude of 13,200 feet.

The test missiles used were normal 110-pound and 550-pound bombs, in which the standard stabilizers were replaced by apecial gunfiring stabilizers adapted to the gun caliber. The attached photo shows specimens of the SC-50 and SD-50 mine-type and multi-purpose bombs thus adapted. Two gas and guiding bands were lightly shrunk on to improve gas pressure and balance in the smooth gun barrel. On impact these rings slipped off.

These missiles were similar to mortar shells and were

Photo

110-pound (50-kilogram) Bombs
Adapted for Testing by Gunfire

53 adequately stable in trajectory for the short ranges involved; slow-motion recordings were made of impact and penetration by means of cameras placed alongside the targets. In adapting older types of bombs it became necessary to use a metal plate conus to fasten the stabilizers, and this cone had to be pierded with holes to prevent crumpling by the gas pressure.

Most of the bombs used in these test firings had an inert filling and compression recorder was built into the side fuse chamber to register the lag at impact.

Occasionally, and during demonstration firing, use was made of live bombs. In such cases mechanical fuses were built in which had the same sensitivity and delay factors as the electrical bomb fuses normally used.

Photo 3 shows a 30-mm plate of ship construction steel used as a target for ~~110XXXXXXX~~ 110-pound bombs. The out-of-round holes show that the impact angle was less than 60°. The following two photos show the 110-pound bombs after they had penetrated through the steel plates.

The multi-purpose bomb, SD-50, naturally had a greater casing wall thickness and therefore a greater penetration capability than the SC-50 mine-type bomb of the same weight, which, however, carried a 50% heavier explosive charge. The deformation of the bomb numbered "Schuss 6" is due to the fact that its casing was from pressed tempered steel, while

52a Photo

110-pound (50-Kilogram) Bombs
Adapted for Gun Firing Tests

53a Photo

30-mm Plate of Ship-Construction Steel II
(R_2=54 kilograms per square millimeter)
taken under fire with 110-pound bombs.
Impact angle 60°; impact velocity 250
meters per second.

53b Photo

<u>Legend</u>:

Sch[uss] 6 = Round 6
Press-Stahl = Pressed Steel
Stahlguss = Cast Steel
SD-50 nach Beschuss = SD-50 Bomb after Firing

54 whereas that of the bomb numbered "Schuss Nr. 11" was of cast steel, the material normally used for these bombs.

Provided the casing did not ~~kxxxt~~ crack it was considered as having met the requirements in point of penetration hardness.

Multi-purpose bombs of steel Quality 7011 conforming to the German industrial standard (Deutsche Industrie Norm) gave better impact results and a better fragment count at detonation than those with cast steel casings, whereas DIN 3516 steel proved better for mine-type bombs.

The SC-50 mine-type bomb (numbered Schuss Nr. 10) shown in photo No. 5 had a casing of seamless steel, with a pressed-on nose section and a welded-on base (Manufacturing index "L" and Quality Category II). After penetrating through the 30-mm steel plate it was found that a bulge had begun to form at the point of transition from the nose section to the cylindrical middle section (the cross-sectional part endangered at impact) which showed that the bomb with the same wall thickness was at the extreme lime of tolerance.

The following two photos show a 50-centimeter thick, cubically armored, slab of fortification concrete after penetration , and the SC-250 mine type bomb which had penetrated it. This bomb was of pressed steel but also with a welded-in base, and also represented an ultimate tolerance limit.

Photo

SC-50/II Bomb after Firing

55 On the basis of these results, mine-type bombs were developed which, similarly to large-caliber artillery shells, were made of one-piece casings by the Ehrhardt press-and-draw manufacturing process. In this process the casing wall was thickest in the nose section and gradually became thinner towards the rear end, in consonance with the pattern of stresses at impact, and the base was also worked on by hammering, for which reason the bomb "hardness"was consistent throughout.

SC-250 bombs, Quality Category 1, of this type even penetrated satisfactorily through shipbuilding steel with a thickness of 50 millimeters, an astonishing performance for a missile with a walling thickness of only 8 millimeters. None of the mine type bombs in this caliber class used by the opposing air forces was as well designed and constructed or submitted to such severe tests as this German SC-250 bomb.

Besides the manufacturing process just mentioned, an exceedingly important factor for the high degree of "hardness" of these mine-type bombs was found to be the structure of the massive nose section, which was not weakened by fuse cavities. Already in the Spanish Civil War experience had shown that Russian 110-pound and 22-pound bombs of the older type usually broke at impact, since the strongly constructed fuse-center-section was subjected to shearing stresses which ripped the bomb casing lengthwise.

During World War II many of the American Demo bombs
56 even when striking ordinary cobblestone surfaces burst immediately from the nose and thus became ineffective. When it was pointed out to them after the war that when American forces bombed the German Air Ministry in Berlin 50 percent of the bombs which struck the target burst ineffectively while ineffective bursts in the garden terrain were a rare occurrence American weapons experts replied that they preferred to deliver a plurality of bombs on a spectfic target rather then depart from their convenient manufacturing processes available in the tube manufacturing industries. In the German Air Force such an attitude would have been considered wasteful and the greatest possible degree of effectiveness was required of each bomb.

War conditions in Germany made it necessary to depart from the ideal structure of SC-bombs. Here the method of testing the bombs by firing them from a gun barrel made it possible to determine precisely their reduced hardness and, accordingly, to class them in "Quality Categories" for the various operational purposes. Only J type ammunition was used against ships.

When the necessity arose to determine the penetrating capability of the PC-500 armor-piercing bomb, the barrel

55a   Photo

SC-250 Bomb after Firing

55b   Photo

50-centimeter slab of Fortification Concrete (with 50 kilograms armoring per cubic meter) after Impact of an SC-250 ⊥ n. 250 meters per second.

length of the gun used in the test firings became a matter of particular importance. As previously mentioned, the diameter of the bomb was too large. For this reason use was made of a PC 500/38 model bomb which was 10 percent lighter but which in point of structure and of the materials used conformed precisely to the principles of the standard PC-500 bomb and with the same impact velocity was required to breach armor steel with a thickness of 70 millimeters in order to insure that the original PC-500 bomb would achieve the required breaching capability of 80 millimeters.

Prior to the war only very few steel presses existed in Germany which were capable of manufacturing such bombs and these were fully occupied with Army and Navy contracts.

Until the German Air Force could create the necessary manufacturing installations, bombs of this type were also manufactured of cast steel and designated PC-500-E, the "E" denoting "Export." These bombs were slightly shorter and had an explosive charge of only 170 pounds instead of the 220-pound explosive charge of the genuine PC-500. It was only in this form that the export of these bombs to Japan was authorized.

Armor-piercong bombs were bi-ogivale, meaning that not only nose was a pointed arch but that the rear end of the casing was also much shortened in order to prevent shearing stresses

57 stresses during passage of the bomb through armor plating. The attached Photo No. 7 shows a PC-500/38 bomb after piercing through 70 millimeters of armor steel with an impact angle of 60° and at an impact speed corresponding to delivery in dive attack from an altitude of 4,000 feet. The bomb withstood the impact and penetration well, but the crack in the nose section shows that tolerance limits had just about been reached.

All test firingswere carried out at velocities close to or above the breaking point.

In vertical impact the test bomb showed a very high degree of hardness, which revealed the advantages of the bomb for delivery on target from horizontal flight. Photo No. 8 shows the reaction of the PC-500/38 bomb in vertical impact on a 120-mm thickness of armor steel. Contrary to expectations, the bomb did not break, but remained intact apart from deformation of the point, and remained embedded, and,given altitudes between 13,000 and 16,500 feet, would have pierced through the armor-plated

58 decks of battle ships with a displacement up to 25,000 tons.

In the case of the 2,200- and 4,000-pound bombs developed at the beginning of the war under the large-scale bomb-development program, no possibilities existed fo test them by firing from a gun barrel. In view of the long time it would have taken to construct an appropriate test gun

57a Photo

PC-500-E/38 Bomb after Piercing through 70-mm of Armor Plating, V_z = 176 Meters per Second, Impact Angle = 60°.

beginnender Anriss = Incipient crack.

57b Photo

PC-500/38 Bomb embedded on 120-mm Armor Steel Plate, V_z = 186.6 meters per Second.

278
58
and because of the necessity to make use of the ammunition immediately after production reliance had to be placed on tests in actual attack against the enemy.

It was only in 1942, following the hardly satisfactory results obtained in the bombing of large enemy warships, that instructions received approval for the construction of the Missile Projector 66 (Koerperwerfer 66), illustrated in Photo No. 22, with which it was possible to fire all explosive bombs which had been developed in the meanwhile at the requisite velocitiesin order to check the ~~xxxxxxxxx~~ target penetration capabilities which had in the past been computed mathematically.

However, only one of these projectors was placed in service by 1944, with a caliber of 562 millimeters. Tests showed that most of the bombs meanwhile introduced for use in combat operations met the requirements stipulated in their designing. The most important of these bombs, the PC-1000-RS rocket-accelerated armor-piercing and the PC-1400 armor-piercing bombs actually showed better capabilities than had been assumed in the past.

In the gunfiring tests, however, the PC-1000 bombs showed less favorable results because it was manufactured from weakly alloyed steel which, in the relatively thick point section could not be properly tempered through to the

58 through to the core, as previously mentioned. This was due to the foolish stipulation that the bomb had to be constructed to fit into a specified bomb storage space.

59 As described in the previous chapter, the reaction of the three named armor-piercing bomb types when delivered from a high altitude against hard ground was the same as when the bombs were fired against a similar surface from a gun, the only difference bein that the latter method of testing made it possible to determine the bomb's breaching or piercing capability.

Photo No. 11 shows the point of a PC-1000 bomb protruding from the far side of a 100-mm armor plate. The point shows incipient cracks, without the bomb having pierced completely through the plate.

Since no enemy warships had protective decks with a 100-mm thickness of steel plating, production of the PC-1000 armor-piercing bombs was halted, and the bomb was replaced by a multi-purpose bomb, the SD-1000-A, using unalloyed materials in the manufacture. This bomb was suitable for general purposes and carried an explosive charge weighing 440 pounds instead of the 350-pound explosive charge of the original PC-1000 bomb; it still had a breaching capacity of 80 millimeters.

Photo No. 12 shows a rocket-accelerated armor piercing

59 [illegible], the PC-1800-RS, after penetrating through 180-mm of armor steel at the impact velocity achievable in dive-bombing attack.

The casings of armor-piercing bombs have such thick walling that they can be given a cylindrical outer shape without any disadvantages and at an equal weight are shorter than biogival bombs, which is an important feature with rocket-accelerated bombs since it reduces structural length. Because of the extreme stresses caused while penetrating at an angle through the armor plating, the PC-1800-RS shows a slight denting in the rear third of its length without any reduction of its blast effect.

The intention also existed to use Missile Projector 66 in tests with combinations of steel plates representing the structure of the various decks of a warship, as indicated in Photo 12. Owing to its relatively weak mount, the old Model 60 38 Missile Projector could be used only for the testing of PC-500/38 bombs and a missile velocity of 185 meters per second, making it possible to pierce 70 millimeters of steel plating. This naturally was inadequate for any appreciable combination of steel plates.

The maximum performance of Missile Projector 66 was with the PC-1600 (Rocket-Propelled PC-1800-RS bomb minus the

Photostat

Legend:

Koerperwerfer 66 mit Rohr 56.2 cm) = Missile Projector 66 with 562-mm barrel

Es koennen verschossen werden) = Can fire

Aus 56,2 cm Rohr = Using 562-mm barrel

PC 1000 mit V_z =320m/s Entspr. ha = 6000 m.) = PC-1000 at velocity of 320 meters per second; corresponding to bomb-release altitude of 20,000 feet

etc. etc.

Aus 68 cm Rohr (Einsatzbereit 1944)) = Using 680-mm barrel (Ready for service in 1944)

Hoechste Leistung des Koerperwerfers bei einem Bombengewicht von 1600 kg und einer V_z = 400 m/s) = Maximum performance of the missile projector with a bomb weight of 3,520 lbs and a velocity of 400 meters per second.

Appendix to p. [illegible]

59a Supplementary to pp. 277/278

Photo

Gun-fired C-500/21 Bomb Lodged in 100-mm Armor Plate (K_2 = 110 kilogram per square millimeter) V_Z = 321,4 meters per second.

59b Supplementary to pp. 277/278

Photo

PC-1800-RS Bomb after Penetrating through 180 millimeter of Armor Plating; V_Z = 289.4 meters per second; Impact Angle = 60°

rocket [illegible], at an impact velocity of approximately 400 meters per second giving a theoretical penetrating capability of 475-mm of armor plating, which would have been adequate for the any thickness of deck armor protection found in warships.

However, this confirmation of the penetrating capability of the large caliber armor piercing bombs by the results obtained with the new missile projector failed to remove the distrust of the German Air Force Command in technology. At a later juncture the use of the penetration capability factors obtained with the missile projector was disallowed ~~to~~ establish the penetrating capabilities of the bomb types involved in service regulations for the troops, when the bombs were introduced. ~~prohibited~~. Instead, orders required the erection of a special target, as shown in the attached photo, for use in test bombings from the air. However, this target was only ready for use in 1944 and for various reasons was never used.

This target was only 33 x 66 feet in size and the chances of hitting it with unguided bombs would have been so small that its use would have represented an irresponsible waste of valuable test ammunition.

After occupation of the territory by Allied forces in 1945 both the missile projector and the armor-piercing bomb target were immediately dismantled and taken to England.

61a Supplementary to p. 281

Photostat

Legend:

Panzerbombenziel	=	Target for testing of air-delivered armor-piercing bombs
(xxpxaxixxtxsentspricht) annaehernd einem Ausschnitt aus dem Hauptspant eines USA Schlachtschiffes vom Typ "North Carolina	=	Approximates a cross section of the main bulkhead of a US warship of the North Carolina class.
Materialaufwand:	=	Materials used:
380 to Panzerplatten (Cr-Mo-Mo)	=	380 tons of armor plating (Cr-Ni-Mo)
86 to Baustahl	=	86 tons Construction steel
141 Eisenbahngleis	=	141 tons Railroad rails
135 m^3 Holz	=	135 metric tons of timber
290 to Zement	=	290 tons Cement
Kosten rund RM500000	=	Funds expended: approximately 500,000 Reichsmark
Panzerstaerken:	=	Armor plating thicknesses
Aufbaudeck:6 mm Stahlblech	=	Bridge deck: 6-mm steel sheeting
Oberdeck:40 mm WH-Platten	=	Upper deck: 40+mm Wh-armor plating
Panzerdeck=140 mm "	=	Main armored deck: 140-mm Wh-armor plating
Laengsschott:30 mm "	=	Longitudinal bulkhead:30 mm " "
Querschott: 20 mm "	=	Transverse bulkhead=20-mm " "

The missile projector installations proved a very useful aid in the development of new types of bombs, particularly since weather conditions in no any influenced testing activities; in German climatic conditions, the weather otherwise seriously delays bomb testing if carried out from the air. This testing of bombs by means of firing them from a gun barrel proved indispensable as a severe check on their construction, method of manufacturing, and the materials used.

The armor-penetrating coefficients given for German bombs in bombing charts in each case refer to the minimum release altitude stated in each case, to a specific type and strength of armor, and to a minimum impact angle of 60°and in this form cannot be used for comparisons. In the charts for multi-purpose bombs of the newest German types, the coefficients given referred to a missile velocity of 180-190 meters per second (dive-bombing attacks). This was admittedly correct for the SD-70 and SD-250 bombs; in the case of SE-500 and SE-1000 bombs, however, their structure justifies the assumption of a considerably higher velocity, since in this respect they really represented armor-piercing bombs (see Chapter II, 3). In the charts given in Chapter II, 3, for British cast-steel General Purpose bombs a velocity of 200 meters per second has been

284 has been assumed and for the pressed steel type IV bombs of the same class a velocity of 22. meters per second.

t

In the light of wartime experience the American demolition bombs, which, similarly to theix German xxxx SC class bombs, have an explosive charge making up roughly 50 percent of their weight, cannot be expected to have any considerable penetrating capability on resistant targets. American SAP class bombs carry the same explosive charge as the British General Purpose class bombs for which reason they have been computed with an impact velocity of 200 meters per second, while a velocity of 250 meters per second has been assumed for American AP class bombs with their 14 percent explosive charge (SAP = Semi Armor Piercing).

However, it might be more to the point to compute the penetration capabilities of these bombs with reference to the maximum bombing altitude allowed by their structure. For this reason the maximum impact velocity of German bombs, as determined in practice, is entered contingent upon their explosive charge percentage. From the resultant curve it is also possible by comparison to read off the maximum impact velocities of American and British bombs and use these factors in calculating their XXXXXXXXXXX armor-piercing capability by the de Marre formula. The following compilation provides a better concept of the penetrating capabilities of the various bombs.

6 a Supplementary to page 234.

Legend:

XXXIXXX
Max.Auftreffgeschwindigkeit V$_z$ fuer Panzerdurchschlag in Abhaengigkeit des Ladungsanteiles = Maximum impact velocity for armor piercing contingent on ratio of explosive charge to overall bomb weight

PD, PC/RS, AP = Armor-piercing bombs

SS, PC, SAP = Semi-armor-piercing bombs

SD, GP = General purpose or multi-purpose bombs

SC, MC, Demo = Mine-type bombs

(a) = American

(e) = British

V$_z$ = Maximum impact velocity

Sprengladung = Explosive charge.

65

BREACHING CAPABILITIES OF VARIOUS BOMBS

Bomb Type	Explosive Charge (in % of weight)	Impact Velocity (meters per second)	Armor plating breached (in millimeters)
GP 250 lbs I	27	185	36
IV	21	200	41
SC 250 kilograms	50	150	33
SD 250 "	29	185	45
GP 500 lbs I	29	185	47
IV	26	190	49
SAP 500 lbs (e)	18	210	55
(a)	30	180	47
SD (500kilograms) A	33	175	59
B	18	210	83
SE 500 kilograms	20	205	80 (Hexogen charge)
GP 1000 lbs	29	185	57
SAP 1000 lbs (e)	20	205	76
SAP 1000 lbs (a)	31	180	63
AP 1000 lbs (a)	14	240	122
PC 1000 kilograms	16	225	117
SD (1000kilograms) A	20	205	102
SE (1000 kilograms)	15	230	133 (Hexogen charge)
SAP 2000 lbs (e)	19	210	103
GP 1900 lbs (e)	32	175	79
AP 1600 lbs (a)	14	240	146
PC 1400 kilograms	21	200	153

BREACHING CAPABILITIES OF VARIOUS BOMBS--Continued

Bomb type	Explosive charge (in % of weight)	Impact Velocity (meters p.second)	Armor plating breached (in millimeters)
SD 1700 kilograms	42	160	77
MC 22,000 lbs	42	160	150

Remarks: Assuming the shape and manufacturing materials and processes of the various bombs to be the same.

(a) = American; (e) = British bombs.

64 5. The effects of Bombs on Warships (A Study). As previously mentioned (in Part A) concepts were very unclear at commencement of the "major explosive bombs development program" on the manner of how these bombs were to be designed.

In the past, the caliber of bombs for use against ships had remained to a weight of 1,100 lbs (500 kilograms); there were in existence

the SC-500 mine-type bomb
the PC-500 armor-piercing bomb
the PC-500-RS (rocket accelerated) armor-piercing bomb,

the latter with rocket acceleration designed to give it the necessary impact velocity to penetrate through the more heavily armored decks of warships.

The problems in question were: Armor-Piercing or Mine-Type Bombs; Full or near hit (with the bomb exploding close to the side of the ship).

The most important target for German air attack at the time was the British High Seas Fleet, namely, the large naval units.

Of the other weapons available at the time for use against ships the F-5-h air torpedo was completely useless because of factors which seriously restricted the possibilities for its tactical use. The German Navy had not been able to make available to the Air Force a German developed

64 usable air torpedo and the Horten torpedo purchased from Norway pursuant to Naval advice had proved impracticable in use because its maximum launching altitude was only 99 feet and because it could not be launched at flying speeds greater than 132 miles.

The Air Force had rejected the LMA and LMB parachute mines since the command desired immediately visible results.

65 For these reasons the only weapon which could be quickly developed for use against large warships was large caliber bombs.

Based on instructions from the Air Force General Staff only one 2,200-pound armor-piercing bomb was under development at the beginning of the war, but neither the penetrating capability nor the explosive effect of this bomb, the PC-1000, which had to constructed to measurements for the Me-210 fast bomber, were adequate to meet the new requirements. For this reason work started immediately on designs for an SC-100 mine-type and a PC-1000-RS rocket accelerated armor-piercing bomb.

At the beginning of the war the trend in the designing of military aircraft was away from horizontal bombing units towards dive-bomber units. Owing to its small striking range, the single-engine Ju-87 in the new circumstances was reequipped exclusively for Army support operations and was

65 to be supplemented with the twin-engine Ju-88. This latter aircraft had admittedly also originally been intended for high-altitude bombing, for which purpose it was to carry a crew of four, but the wings of the Junkers planes were sturdy enough for their use in dive-attack, in which the pilot could serve simultaneously as aircraft commander and bombardier. Steps were now taken to equip the Ju-88 completely for action against the hostile navies: the bomb bays XXXX fitted to take smaller caliber bombs inside the body of the plane were used to install additional fuel tanks to enable the plane to attack the British naval base of Scapa Flow with 2,200 bombs suspended under its wings. The previously mentioned Me-210 fast bomber and the He-177 four-engine dive bomber were already under development and were to replace the older bomber types in 1941 and 1942. As is generally known, however, these models did not become available for front line service in time, so that the 66 He-111 horizontal bomber had to remain in service for a long time although its defensive firepower was completely inadequate. Requirements for the Ju-88 and He-111 aircraft placed no restrictions on the length or diameter of bombs, although the diameter was actually limited to that of naval mines, namely, 66 centimeters.

The dive-bombing concept, which governed thinking in the German Air Force command at that time, created the necessity

66 to require decisive results from each individual bomb, so that the calibel of 2,200 pounds appeared too small to sink even the heaviest warships with a single hit.

By reason of the fact that high Air Force levels of command had established direct contact with lower naval levels at the beginning of the war (for example, the Chief of Air Force Special Supply and Procurement Services personally with the explosives specialists of the Naval Chemo-Physical Experimental Station) and in so doing had absorbed disconnected data on the pressure effects of underwater explosions, an exxagerated estimate of the effectiveness of large-caliber mine-type bombs had developed, which contrary statements by experts, including even the Chief of Naval Ordnance Offices himself, failed to dispel.

It was maintained that 300 kilograms (660 pounds) of Trotyl would suffice to sink any warship up to a water displacement of 35,000 tons if detonated below the armor-plated deck, and that 2,200 pounds of Trotyl would definitely sink such a ship if it exploded within 15 meters of the midship section. Given this 15 meter wide water belt around a warship of the 30,000 ton Queen Elizabeth class the target area to sink the ship by ~~a 2,200~~ mine-type bomb carrying 2,200 pounds of explosives would thus be approximately 6,000 square yards, whereas with its overall length of 195 meters and width of 32 meters

67 the ship's decks only represent a target surface of roughly 4,500 square meters.

The "effective target area" is expressed in a percentage of the deck surface area when comparing the effectiveness of various bombs in use against the various types of ships.

If the above assertion were correct, an SC-1800 mine type bomb would have had an effective water area target 133 percent greater than the deck area if used against the Queen Elizabeth. Since thin-walled bombs cannot penetrate through the armor-plated decks, a full hit with an SC-1800 bomb, in contrast, could only have damaged the superstructures.

For a PC-1400 armor-piercing bomb loaded with 660 pounds of Trotyl explosive, only approximately one-half of the 4,500 square meters of deck surface area would have presented an effective target area, since the bows and stern are not included in calculations and since the turrets and the midship superstructures offer more resistance than the armor-plated decks themselves and individual near-hits would not have sunk the ship. These chances of success, based on expert technological calculations, were naturally far smaller than those based on the assumed effectiveness of near hits.

Even if bombs of equal weight were assumed, and assuming the existence of ~~a~~ a 15-meter-wide belt of water around the ship in which an exploding bomb could sink the ship, the effectiveness of an

67 SC-1800 bomb bursting alongside the ship would have been decidedly superior to that of a SC-1800 armor-piercing bomb in a direct hit; the latter would admittedly have penetrated through the turret roofs and placed 220 kilograms of Hexogen explosive inside the target, but lacking the underwater blast effect, its effective target area would have been far less than 100 percent of the deck surface area.

68 The recommendatien to use only mine-type bombs against heavily armored warships was in direct contrast with the opinions of the well-known French Chief Engineer Rougeron, who recommended the use of numerous small-caliber armor-piercing bombs for the purpose.

The failure of the mine-type bomb was proved by events when returning aircraft crews reported that little effect was observed on ships even when bombs hit xxxxxxlax the water very close to their sides. Frequently, photos showed that the distance of the near-hit had not been calculated from the center-point of the bomb hit xxdxxxxxhxxxxxxxxxxxxxbut from the edge of the disturbed water caused by the under-water eeplosion. The diameter of this zone of disturbed water, indicated by bubbles rising from the explosion, probably approximates the diameter of a bomb crater in light sand, and thus would be at most 25 meters in the case of an SC-1800 bomb.

Therefore, only SC-1800 bombs striking in the water within 12.5 meters of a ships sides could be expected to

68 cause serious damage to the heavily bulwarked bottoms of warships. To be on the safe side, the figures given in the attached table for the distances at which bombs can be expected with certainty to cause serious damage to the ship's bottom have been taken as 8 meters for the Queen Elizabeth, 6 meters for the Nelson--a modern battleship in 1939, and 10 meters for the heavy cruiser Dorsetshire. A number of such underwater near hits could naturall cause the sinking of a ship although lateral and longitudinal bulwarks, torpero-tube bulges, and double bottoms are designed to afford protection against hits below the waterline.

In the summer of 1940 a study, supported by sketches, was therefore prepared in cooperation with naval experts showing the effectiveness of large caliber explosive bombs which had been meanwhile developed against three different
69 British warships, and a discussion of that study now follows.

The following types of ships were chosen for the study:

I. The modern battleship Nelson, 34,000 tons; similar ships: 1
II. The older battleship Queen Elizabeth, 30,000 tons; similar ships: 8
III. Heavy cruiser Dorsetshire, 10,000 tons; similar ships: 15

The effectiveness of the following explosive bombs, ranging in caliber from 2,200 to 4000 pounds, on ships of the ebove types was examined:

68a

Supplement to page 291.-TABLE

Legend:

Abstaende in Metern von der Bordwand, auf welche Wirkung mit einzelnen Bomber zu erwarten sind und wirksame Zielflaeche in % der Decksflaeche	Distances (in meters) from ships sides at which effects can be expected from individual bombs and effective target area in percentages of deck surface area.
Bombenmuster	= Bomb type
Sprengladung	= Explosive charge
Zerstoerer	= Destroyer
leicht. Schaeden	= Damages (slight)
schw. "	= " (serious)
Versenkung	= Sinking effect
wirksame Zielflaeche	= Effective target area
leicht. Kreuzer	= Light cruiser
schw. Kreuzer Dorsetshire	= Heavy cruiser Dorsetshire
aelt. Schl. Schiff Queen Elizabeth	= Older type battleship Queen Elizabeth
neu. Schl. Schiff Nelson	= Modern Battleship Nelson
Bemerkungen	= Remarks
Die eingerahmten Zahlen geben die zweckmaessigste Bombe an	= The inset figures denote the most effective type of bomb
Erlaeuterung des Begriffes "wirksame Zielflaeche": Die Zielflaeche eines Schiffes, auf welche eine Bombe fallen muss XXXXXXXX XXXXXum es durch einen Volltreffer oder Einschlag, nahe der Bordwand zu zerstoeren, besteht aus der gefaehrdeten Deckflaeche und Wasserflaeche um das Schiff herum, in welcher die Bombe bei der Detonation mindestens 2 wasserdichte Abteilungen eindrueckt. Die wirksame Zielflaeche ist in Prozent der gesamten Decksflaeche angegeben	= Definition of the concept "Effective target area": The target area of a ship on which a bomb must fall to sink it by a full hit or by a hit close to the ship's sides consists of the vulnerable deck surface area and the waterarea around the ship within which the detonation will breach at least two XXXXXXXXwatertight bulkheads. The effective target area is given in percentages of the overall deck surface area.

	Bomb Type	Explosive Charge		
1.	SC-1000, mine-type	550	kilograms	Trotyl
2.	PC-1000, armor-piercing	160	"	"
3.	PC-1000-RS " -breaching* rocket-accelerated	64	"	Hexogen
4.	PC-1400, armor-piercing	300	"	Trotyl
5.	~~multi-purpose~~ SD-1700, multi-purpose	700	"	"
6.	SC-1800, mine-type	1000	"	"
7.	PC-1800, armor-breaching, rocket-accelerated	220	"	Hexogen

In the case of decks protected by homogenous, wolfram-alloyed steel plating, Quality WH with a resistance coefficient of 110 kilograms per square millimeter, the penetrating coefficients at a dive-attack angle of at least 60° and a bomb release altitude of 4,000 feet were: for both mine-type bombs only 30 millimeter; for the multi-purpose bomb 60 millimeter, for the 1,000-kilogram(2,200-pound) armor-piercing bomb 100 millimeter; for the 1,400-kilogram (3,080-pound) armor-piercing bomb 110 millimeter; for both armor-breaching* bombs 180 millimeter. I high-altitude release the 1,400 kilogram bomb could be expected to penetrate 130 millimeters, the rocket-accelerated version of the same bomb, IXDXXIIIXXXXXXX the PC-1400-X even penetrated through the 150-mm thick steel deck of the Italian battleship Roma from an altitude of approximately 20,000 feet while trying to desert to the Western Allies and was sunk by one full hit.

X Armor-breaching has been used for the German term "Pandurchschlag", meaning to penetrate through.

The penetrating coefficients for armor-piercing bombs quoted above were determined by firing the bombs at armor plating with the missile projector discussed in the previous chapter. The larger calibers of mine-type bombs were not expected to have a greater hardness coefficient than the SC-250and SC-500 medium-caliber bombs because of their thin-walled casings.

In the table on page 292 the distances are given, for each of the bombs dealt with, at which the detonation near the side of a ship of the types under study could be expecte to sink the ship by a near hit, together with the distances at which the detonation would cause serious or minor damage to the ship, such as serious or minor leaks and/or damage to machinery.

The attached sketch (photocopy) [not included--Note by Translator] shows the effect of three different 2,200-pound explosive bombs on the three target ships. The areas shaded red around and on the ships show the positions at which the bomb explosion could be expected to sink the ships. The green shading shows the positions at which bomb hits could cause serious, and the yellow shading position where hits could do minor damage.

In detail, the presentation reveals as follows:

70 a. The SC-1000 mine-type bomb can not sink a modern or even an older type battleship by a single full or near hit, since neither the penetrating power nor the explosive charge are adequate for the purpose. However, the bomb could possibly sink a heavy cruiser not only by a full hit fore or aft but even by a near hit in a wide zone along midships.

b. The PC-1000 armor-piercing bomb can cause serious damage, as could the mine-type bomb, in a hit on the decks of ~~a~~ the modern battleship Nelson, but in a near-hit can do only minor underwater damage because of its smaller explosive charge. It can hardly be expected to sink the ship, since the main armor-plated deck has a thickness of 160 millimeters, which the armor-piercing bomb could not penetrate.

A hit with a PC-1000 armor-piercing bomb on the horizontal protective armor plating of the Battleship Queen Elizabeth, considered obsolete in 1939, could, if it entered the ammunition bunkers, cause the explosives stored there to detonate and destroy the entire ship. The heavy-gun turrets would offer impenetrable resistance to the bomb. Although they would be put out of action, they would protect the handling areas below and prevent an explosion of the ammunition bunkers.

In the case of the heavy cruiser Dorsetshire, a direct hit amidships with a PC-1000 armor-piercing bomb, or a near hit at a very short distance could cause the ship to sink. With the exception of the foreship, the turrets, and the superstructures, large areas of the decks are highly vulnerable to this bomb.

c. The rocket-accelerated PC-1000-RS armor-breaching bomb because of its higher cross-sectional resistance coefficient and its accelerated impact velocity could, if

71 if released in a dive attack, even penetrate through the armor of the ammunition bunkers of the Nelson and detonate the explosives stored there. The same applies to ships in the Queen Elizabeth and Dorsetshire class, where even hits on the turrets could cause total destruction.

72 Turret roofs are relatively weakly armored. This is particularly the case in older and lighter naval units and can be pierced even by the normal mine-type 55-pound bombs, as was shown in an inspection of the British cruiser York (Crete, May 1941). However, in ships of the Nelson class, even the rocket-accelerated armor-piercing bombs failed to pierce through the additional protection provided by the guns, gun sockets, and cradles. Owing to the fact that the ammunition bunkers are hermetically sealed off from the turret interior, it is not to be expected that the explosion of a bomb or shell inside the turret will have any effect below decks, as shown already in the Battle of Skagerack of World War I.

Owing to its small explosive charge, the PC-1000-RS rocket-accelerated armor-piercing bomb naturally cannot do much damage to the hull of a battle ship when exploding in the water alongside.

The following should be noted concerning the danger zones shaded green and yellow on the attached sketch:

An SC-1000 mine-type bomb exploding in the water less than 17 feet away will cause the floodinf of at least one watertight compartment, even in the case of a battleship. In ships of pre-World War II construction, it was to be anticipated that leaks in more than two of the watertight compartments would cause the ship to sink; therefore, three to five SC-1000 bombs exploding alongside and properly distributed within the green-shaded zone should suffice to sink a ship. The possibility exists, however, that a large-caliber bomb exploding at a particularly favorable point in the water, might cause the flooding of two adjoining watertight compartments. (The German battleship Scharnhorst was kept afloat by its longitudinal watertight compartments although three of its watertight compartments were struck by armor-piercing bombs -- La Pallice, July 1941).

73 It is difficult to appraise the capability of smaller caliber bombs to sink ships, even in the case of several hits.

The study under discussion here is based on the effects of individual hits. Therefore, the question as to which type of bomb in the 2,200-pound class presents the most favorable chances to sink one of the three ships mentioned produced the following answer:

> In the case of smaller and weakly armored ships, the mine-type bomb is most suitable for the purpose. It is hard enough (particularly with a one-piece casing) to

pierce through the upper decks plus 30-40 millimeters of protective armor plating and its explosive charge, making up 50 percent of the overall bomb weight, gave it a large blast effect range in the event of near hits. Events showed the Amatol-Ammonal explosive charge ~~originally~~ used in the original SC-1000 bomb to be less effective, not only because of the substitute explosive ammonal, but also because of the reduced hardness of the bomb casing due to the loose explosive filling.

According to the finding of the study, which were based on the opinions of experts, the best bombs to use against ~~battleships~~ larger warships were the armor-breaching type--also called semi-armor-piercing, a term borrowed from naval artillerists--; with an explosive charge making up approximately 20 percent of the bomb-weight, these were adequate to sink most of the types of battleships then in service. Armor-breaching (Panzerdurchschlag) bombs were necessary only againsst modern large naval units, and carried only 5-6 percent eeplosives.

In point of bomb effectiveness no reason therefore existed in the first year of the war to exceed a bomb weight of 2,200 pounds. It was only later in the war, when battleships with a displacement of more than 40,000 tons made their appearance, that larger bomb calibers

74a

Supplementary to page 301-303

Sketches

Legend:

Lage von Ziel und Treffpunkt bei unerwarteten starken Richtungsveraenderungen des Zieles = Position of target and point of intersection in event of sharp and unexpected changes of target course

1. Abwurf im Sturzflug aus 1000 m. = Bomb release in dive attack at altitude of 3,300 feet

2. A " " " aus 2000 m. = Bomb release in dive attack at altitude of 6,600 feet

3. Abwurf im Waagerechtflug aus 4000m = Bomb release in horizontal flight at altitude of 13,200 fee

4. " " " " 6000m = Bomb release in horizontal flight at alt. of 20,000 feet

Schiffsgeschwindigkeit (geradeaus) 12 m/s=43 km/h = Ship's speed (straight course) 12 meters per second=43 kilometers per hour

Drehkreisdurchmesser 500 m = Diameter of turn 500 meters

Masstab 1:2500; 4 cm = 100 meter = Scale 1:25000; 4 centimeters = 100 meters

Bereich der 50%Streuung = Zone of 50% dispersion

Lage des mittleren Treffpunktes = Point of average hit

Lage des Zieles beim Aufschlag = Position of target at moment of impact

Lage des Zieles beim Abwurf = Position of target at moment of bomb release

Abwurfhoehe 1000m (Sturz) Fallzeit 7 sec = Bomb release altitude 3,300 feet(in dive attack, falling time 7 seconds

(Horizontalflug) = in horizontal flight

could have been necessary.

Cruisers could be attacked successfully even with mine type bombs of medium weight calibers, and thus with the SC-250 and SC-500 bombs, as became evident in 1941. The cruisers best defense was its high meneuverability, so that angle bombing was more favorable than horizontal flight bombing at high altitudes.

This was also so in the case of battleships, as will be seen from the attached illustration, in which the position of the target and the point of intersection are shown for a battleship travelling at 23 knots and veering to port at the moment of bomb release in a trun with a diameter of 500 meters.* In the case of a dive attack, the Nelson with its entire deck target area plus its extended target areas alongside would still be within the 50 percent zone of dispersion of a bomb released at an altitude of 6,600 feet. In the case of a high-altitude attack of ~~XX~~ 13,200 or 20,000 feet the ship would be far outside of this zone of dispersion.

Consideration of the above factors resulted in the development of a radio controlled armor-piercing bomb, the PC-1400-X, with a field of dispersion roughly only one-half as great as that in dive bombing.

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* In his sketch the author gives "Drehkreisdurchmesser" = "Diameter of turn". Probably this should read radius.

Apart from the fact that the German Air Force Command ascribed an exaggerated degree of effectiveness to the SC-1800 mine-type bomb, another factor contributing towards the preference shown for it was the greater simplicity of its manufacture from rollered and welded sheet metals which facilitated speedier production than the manufacturing processes involved in the armor-piercing bomb of alloyed steels. Due to its small degree of hardness there was no possibility for the use of delayed-action fuzes in the case of direct hits and its effectiveness was to be expected primarily in near hits, with the bomb exploding at a considerable depth under water. In these circumstances better results could have been expected from an SC-2000 mine-type bomb, also with a 2,200-pound Trotyl explosive charge. This bomb would have had a one-piece casing and would have been capable of piercing armor steel with a thickness of approximately 50 millimeters. However, the production of this bomb required such extensive manufacturing preparations that it only made its appearance at a time when the German Air Force no longer had any chance to make profitable use of it.

The PC-1400 armor-breaching and the SD-1700 multipurpose bombs, the latter with an explosive charge making up 40 percent of its weight and actually in the mine-type class, with improved penetrating capabilities, closed the

75 gap between bombs with a normal weight of 2,200 and 4,400 pounds.

The PC-1400 carried the necessary explosive charge of 660 pounds of Trotyl which enabled it to destroy most types of foreign naval units if it hit the decks, and the SD-1700 was hard enough to penetrate the protective armor plating of aircraft carriers while its 700-pound explosive charge insured optimum effectiveness in both full and near hits.

As early as in 1940 plans also provided for an armor-breaching bomb, the PC-1800-RS. Delivered in dive attack and with rocket acceleration, this bomb was to have an aromr-penetration capability of 180-mm and a special arkor-breaching explosive charge weighing 440 pounds and considered adequate to sink the largest ships afloat at the time. The explosive charge consisted primarily of Hexogen and was to have a blast effect equivalent to that of 660 pounds of Trotyl.

In detail, the probabilities for successful action with these bombs of above 2,200 pounds against the types of warships mentioned were appraised as follows:

a. Hits on practically any part of the decks or within an extended target area 3 meters wide along the sides of the ship and making up alomst 30% of the deck surface are could sink the heavy cruiser Dorsetshire. On the whole the possibilities of success with the PC-1400 against the

76 Dorsetshire were about twice as favorable as with the use of the PC-1000 bomb. In attacks against older types of battleships, such as the Queen Elizabeth, the chances could even be considered as trebled, since not only bombs penetrating into the ammunition bunkers, but even hits on the midship decks, unless arrested by superstructures, would penetrate into the ship, where their detonation would breach the ship sides from the inside and cause its destruction. This was what happened in the case of the Italian battleship Roma, previously mentioned. In the case of near hits in the water alongside the ship, however, the explosive charge of the PC-1400 was not adequate to sink larger warships.

It would not be possible ti sink the heavily armorplated battleship Nelson with a single hit by a PC-1400 bomb, which could only cause damage of a greater or lessor extent by full or near hits.

b. In the case of the SD-1700 multi-purpose bomb, designed for use against less heavily armored warship~~s,~~ over 10,000 tons the relatively largest degree of effectiveness would be in use against the Dorsetshire, where the effective target area would be more than 150 percent of the deck area. Of the battleships taken under study only the older Queen Elizabeth would be vulnerable to the SD-1700 bomb, and only if struck midships, whereas the Nelson could only be

76 could only be damaged by direct hits with this bomb. In use against aircraft carriers of the Arc Royal type, the effective target area for the SD-1700 bombs would be at least 100 percent of the deck area, since the bomb was designed specifically for such purposes.

77 c. The SC-1800 mine-type bomb could still be considered to be 100 percent effective against the Dorsetshire since it not only had a blast effect adequate to sink the ship within a wide zone in the water alongside but was also hard enough to breach the relatively thin deck plating and then shatter the ship by its detonation. However, the effective target area of this bomb was smaller than that of the SD-1700 which stresses the importance of not neglecting the hardness factor of bombs. Used against the Queen Elizabeth, the thinn-walled SC-1900 bomb could only have caused its target to sink if it detonated within a very narrow zone in the water alongside midships; this "extended target zone" had a surface area only one-half a large as the deck area vulnerable to the SD-1700 multi-purpose bomb. Deliberations by experts had meanwhile reduced the estimated effective target area from 15 to 3 meters distant from the ship sides , and that only in the casx of older types of battleships; in the case of the Nelson with its more effective system of bulkheads, the SC-1800 bomb in a full hit could still have caused considerable

77 damage to the battle value of the ship, but at best the bomb could have caused the flooding of two watertight compartments which would not have been sufficient to to sink the ship.

A comparison of the quantitatively tangible effectiveness of the SD-1700 bomb with that of the SC-1800, shows that the chances of sinking the naval units in use by Germany's opponents in 1940 were 50 percent greater with the SD-1700 bomb than with the SC-1800. In spite of this, the production of the SD-1700 bomb was halted prematurely because the Air Force General Staff desired to have either armor-piercing or mine type bombs, but no compromise between the two, for combat action against ships.

d. The PC-1800-RS rocket-accelerated and the PC-1400 bombs could have breached any part of the heavy cruiser Dorsetshire. The blast effect of both bombs being equal, the light bomb was preferable for use against such ships.

Used against the Queen Elizabeth, the PC-1800-RS could also pierce through the gun turrets, so that the chances of sinking the target were 20 percent greater with this bomb than with the PC-1400 armor-piercing bomb.

Only armor-breaching bombs could have sunk the Nelson, and these only in the event of hits in the ammunition bunkers of the forard 380-mm buns or those of the medium caliber artillery aft. Experts doubted that bombs carrying a

78 442- or 660-pound explosive charge could have sunk so heavily protected ships with a hit in any other part. However, the PC-1000-RS rocket-accelerated bomb should have proved adequate to initiate detonation of the explosives stored in the ammunition bunkers if one disregards the fact (sic) that even bombs exploding outside of the ammunition bunkers could cause detonation of the stored explosives at a distance proportionate to their pressure front.

However, the fact that armory experts pointed out the superiority of armor-piercing bombs for use against warships made no impression on the German Air Force Command, which continued to adhere to the preconceived opinion of being in possion of the proper weapon, in the form of the SC-1800 bomb, for combat action against large naval units. Even the super-caliber SB-2500 bomb produced at the end of 1940 had to be adapted later (as the SB-2300) for water-impact detonation with delayed action to affect the lower underwater parts of ships.

79 In 1942 a crisis developed in the matter of bombs. The dive-bombing tactics had proved sound in the past swiftly conducted campaigns, in which dive-bombing forces had supported the ground forces; the results achieved in action against hostile naval forces, however, had remained extremely modest. The enemy did everything humanly possible to keep

their ships beyond the striking range of German aircraft and to conceal the results of air attacks, which are rarely immediately evident. The enemy also increased their fighter and antiaircraft artillery dxfenses to such an extent that formerly so highly vaunted dive-bomber theory was shaken. The four-engine He-188 dive bomber proved a serious failure for the German Air Force, not only in point of its technical capabilities but also tactically. It had not only become useless but proved a serious burden on the aircraft manufacturing industry and the supply services, depriving the front line forces of other, urgently needed, materiel, particularly engines.

It was also at this juncture that more heavily protected battleships made their appearance, namely, ships of the King George and North Dakota classes. Although the factor determining the required penetrating capabilities of bombs is the resistance coefficient of the actual armor plated decks of ships, and although the penetrating capabilities of the PC-1000-RS rocket-accelerated bomb would still have been adequate, various cricumstances created the necessity to prepare for the production of a stronger armor-breaching bomb.

In test firning with bombs against armor plating, as described in the previous chapter, it had been observed that in cases of ultimate penetration limits the bombs had been become unstable after penetrating the greatest thickness of armor plating they were capable of penetrating. The armor-plated decks of modern ships were divided and in general consisted of a more heavily armored upper and a less heavily armored lower deck. The purpose of this arrangement was to arrest the fall of steeply falling bombs ~~by means of~~ after their penetration through the thick upper deck and to protect the inner ship by means of the secons armore deck against the blast effect of the detonating bomb. This meant that bombs would have to have an impact velocity of at least 400 meters per second and increased cross-sectional resistance coefficient.

A start had been made already in 1941 to meet these requirements in the form of the PD-1800-RS rocket-accelerated bomb which was to carry an explosive charge of only 176 pounds but was to be capable of piercing 230 millimeters of armor plating. The corresponding data for the PC-1800-RS rocket-accelerated bomb were: Impact velocity 280 millimeter per second; explosive charge 442 pounds; penetrating capability 180 millimeters.

Before the PD-1800-RS bombs was ready for service, the dive-bomber tactics crisis reached culmination, making the further use of rocket-accelerated bombs impossible.

Although the tactical possibilities for high-altitude

80 bombings of important targets during daylight were already small at the time, orders were received to copy the British 2,000-pound armor-piercing bomb, used in the summer of 1941 against the German 25,000 ton Battleship Scharnhorst. This led initially to development of the PD-500 and later the PD-1000 armor-breaching bombs for use in high-altitude bombing. These bombs had no rocket acceleration unit and had a xxxxx maximum penetrating capability of 180 millimeters, and the explosive charge weighed only 6 and 9 percent,respectively, of the overall bomb weight. The PC-1000 armor-breaching bomb led to the development of a new multi-purpose bomb, the SD-1000-A; carrying a 440-pound explosive charge this bomb was, in spite of all, hard enough to pierce through armor protected decks with a thickness of 80 millimeters and thus was more effective against more lightly armored war ships than the faultily designed PC-1000 bomb.

In 1943 the Naval Operations Staff issued new data on the deck armor plating of enemy aXXXX warships (see illustration, p. 312), now including the modern battleships of the US Navy, showing that a bomb weight of 2 tons was now necessary to sink modern battleships. At this juncture the German Air Force Operations Staff no longer accepted the results obtained in test firings of bombs as valid data for the introduction of new types of bombs for introduction for use

Supplementary to page 311

Legend:

Deckpanzerungen von Britischen und USA-Kriegsschiffen	= Armor plating protecting decks of British & USA warships
30, 10, etc. mm	=30, 10 etc millimeters
Kreuzer Gr.Brit	=Cruiser, Great Britain
Modernes Schlachtschiff	=Modern Battleship
Aelteres Schlachtschiff	=Older type battleship
Flugzeugtraeger	=Aircraft carrier
Modernes Schlachtschiff USA	=Modern US battleship

80a **<u>Supplementary to page 311</u>**

<u>Legend:</u>

Deckpanzerungen von Britischen und USA-Kriegsschiffen	=Armor plating protecting decks of British & USA warships
30, 10, etc. mm	=30, 10 etc millimeters
Kreuzer Gr.Brit	=Cruiser, Great Britain
Modernes Schlachtschiff	=Modern Battleship
Aelteres Schlachtschiff	=Older type battleship
Flugzeugtraeger	=Aircraft carrier
Modernes Schlachtschiff USA	=Modern US battleship

80a/2 Supplementary to page 315

Legend:

Groessere Kriegsschiffe und Bomben zu ihrer Bekaempfung	= Larger types of warships and Bombs for use against them
Nr.	= Consecutive number
Land	= Country
Schiffs-Typ	= Ship type
Klasse	= Class of ship
Wasserverdraengung	= Displacement
Deckspanzer	= Deck armor plating
Aequivalente Deckstke.	= Equivalent to deck thickness of
Schw.Kreuzer	= Heavy cruiser
10,000 etc. t.	= 10,000 etc. tons
10 + 10 + 60 mm etc	= 10+10+60 millimeters, etc.
Flg-Traeger	= Aircraft carrier
Schl. Schiff	= Battleship
Schl.Kreuzer	= Battle cruiser
Erklaerungen	= Explanations
1. Die Raketenbomben sind fuer den Abwurf aus dem ohne Zuendung der Rakete aus dem Hochangriff	= The rocket-accelerated bombs are intended for release in high-altitude attack without ignition of the rocket (sic)
2. Fuer die Durchschlagskraft einer Bombe ist die Abw. jedoch durch das staerkste Panzerdeck bestimmt	= However, the penetrating capability of a bomb is determined by the resistance coefficient of the strongest deck.

80a/3 Supplementary to page 315

Legend:

Bombenmuster und Sprengladung = Bomb type and explosive charge

Durchschlagskraft = Penetrating capability

Abwurfhoehe und Auftreffwinkel = Bomb release altitude and impact angle

kg = Kilogram

mm = Millimeter

km = Kilometer

m/s = Meters per second

Deckspanzerung = Deck armor plating

nach Angaben des OKM Herbst 1939 = According to data from Navy High Command, Autumn 1939

ohne Rakete berechnet (mit Rakete wie unten) = Calculated without rocket acceleration) (with rockets see below)

Lt. OKM 1942 = According to Navy High Command 1942

Ohne Raketenanteil berechnet; mit Rakete Abwurfhoehe im Sturz 1.2km = Calculated without rocket element; with rocket bomb release altitude 1.2 kilometers in dive attack.

Lt. OKM 1943 = According to Navy High Command 1943 by the field forces and demanded the results obtained in actual bombing tests as proof of the bomb penetrating capability. A contract was awarded for the construction of a target measuring 10 x 20 meters (see illustration) for test bombings with armor-piercing bombs and was to be set up at the Unterluess firing range. (The parts completed by the end of the war were removed to England immediately after occupation of the area by British troops). In spite of the considerable expenditure involved, however, the target would have been so small that prospects of hitting it would only have existed with the use of guided bombs.

Since the capabilities of the PC-1400-X armor-piercing bomb were inadequate against targets stronger than those already in existence, and since it was anticipated that ships with a displacement of 45,000 tons of the Iowa class and the British Battleship Vanguard would make an appearance in 1944, development work commenced on a 2.5 ton remote control armor-breaching bomb to be designated the PD-2500-X. Released from an altitude of 20,000 feet, this bomb would have had an adequate impact velocity and hardness to pierce through 230 millimeters of armor plating and place 320 pounds of high-explosives inside the target. However, a bomb of this type could only have caused destruction of the new big ships if it struck the ammunition bunkers, and the

81 effective target area on these new ships totalled not more than 15 percent of the overall deck surface area.

In the comprehenseive table offered on pages 313-4 all hostile warships are listed which, during the 1939-1945 war were taken under study by the German side to determine their resistance against bombs.

The fact of the lesser penetration resistance capability of separated decks when compared with a single solid armor plate is commonly expressed by de Marre's formula, in which the impact force required for penetration, if all other conditions remqin unchanged, increases with the increased thickness of the armor plating by a power of 1.4 of the plating thickness. Besides figures on the thickness of each successive deck, the table also gives the equivalent armor plating thicknesses (in one solid plate) calculated by de Marre's formula. This thickness equivalent is thus less than the sum of the thicknesses of the individual decks and had been used as the determining factor in all penetration tests carried out with bombs fired from a gun barrel, which tests were now to be replaced by actual bombings of the test target with armor-piercing bombs.

The other columns of the table show the types of bombs prescribed in tactical instructions for use against ships, together with their penetration-hardness, the impact velocity

32 velocity required to achieve penetration (at impact angles of less than 60°) and the [illegible] xxxxxxxx altitude needed for that impact velocity (rocket-accelerated bombs could also be released, without rocket propulsion, in high altitude attacks).

Apart from the He-177, which was hardly used in front line combat, the bomb payload of German bombers was restricted to 5,500 pounds.

Here, the British Royal Air Force had an advantage in its Lancaster bomber, which could carry up to ten tons with a reduced striking range. In 1944, for example, a near hit with a Medium Capacity bomb of 12,000 pounds, carrying an explosive charge of 2.4 tons sank the German battleship Tirpitz.

In contrast, the British battleships Prince of Wales and Repulse at Singapore were not sunk by single hits but rather by a number of torpedos delivered on target ~~by~~ in a series of air attacks after their AA batteries had been put out of action by fragmentation bombs. Roughly ten hits with air-delivered torpedos were also needed to sink the gigantic Japanese battleships Yamato and Musashi, and that after these ships had received 5 and 15 direct hits, respectively, with American armor-piercing and semi-armor-piercing bombs with a caliber of 1,000 pounds.

Wartime eoperience showed that even medium-caliber

83 mine-type bombs could serve to sink smaller types of warships. Thus, the German destroyer Leberecht Maass, with a displacement of 1,625 tons, was sunk by a single SC-50 mine-type bomb in an attack by a German reconnaissance plane which mistook it for an enemy naval unit.

In the English Channel in Junly 1940 2 bombs struck a British light cruiser of the Leander Class midships and aft. The cruiser caught fire and exploded two hours later. By mistake the fuses of the two bombs, an SC-250 and an SC-500, had been set at "non-delay," otherwise the ship would have sunk immediately.

At Crete in May 1941 the heavy British cruiser York, of 8,250 tons, was attacked with SC-250 and SC-500 bombs with delayed action fuse setting and sustained such serious underwater damage that it had to be put on the beach in Suda Bay. The cruiser's gun turrets continued participating in the battle for the Isle of Crete, for which reason dive bombers took them under attack and subdued them. In a few bombing runs the dive-bombers destroyed the turrets, the bomb explosions blowing the turret covers completely off, lifting the 203-mm guns out of their mounts, and setting the cruiser's oil bunkers on fire.

At this point mention must be made of two additional items fixed to the high-explosive bombs for use against ships. These
84 items were the so-called point rings and the impact plates. The first were designed to prevent bombs released from high

84 rebounding to the surface when they struck water and consisted of a wrought-iron ring with triangular corss-section, which was fixed near the middle of the ogivale front section of armor-piercing and mine-type bombs; it produced a bubble around the bomb, causing it to travel in a straight line under water and insured that the bomb would detonate at the proper depth. The impact plates and discs were used in low-altitude bombing and prevented the bomb from bouncing off the water surface, in doing which they had often bounced right over the target. The plates and discs were also used occasionally in the bombing of targets on land, such as concrete surfaced highways, etc.

83a/1 Supplementary to pages 317-319.

Legend:

Verhalten von Bomben ohne und mit Kopfring beim Eindringen in Wasser = Behaviour of bombs, without and with point rings, on entering water

XXXXXXXX

Aufschlaggeschwindigkeit 200 m/sec. = Impact velocity 200 meters per second

Wasseroberflaeche = Water surface

Meter Wassertiefe = Depth under water in meters

Bahnverlauf unbestimmt = trajectory indefinite

83a/2 Supplementary to pages 317-319.

M. 1:5 = Scale 1:5

Prallplatte und Anwendung der Prallscheibe = Impact plate and use of the impact disc

E.Az hr. (38) = Electrical impact fuse hr (38)

Schwerpunkt (ohne Platte) = Center of gravity (without plate)

Prallplatte aus Stahlguss gegen Ziele zu Land = Point plate of cast steel for bombing of targets on land

Prallscheibe geschweisst, nur 300 ⌀, gegen Schiffsziele = Point disc, diameter only 300 millimeter, welded, for bombing of ships

M. 1:1000 = Scale 1:1,000

Ohne = Without

mit = with

Scheibe = disc

Bombenbahn = bomb trajectory

Detonation nach 5 Sek. = Detonation after 5 seconds

10 m, 20 m = 10, 20 meters.

CHAPTER II

SPECIAL TYPES OF BOMBS

1. Chemical Bombs. During the German advance into Soviet Russia, several hundred modern gas spraying apparatuses with a capacity of 300 liters had been found in supply dumps of the Soviet air forces, a fact which caused serious concern in the German Air Force Operations Staff.

The only actual combat gases found were a few barrels of very fluid dichlorethylsulphide. No gas bombs were found in captured stoxks although captured regulations contained mention of numerous types of such bombs in calibers from 33 pounds to 200 liter, with various fillings.

In the matter of the conduct of chemical air warfare the Soviets apparently still adhered to the views held at the time of Russo-German cooperation in this field in the 1929-1931 period; the showed a clear preference for gas dispersion with spray equipment, while the German Air Force had adapted itself completely to the use of chemical bombs.

The German Air Force Inspector of Gas Defense drew attention to the superiority of spray equipment if the intention was to ~~infect~~ contaminate large areas, which would have been uneconomical with gas bombs. He demanded the development of similar spray equipment against the eventuality of the Air Force at some future date possibly being required to execute

Ch.II/1 missions of this kind. Owing to the difficulties which this would have involved for the ground organization, which under wartime supply conditions was already strainied to the utmost, however, the Air Force Operations Staff was even less inclined to follow this recommendation than it had been prior to
2 the war. The Operations Staff ordered adherence to the gas bomb principle and that gas bombs were only to be used as a means of retaliation in the event of the enemy commencing gas warfare.

A compromise solution was finally reached by adapting the captured Soviet-Russian VAP-500 gas spray equipment for suspension in German aircraft, which was possible with only a few alterations. One exercise was carridd out in the use of these gas sprays, with the filling taking place at tactical air fields, and produced a whole series of practically insoluble problems.

Later in the war xxxxxxxx VAP 500 and similar smaller capacity gas spray tanks were also used by the Soviet forces as fire sprays, a filling of finely diffused phosphorus being sprayed from low altitudes over German moving columns, battery positions, and similar targets. Although phosphorus, similarly to Yellow Cross (Mustard) gas, has a caustic effect on the skin of live targets and develops toxic gases, this use by the Russians was not considered as constituting commencment of gas warfar

2 gas warfare.

Also later during the war it was revealed by a Polish General returning from Soviet captivity, that the Soviet forces in the field also had supplies of a new type of gas, dichlorforoxym (code name"Kanton") besides the known gases Adamsit, Phosgene and Mustard Gas.

On the German side during the war, emphasis in the procurement of gas bombs shifted from the slow-acting mustard type of gas to the immediately effective gases affecting the nervous system, namely alkylfluorphosphomat, which was further developed under separate designations as Trialon 83, Tabun, and Sarin. Being so highly volatile, these gases were not suitable for spraying and the standard German gas bomb 3 casing, the KC-250 was too large. The large filling of a bomb of this caliber produced a very dense concentration in the immediate area of impact and allowed the enemy personnel not in the immediate vicinity time to fit on gas masks.

Plans therefore provided for small nerve gas cannisters with a content of 5 liters, which could be packed in bomb containers in a manner similar to the small types of incendiary and explosive bombs; this would have made it possible to suddenly contaminate large areas.

Altogether roughly the following quantities of gas bombs were filled in Germany during World War II:

Ch.11/2a Photo

Soviet Fire Spray Apparatus SAP 500
(without Phosphorus Cylinder (12) VAP 500)

Gas Container

Gas-Bomb Type	Weight in Kilograms	Fuse Type	Contained	Ring Marking	Number of bombs filled
KC-250-gb	150	(15)	70 liters summer Mustard Gas	1 yellow	30,000
KC-250 I-gr	140	(26)	70 liters winter Mustard Gas	1 green+ 1 yellow	10,000
KC-250IIgr	130	(26)	60 liters Phosgene	1 green	15,000
KC-250IIgb	150	(9)	70 liters viscuous Mustard Gas	2 yellow	10,000
KC-250 w	150	(9)	80 kilograms Chloraecetophenon	1 white	5,000
KC-250IIIgr	140	(55a)	70 liters Trilon, etc.	2 green	25,000

Owing to the risk of leakages, the almost 100,000 gas bombs thus held in stock had to be kept under constant supervision; this was a laborious process and almost 10 percent of the stocks had to be replaced annually. The dichlorethylsulphide contained traces of hydrochloric acid which corroded the containers, and the volatile gases caused such pressures, even at relatively low temperatures, that even thick-walled bomb casings developed leaks.

Another point deserving mention here is that, under instructions from the Armed Forces High Command (OKW), the Air Force also carried out a test with airborne bacteria. In the autumn of 1942 a Ju-88 plane was dispatched for this purpose from the designated tactical base to the Greifswald airfield. The plane carried two suspended chemical tanks previously filled on the Isle of Riem with a fluid containing

ant
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hra

anthrax bacteria. (For some time past a bacteriological station on the Isle of Riem had been carrying out research on animal diseases). The plane proceeded to over an island in the Gulf of Riga, on which there were a large number of experimental animals, and released the fluid from a low altitude. The crew had not been informed concerning the purposes of their test flight and no other observers from the Air Force were present. All that could be ascertained later was that the experiment had produced biologically positive results.

2. Incendiary Bombs. In World War I both opposing sides had made only small use of incendiary bombs, and the few used had usually been of relatively large caliber, weighing between 22 and 55 pounds each; these had been filled with highly viscuous oils and pitch ignited after impact by a thermite heating element. The naptha bombs used by the Soviets in World War II corresponded to this type of structure.

Incendiary bombs of the above type usually penetrated through the attics of buildings and set the lower premises on fire. It was anticipated at the time that the dense fumes produced by the combustion of the highly molecular carburetted hydrogen substances would act as a deterrent on firefighting personnel unless they wore protective masks. The results produced were smaller than those of explosive bombs.

In 1917 the firm of Griesheim-Elektron suggested that this newly developed magnesium-copper alloy should be used to produce small incendiary bombs to be dropped in masses. In view of the high temperature of burning 'elektron' it was suggested that the heat would be concentrated at the point of penetration without being lost through dispersion over a large area.

A bomb weighing 1 kilogram (2.2 pounds), with a diameter of [illegible] millimeters and a length of 350 millimeters in the form of a cylindrical rod was found adequate to set attics on fire. A 200-gram filling of thermite melted the casing at impact and ignited it. Stabilization [illegible] particular difficulties as long as the rounded nose section was retained; it was only when the fact became evident that the sharp edge of a flat front surface had a more stabilizing effect that the actual stabilizing surfaces that it became possible to reduce the overall length of the bomb to about one-third of its original length.

In the summer of 1918 the large units of the 3d Bomber Wing received equipment to carry a few thousand 1-kilogram ~~xkx~~ electron bombs and Lieutenant Colonel Siegert, at the time Inspector of Air Forces, drafted the tactical order, predicting that the effect of the numerous small fires started would be to produce what was called a "fire storm," something which actually happened as a result of large-scale attacks in World War II. However, the German Emperor forbade the use of electron incendiary bombs and the planned mass bombing of Paris was cancelled.

At the beginning of World War II all bombing attacks were directed against military or militarily important targets, such as airfields, armament factories, and traffic centers, which were more vulnerable to attack with explosive

6 than with incendiary bombs. During the Battle for Britain also, explosive bombs were more generally used and the German Air Force achieved only partial and chance success in the use of electron incendiary bombs, which had meanwhile been given an iron nose part. This failure to achieve any real success was due both to navigational difficulties in finding the targets at night plus the strong British defenses and XXXXXXX to the wide field of dispersion of the small bombs when released from high altitudes as well as to the small concentration achieved with the first bombing containers used. The

7 practice of including a small disintegrator charge in the incendiary bombs, first introduced by the Royal Air Force and later copied by the German side, was a measure of doubtful value, since the blast effect of these explosive charges frequently extinguished fires which were just starting. Later, even explosive heads with a considerable fragmentation effect failed to deter experienced air raid protection personnel in their fire fighting activities.

The British Inc-4-lb incendiary bomb corresponded in its effectiveness roughly to the German B-1.3-E bomb, except that it had a slightly greater penetrating capability. The steel head was poured into the electron, the base igniter remained as safety until release and the hexagonal shape insured tighter packing in the British "Small Bombs Container" than

7 was the case with the German electron incendiary bomb with its round shape. Following the pattern of the British Inc-4-lb-Mark III, a German 2-kilogram (4.4-pound) electron incendiary bomb with an explosive head was also constructed, the head separating from the incendiary bomb proper at the moment of impact and set to explode only a few minutes later, when fire-fighting operations were likely to be in a critical stage. However, this B-2-EZ incendiary bomb came into service at too late a stage to achieve spectacular results in its use.

As the war continued, two trends became evident in the large-scale use then made by the enemy of incendiary bombs in their attacks:

(1). The purpose of preventing fire-fighting activities by the population by concentrating the attack and dropping high-explosive bombs among masses of small incendiary bombs

(2). Intensification of the incendiary effect of the individual bomb by increased calibers and longer burning duration.

Concerning (1) above: In the attack against Luebeck in March 1942, which according to "Bomber Harris" served exclusively for study purposes, 234 aircraft of the Royal Air Force dropped 160 tons of explosive bombs--the majority 2,000-pound High-Capacity bombs--with highly sensitive fuses

8 plus 144 tons of smaller caliber incendiaries, the result being that the larger part of the central city was destroyed by fire. The attack was conducted in waves following each other at short intervals, forcing the population into their cellars for almost a whole hour, so that it was too late to extinguish the fires by the time they could start.

Concerning (2) above: Since most attics had been cleared of rubble, the incendiary effect of the small-caliber electron incendiaries gradually proved inadequate. To set fire to dwelling houses it had become necessary to secure greater penetrating capabilities, meaning that efforts had to be made to increase bomb weights. Efforts to secure longer burning duration by the use of heavy oils and textiles failed. A new method was indicated by the Inc-50-lb fire canister filled with a thickened petrol/benzol mixture with a phosphorus additive, used by the Royal Air Force against targets in the Rhineland for the first time. These were genuine fuse-less petrol canisters which burst at impact and splashed out their contents, which ignited on contact with the phosphorus additive and with air. Hiwever, the canisters had a small penetrating capability, and it was only the Inc-250-lb canister introduced later which penetrated deeper into houses and produced fires which the civilian ARP forces were unable to extinguish. In response to orders, the German side copied these canisters, designating them Brand C-50 and Brand C C-250.

Initially, both the British In-250-lb and the German Brand-C-50 and Brand C-250 canisters used rubber as a thickening agent, until it was found that artificial resin added in very small percentages served the same purpose. Combustion was secured by means of a black-powder charge or by means 9 of phosphorus. Magnesium powder and nitrates served to increase the temperature generated at combustion.

Napalm, which later became so widely known, was actually a mixture of sodium and palmine acid, which served to thicken the incendiary fluid and intensify the burning ~~XXXXY~~ temperature. The original designation was retained at a later stage, when socalled aluminum soaps were used to thicken the incendiary fluid.

In spite of the greater incendiary effect of the large-caliber fire bombs it still proved impossible with them to achieve within the target area a lateral density great enough to produce fire storms within cities; the local results - achieved with them were smaller than those achieved with explosive bombs of the same calibers and finally they were used only ~~against~~ in low-level attacks against isolated targets and with ~~delayed~~ a brief delayed action to insure that they would penetrate into the target.

9 The most appropriate size for xxx fire bombs of this kind, with a fluid filling, proved to be between 22 and 33 pounds, corresponding to a filling of 4 to 6 liters, such as the British Inc-30-lb and the German Brand-10 bombs. Bombs of this size were capable of breaking through the roof and one or two ceilings of a house , the incendiary fluid being ejected rearward and ignited during the fall, usually in more than one floor of the building. The burning flakes adhere to walls and doors and owing to the closed in heat the fire spreads upwards, whereas the electron bombs frequently only burned holes in the ceilings, in which the fire spread sideways. On the other hand, it was possible with the latter to achieve a multiple hit density, with correspondingly greater chances of producing fires of catastrophic proportions.

10 An interesting point is that the USAAF, besides copies of German and British electron incendiaries of small calibers used only an Inc-100-lb incendiary bombcontaining gasoline without a phosphorus additive but with a relatively large explosive charge.

The Soviet air forces carried in their stocks both the old 22- and 50-pound types of naphtha-thermite incendiary bombs as well as 2.2-pound electron and 5.5-pound thermite incendiary bombs, the latter probably in order to economize in electron.

9a Supplementary to page 332

Diagram

Incendiary bomb "Brand 10.

1070 millimeters
545 millimeters

115 / 3 Diameter 115 millimeters

For special purposes both opposing sides developed special types of incendiary bombs and other incendiaries.

The German fire bomb, used in the bombing of large-are targets, only produced worth-while results in low-altitude attacks, for which electron bombs could not be used, and were soon replaced by the C-50 and C-250 incendiary bombs.

In the first years of the war, Royal Air Force units attempted to set fields and forests on fire by what were called incendiary discs. These were ten centimeters square and one centimeter thick, including anXXXXXX inserted rubber layer and two pills of white phosphorus. The discs had to be kept under water, wigether with which they were poured from buckets through an opening in the bottom of the plane.

Although the results obtained with these discs were completely out of proportion to the effort expended, they had to be copied by the German Air Force in response to orders. Small celluloid containerswith a filling of parafin and sawdust and bach between 1200 and 1400 of these German incendiary discs were packed into the sheet metal XXXXX casings of the C-500 XXXX fire bomb and stored in cold temperature stabilized solution of spirits and water. A time fuse set at between 3,300 and 6,600 feet above the target spread the contents of the C-500 Fire-scatter Bomb (*Streubrandbombe C 500*) over an area of 10 to 12 square kilometers and the adhesive phosphorus pills served to ignite the

10a Supplementary to page 334.

Diagram

Legend:

Brand C 250 = Incendiary Bomb C 250
Luftraum = Air space
Aufhaengeoese = Suspension eye
El.Az 25 B = Electrical impact fuse El.Az 25 B
Glasampullen mit Phosphor = Glass ampules containing phosphorus
Verdammung = Capping or tamping
1100 = length 1100 millimeters
200 ø = Diameter 200 millimeters

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10b Supplementary to page 334.

Legend:

Brand C 250 = Incendiary bomb C 250
Leitwerk 45° versetzt gezeichnet = Steering surfaces shown transposed by 45°
Blindstecker = Dummy plug
Luftraum = Air space
Aufhaengeoese = Suspension eye
El.Az 258 = Electrical impact fuse El.Az 258
kz.Zladung C/98 = Short igniting charge C/98
Verdammung = capping or tamping

11 incendiary containers with a delay of several hours or days according to atmospheric temperature and moisture.

Owing to the lack of worthwhile targets in England, however, no use was made of the scatter fire bomb, after its proper handling and satisfactory functioning had been secured at great expenditures.

Bombs with a combined blast-incendiary effect were also tried repeatedly, but proved unsatisfactory. The Royal Air Force started with its Inc-120-lb bomb, used in high-altitude bombing of industrial installations in the Rhine-Ruhr region. After impact, this bomb ejected rearwards ten electron discs, each weighing about 2.2 pounds, which were to spread out in the target, and finally the explosive charge of the bomb detonated.

The German Air Force lacked an incendiary bomb suitable for low-altitude delivery on target during the winter 1940-41 drive to disrupt production by the British armament industries. Due to dissatisfaction at the target results obtained with fire bombs, the "blast-incendiary bomb C-50 (Sprengbrand C-50)" was developed; at impact, this bomb ejected roughly thirty B-1-E electron incendiary bombs while the rest of the bomb penetrated farther into the target to explode three seconds later. The purpose was to provide an air draught for the fires by shattering roofs and windows.

11b

Diagram

Supplementary to page 336.

Legend:

Sprengbrand C 50	=	Blast+Incendiary Bomb C-50
Grosser Elektron-koerper	=	Large electron element
Pulverscheibe	=	Powder disc
Kl. Elektronkoerper	=	Small electron element
Treibladung	=	Propelling charge
Sprengstoff	=	Explosive charge

12 The Soviets also tried out mine-type bombs with a caliber of 220 pounds with incendiary additives. These were the ZAB-100-ST and the ZAB-100.TSch, which spread thermite balls in a wide radius, but both produced small results.

Obviously, it is not a paying proposition to introduce complicated designs for a combined blast-incendiary effect. The simultaneous delivery of the German C-50 incendiary and SD-50 explosive bombs produced better results than the combined C-50 blast+incendiary bombs or similar bombs used by the opposing side.

15 3. Multi-Purpose Bombs. Up to shortly prior to World War II, the German system made a clearcut division ~~bet~~ in the matter of explosive bombs between the small 22-pound fragmentation bomb, the 110- to 1,100-pound mine-type bomb, and the 1,100 armor-piercing bomb, with a decided emphasis on the mine-type bomb due to experience in World War I.

British explosive bombs, in contrast, all belonged in the class of multi-purpose bombs with calibers ranging from 40 to 1,000 pounds if one disregards a 20-pound fragmentation bomb, which was never used, and armor-piercing and semi-armor-piercing bombs in calibers of 250 to 450 pounds.

British General Purpose bombs had thick casing walls of cast steel with an explosive charge only 30 percent of the bomb weight, while the German counterparts, the SC bombs, had thin-walled drawn metal casings and carried roughly 50 percent explosives. This fundamental difference was largely due to the manufacturing facilities available: Britain had older machinery manufacturing plant in which cast-metal manufacturing processes predominated, while Germany was able to rely, in the manufacture of bombs, on more modern installations using pressing and roller processes.

In World War I the American air forces had adopted the British types of bombs, but had meanwhile converted to the German classification and had a Frag 20 lb as well

1> 1[illegible]0- to 2,[illegible]0-pound demolition bombs, the latter also with rollered casings and roughly 50 percent explosives.

A remarkable feature of the first years of warfare was that the German Air Force copied the British bomb types while the British Royal Air Force copied the German mine-type bombs.

As early as the beginning of 1939, however, Germany had already introduced a thick-walled 110-pound explosive bomb, the SD-50, for use against aircraft on the ground, refraining initially from the use of 22-pound fragmentation bombs because of the greater simplicity of the bombing equipment required in the bombers when using other types. In its effects, however, the SD-50 was actually a fragmentation bomb since its XXXX 35-pound explosive charge did not produce a blast effect adequate against buildings, even the 53-pound (24 kilogram) of the SC-50 mine-type bomb being too small to destroy normal types of buildings. The SD-50 nevertheless remained designated as a multi-purpose bomb because it had an explosive charge of roughly 30 percent while normal fragmentation bombs xxx carried only about 10 percent explosives (the SD-10 9%; the Frag 20 lb 14%).

The development of the German SD-250 and SD-500-A multi-purpose bombs has already been discussed (Part A, 14 Chapter IV, 2, and Part B, Chapter [illegible], 1); Besides their fragmentation effect, these bombs could also be expected to have an adequate blast effect to damage solid walls, so that they were proper multi-purpose bombs. The identifying symbol "A" was adopted because in the first version of this bomb, the SD-500, the weight (1,180 pounds) and the dimensions had exceeded specifications and caused loading complications in certain aircraft, for example, the Me-210, of which great results were expected. This had necessitated development of a smaller bomb, the SD-500-B, in the manufacture of which use was made of the swages and patterns for the PC-500 semi-armor-piercing bomb, a bomb no longer in production because larger types had meanwhile become available. However, the explosive charge of the SD-500-B was only 20 percent, a disadvantage which had to be accepted as unavoidable.

The SD-1700 multi-purpose bomb has also been discussed previously, particularly in the chapters dealing with the effect of bombs on warships; in this case the classification of "Multi-Purpose" was applied to denote a combination of high penetrating capability with a high blast effect, although the SD-1700 had an explosive charge ratio of 41 percent and actually only represented a mine-type bomb with an increased degree of hardness. It is only natural that the SD-1700 could not bear comparison with German armor-piercing or even with the British and American semi-armor-piercing bombs; with an explosive charge making up 20 and 30 percent, respectively, of their weight, these were capable not only of piercing actual armor-plated decksbut even presented good prospects of sinking cruisers, aircraft carriers and older types of battleships, and it is regrettable that the command agencies underestimated them so seriously.

As will be seenfrom the attached sketches (pp.343-347) Britain had various versions of the 250-pound and 500-pound GP bombs, probably due to the necessity to make allowances in the specifications for the various factories in Britain and America; the explosive charge ratios varied between 18 and 31 percent of the bomb weight. Another GP bomb, the GP 1900 lb was added in 1941, followed later by yet another, the GP 4000 lb.

The effectiveness of the German mine type bombs used in the bombing of targets in Britain in 1940-41 which led to the British gradually replacing their old type GP bombs with MC and HC bombs carrying explosive charges making up between 50 and 70 percent of their weight.

The British and American semi-armor-piercing bombs, also shown on the attached sketches for purposes of comparison, do not differ very much in appearance from a type of

14a Supplementary to pages 341-342.

Diagrams

Legend:

Mehrzweckenbomben I = Multi-Purpose Bombs I

Kaliber (kg) = Caliber in kilograms

Benennung = Type designation

Sprengladung = Explosive charge in kilograms

Schaubild = Diagram

200 etc ∅ = 200 etc. millimeter diameter

Durchschlagsleistung fuer Panzerstahl bei mindestens 60% Aufschlagwinkel/Horizontalflug = Penetration capability in armor plating at minimum impact angle of 60°/Release in horizontal flight

45 etc m. = 45 etc. meters

Splitterzahl ueber 5g = Fragmentation count (above 5 grams)

2000 etc. Stck = 2000 etc.

Mittleres Splittergewicht = Average fragment weight

Bemerkung +) in Ausfuehrung) fuehrung) = Footnote: + Under development.

1be Supplementary to pages 341-42.

Legend:

Englische Mehrzwecke-bomben = British multi-purpose (General purpose) bombs

Muster = Type

Auftreffgeschwindigkeit. Panzerdurchschlag = Impact velocity. Penetration capability in armor plating

200 m/s, etc. = 200 meters per second, etc

41 mm, etc. = 41 millimeters, etc.

Gewicht: (kg) = Weight in kilograms

Sprengladung: (kg) = Explosive charge in kilograms

Engl.Zdr.Nr = British fuse number

15b Supplementary to pages 341-342.

Diagrams

Legend:

Englische Halbpanzerbomben = British semi-armor-piercing bombs
Muster = Type
Auftreffgeschw. : Panzerdurchschlag = Impact velocity Armor piercing capability
200 m/s, etc. = 200 meters per second, etc.
90 mm., etc. = 90 millimeters, etc.
Sprengladung (Kg) = Explosive charge in kilograms
Gewicht (kg) = Weight in kilograms
Engl. Zdr. Nr. = British fuse number

15c Supplementary to pages 341-342.

Diagrams

Legend:

USA-Panzerbomben = USA armor-piercing bombs
Muster = Type
Auftreffgeschwindigkeit Panzerdurchschlag = Impact velocity Armor piercing capability
200 m/s, etc. = 200 meters per second, etc.
51 mm., etc. = 51 millimeters, etc.
Gewicht (kg) = Weight in kilograms
Sprengladung Kg % = Explosive charge in kilograms and percentage of bomb weight

11d Supplementary to pages 241-242.

Diagrams

Legends :

USA-Minenbomben = U.S.A mine-type bombs

Muster = Type

Gewicht: kg = Weight in kilograms

Sprengladung kg) = Explosive charge in kilograms and
%) in percentege of bomb weight

15 multi-purpose bomb, and this applies particularly to the American types, which were also used in low level attacks
16 against highly resistant targets, against which use of the demolition bomb appeared unsuitable in point of penetration capability.

It is of interest that the USAAF from 19 4 on designated its demolition bombs "Purpose Bombs", meaning that they were suitable for various methods of use: without delayed action to produce fragmentation and blast effect; with delayed action fuse to produce blast effect within the target or underground.

During the latter years of the war, the Royal Air Force developed "Deep Penetration Bombs" in calibers of 12,000 and 22, 00 pounds, carrying a 42 percent explosive charge. The British version of these bombs was designated MC Bombs, the American version SAP bombs.

As the war proceeded, the German Air Force Command raised the following objections to the German SD- and PC bombs:

1. The blast effect of the SD-50 was considered inadequate;

2. the caliber of the PC-500 was too small;

3. the hardness of the SD-500-A was not commensurate with the expenditure involved;

4. the performance of the PC-1000 was inadequate.

16 The following measures were ordered to remedy these defects:

Incorporation of the features of the SD-50 and SC-50 to for the SD-70 bomb,

Use of remaining stocks of SC-500 as multi-purpose bombs.

SD-500 to be produced henceforth only in the "[illegible]" series.

Furthermore, the PC-1000, of pressed alloyed steel, which had too thick a nose and therefore was difficult to ~~xxxxx~~ temper right through, was taken out of production and replaced by a new bomb, the SD-1000-A multi-purpose bomb, the casing of which was from ordinary pressed steel. This latter bomb carried an explosive charge 25 percent larger than that of the PC-1000 armor-breaching bomb and had an adequate penetration hardness for use against heavy cruisers.

17 As late as in 1943 plans provided for increased performances of the large caliber multi-purpose bombs, and the new SE-500 and SE-1000 were developed for this purpose and preparations were made for their production. However, although the casings of these bombs were not of steel alloy but rather of seamless tubing produced from normal steel by the Mannesmann crossroll method, the bombs were more in the nature of armor-piercing bombs. The explosive charge space was so arranged that charges of hexogen pressed with 5 percent mineral wax in a phlegmatized state could be filled in cold. This

1\. not only simplified the filling but at the same time gave increased effectiveness, since hexogen was estimated to have a blast effect one-third greater that that of trotyl, in addition, at this stage of the war synthetic explosives were more readily available than nitrated. As will be seen from the attached tables, the armor-piercing capabilities of the SE bombs increased quite considerably when compared with those of the SD bombs in the same caliber class.

From the sequence of development it is obvious that there was no justification for multi-purpose bombs with an explosive charge ratio of roughly 30 percent and that the orders from the Air Force Operations Staff to copy the British GP bombs was due to an over-estimate of the effectiveness of the enemy bombs.

The soundest sub-division of explosives remains the classification in fragmentation bombs up to a maximum caliber of 220 pounds; mine type bombs for general purposes in calibers ranging from 220 to 2200 pounds; armor-piercing bombs in calibers from 550 to around 11,000 pounds; and super-caliber bombs approximately from 2200 pounds upwards. The US Air Force quite clearly drew this logical conclusion after the ebd of the war.

17a Supplementary to page 349

Diagrams

Legend:

Kaliber (kg)	= Caliber in kilograms
Muster	= Type
Sprengladung (kg)	= Explosive charge in kilograms
Schaubild	= Diagram
Splitterdichte (m)	= Fragmentation count per meter
Panzerdurchschlag (mm)	= Armor piercing capability in millimeters
(180 m/s) etc	= Impact velocity 180 meters per second.

4. *Hollow-Charge Bombs.* In the 1880s an article appeared in the *Zeitschrift fuer Schiess- und Sprengstoffwesen* written by a certain Dr. Neumann (Westfaelische-Anhaltische Sprengstoff AG--Westphalia-Anhalt Explosives Ltd.) and dealing with the control of blast direction at detonation (*Richtungsgebung bei der Detonation*). A remarkable fact is that this explosive effect was not exploited in World War I.

In Italy, the name of the inventor was perpetuated in the designation of *Effeto Neumann* given to the principle; the expression used in Germany is *Hohlladung* (hollow charge), in France *Charge creux*, in England "shaped charge," and in *Russia Akkumulativni effekt*. Apparently, an inventor named Munroe lived in the USA at the same period, after whom the principle is named there.

The first military use made of hollow charges was in the German capture of the Belgian frontier fortification of Eben Emael, airborne troops landing on the tops of the fortification works and blasting the armor-protected cupolas by means of engineer hollow charges.

Then followed a long pause in the use of hollow charges. As in the case of rocketry development, which remained a monopoly of the Army Ordnance Office in terms of a Wehrmacht High Command distribution of functions plan until the Air Force in 1938 secretly assigned contracts in this field to the [illegible]tall

18 the firm of Rheinmetall in Duesseldorf, all work on the development of explosive charges based on the hollow-charge principle had been assigned to the Army.

In the matter of hollow-charge artillery shells for anti-tank action the interests of the Army and the Air Force coincided. For many years the Army Ordnance Office endeavored to development means to use its light infantry guns with hollow-charge ammunition for anti-tank purposes and finally developed
19 what was called the attachable missiles (<u>Aufsteckgeschosse</u>) after finding that the rotation of artillery shells precluded any possibility of achieving a hollow-charge effect and that the penetration capability of hollow-charge ammunition depended on the diameter of the missile.

In the spring of 1942 the Air Force also secured independence in the matter of the development of hollow charges for bombs, but as a result of the normal working procedures of the Army Ordnance Office no armaments producing firm was in a position to take on the necessary work, so that the Air Force was compelled to do the necessary development work itself in order to save time.

Work began with normal 550- and 1,100-pound explosive bombs, the front of the explosive charge being hollowed out in efforts to increase its penetration performances. The unprocessed SD-250 and SC-500 bombs were taken as they came

13 from production and their points were reshaped according to the desired effect, as shown in the "HOLLOW-CHARGE TABLE" on page 354. The hollow can be either conical or hemispherical in shape and just as little was known at the time on the subject of which shape was better for specific purposes as on that of sheet metal lining used in some hollow-charge bombs to line the cavity. Generally speaking, the cone shape was used for small calibers and ~~when~~ the bomb was intended to penetrate only one layer of armor plating, as was the case in the SD-4.Hl antitank bomb developed later. In bombing warships, however, the bomb had to penetrate a number of decks, for which reason preference was given to the hemispherical shape in the SD-250-Hl and the SC-500-Hl after a number of successful blasting experiments.

The SD-250-Hl was to detonate without delayed action and destroy or damage the ship's superstructures through fragmentation; at the same time it was to have an effect in depth, its combusting gases penetrating through the decks to ignite the oil and ammunition below decks. However, it was realized from the outset that in the case of ships with high superstructures the bomb would detonate at a distance from the armor deck too great for the desired effect. For this reason the SC-500-Hl was designed to detonate with a short delay.

19a **Supplementary to page 253.**

Diagrams

Legend:

Durchschlag = Penetration capability
Splitterzahl = Fragment count per square meter
Panzerstahl in mm = Steel plating in millimeters
Loch ⌀ in mm = Diameter of hole in millimeters
Beton = Concrete
o.V. = Without delayed action
m.V. = With delayed action fuse

The massive point of the SD-500-Hl penetrated through 30 millimeters of armor plating of the upper decks and the bomb detonated somewhere between decks. The bomb blast could penetrate the armor plated deck with a thickness of up to 60 millimeters only if it exploded at a distance of approximately 4.3 feet, and the difficult problem was to secure this precise burst point.

In the summer of 1942 an old type French cruiser was hauled high onto the beach during spring tide in the mouth of the Gironde River to serve as a target, Do-217 bombers of the Bomber School at Cognac delivering the bombs on target in dive attacks.

Further developments disregarded existing bomb types because of the limitation of their effectiveness and new large-diameter hollow-charge bombs were constructed to secure maximum penetration performances.

In the case of the SHL-500 and SHL-800 due consideration was given to the dimensions of the SC-2000 mine-type bomb and of the SB-2500 superbomb in order to be able to use the new hollow-charge bombs in the normal suspension installations, but althought having the same diameter, the hollow-charge bombs were only approximately half as long.

It took more than a year to produce the test hollow-charge bombs mentioned, because the development was not given a high priority in the armament program and because of the difficulties encountered in the procurement of armor plating for the tests.

To fill the gap experiments were carried out with what were called a "false bomb nose" (*Bombenvorsatzkoepfe*) to pierce through first layer of armor plating in order to secure greater effectiveness within the target for the normal explosive bomb behind the "false nose." These devices are shown in the BVK-70 and BVK-250 in the Hollow-Charge-Bomb table on page 354.

As an initial step experimental detonations served to show how the actual bomb could be protected against the blast effect of the false nose by layers of wood; these were followed by experimental detonations with actual hollow-charges with flat dish shaped cavities, as was the case with the BKV-250. No actual bombings were carried out with the BVK type bombs because of the lack of suitable targets, but the breaching capabilities are listed in the table. In comparing the BVK-250 With the SD-250-Hl, the advantage of the former is that it carried a 176-pound explosive charge to explode inside the attacked ship.

Numerous experimental detonations of hollow charges had by this time revealed the influence of the lining on the piercing capability; in contrast with the former charges, designed to pierce only one steel plate, a special charge was

21 then developed which was later designated the "distant-shot hollow charge--Jeitshhuss-Hl". This charge was not designed to explode on the surface of the target and pierce a hole approximating its own circumference in the armor plating; instead, a proximity fuse was to detonate it at a set distance from the target surface. This distance was approximately one-and-one-half times the diameter of the hollow charge. The shape lining was no longer of thin metal plate but was several centimeters in thickness; the hole pierced was relatively small but extraordinarily deep so that it

22 could be hoped that a large hollow-charge bomb detonating at the surface of a target, for example, on the upper deck of a warship, could pierce through the armor-plated deck several yards lower down.

Consonant with the most important targets for attack with hollow-charge bombs from 1943 on, a small SD-4-Hl anti-tank bomb with a cone-shaped lining and a "distent-shot " hollow-charge bomb, the SHL-4000 were taken under developmentt

The previously mentioned SHl-500 and SHl-800 were merely preliminary versions of the SHl-4000. In actual bombings t they were tested on the former Czechoslovakian frontier fortification bunkers, where they showed piercing performances of **frax** 3.5 and 5 meters, greater than any achieved with armor-piercing shells. Used against ~~upright steel plating~~ at ~~a distance of approxima~~tely

22 exploded on the ground at a distance of approximately one meter these bombs pierced a total thickness of 700 and 1000 millimeters, creating apertures with diameters of 12 and 16 centimeters, respectively, in armor steel plating, and this apparently was not a maximum performance. Such thicknesses of armor steel plating do not occur in actual practice, and the test structure was constructed by placing one upon the other steel plates taken from the side armor of the World War I battleship Koenig Albert.

Computing these piercing capabilities by the de Marre armor plating formula, a shell of the diameter mentioned would have required an impact velocity of 1,620 meters per second for the same performance, a velocity which could not be achieved with artillery guns. The larger part of the explosive used in the hollow charges was hexogen ~~and in view of the~~ and in view of the detonation velocity of Hexogen, which is 8,400 meters per second, such velocities for the combustion gases

23 of a shaped charge are quite conceivable. The great piercing performances are achieved because the jet of the exploding gases remains weighted by the iron elements of the lining inside the cavity.

To develop hollow-charge bombs for use against ships it would have been necessary as a next step to carry out experimental detonations with steel plate combinations in in order to determine whether the blast actually penetrates to a depth of between 8 and eleven yards. However, quite apart from the great difficulties encountered in construction of the "armor bombing target" mentioned in previous chapters, supplemented by watertight compartments and inside structures, the period following failure of the dive-bombing tactics was characterized by a complete lack of new bombing tactics, particularly for attack against such well protected targets as warships.

Just at the time when experience with the SH1-500 and SH1-800 hollow-charge bombs became available, came suggestions from the air forces to try out a new method of attack with "Mistel" composite aircraft. In carrying out flat-dive attacks from considerable distances, experienced dive-bomber pilots had switched on their three-plane autopilot gear and used it in their target approach runs. The excellent functioning of this gear in the Ju-88 planes produced the idea using this system to place on target these unmanned bomber planes, of which large numbers were held in depots without any prospects of being put to profitable use. For this purpose a manned single-seater Me-109 fighter was mounted above the fuselage of a Ju-88 with releasable struts.

The fighter pilot then flew this composite plane to within visual range of the target, set the steering on a flat

23 dive from a distance of 10 to 1[illegible] kilometers, thereby giving the Ju-88 the proper target course and slope. At a distance of 3000 to 4000 yards from the ship, and thus still beyond range of the hazardous multiple AA guns, the fighter pilot 24 xxkxxxxxxhix disengaged his plane from the unmanned bomber and changed his own course, while the bomber with its set steering continued on its target course.

Test flights with this arrangements showed only very small deviations from target, measuring roughly 11 yards laterally and 22 yards longitudinally, and thus held out good prospects of success in aiming at the silhouette of an aircraft carrier or a battleship.

The weapons development agencies immediately adapted their activities to these new tactics of attack with bomber aircraft. To fill a Ju-88 plane with a few tons of explosives and explode it against a ship would not have caused much damage to a modern battleship. The ideal solution would have been to explode the large charge under the ship, but subsurface bombs, such as the planned Hs-294, were still a problem in themselves, and it was hardly to be assumed that they would have detached from an aircraft disintegrating on the surface. The same applied to torpedoes, which, in addition, were not suitable for such high launching speeds as 360-420 miles. To attain a high speed commensurate with the

23a

Photo

"Mistel" Composite Aircraft
with SHL-4000 Hollow-Charge Bomb

24 high speed performances of the fighter aircraft, the outer surfaces of the bomb-carrying plane had to be as smooth as possible, meaning that the explosive load had to be loaded inside the plane.

Efforts had to be made to exploit the effectiveness of the hollow charge in composite plane tactics. The center of gravity was very unfavorably situated in hollow-charge bombs, since they lacked the massive nose section of other bombs and had to be at least of four caliber lengths to obtain stability in trajectory; the SH1-800 was thus already 3.5 meters long. The question now was how long a hollow-charge bomb would have to be to insure that even at a flat impact angle its blast effect would reach to beneath the armor plated decks.

25 The solution to this problem was found by turning the entire Ju-88 plane into a bomb: the crew space in the nose was made detachable and replaced by a hollow charge with a diameter of roughly 2 meters and a total weight of approximately four tons. At this juncture all work on other large caliber hollow-charge bombs was halted and all efforts concentrated on development of the SH1-4000, since this new weapon might prove important in action to repel the threatening invasion. The only other item still under development was the SD-4-H1 antitank bomb, since it was urgently needed for the conduct of the war in Russia.

Construction of the test SH1-4000 hollow-charge bomb presented no difficulties, since it required no large machine tools for shaping or for inner structure. The most important item was the lining of the hemispherical cavity in the explosive filling, which in the SH1-4000 was of 40-millimeter metal sheeting. Experience had shown that the lining must be of an easily malleable material in order together with the flame jet of the combusting gases at detonation to form what might be called a stopper of molten metal. Because of its high specific weight, copper would have served the purpose, but the use of copper had to be restricted because it was in very short supply. Instead of copper, therefore, approximately 25 dome shaped caps, each of 1.2-mm sheet iron, were formed into one hemispherical dome under hydraulic presses. The weight of the finished lining was approximately 1 ton. With an explosive filling of 2.8 tons, and an inner framework and outer casing weighing together approximately 440 pounds, the weight of the entire hollow charge was thus 4 tons.

This was just within the center of gravity requirements for the Ju-88 plane without any necessity for additional trimming loaded. The SH1-4000 hollow charge had the same diameter as the aircraft cabin.

Only high explosive fillings are suitable for hollow-charges and in the case of such large calibers must be filled in in the fluid state in order to fit very snugly to the lining. To this end the form was first placed on the dome and heated and the explosive compound, consisting of 60 percent trotyl and 40 percent hexogen was then poured in. Additional hexogen in the powder form was then stirred in, so that hexogen made up 70 percent of the final explosive compound filling.

Initially, each individual part of the new weapon was tested, but the final test had to take the form of a practice bombing of an actual warship. For this purpose, the German Navy made the French battleship Ocean, with a displacement of 25,000 tons, available. This was admittedly an outdated ship, constructed in 1911, but its horizontal protection had been reinforced and brought up to modern standards by the insertion of numerous armor plates.

A great advantage of the airborne SHl-4000 hollow charge was that the composite aircraft team crews could practice so long with a crew in each plane until the three-plane pilot gear of the Ju-88 was properly trimmed to insure the minimum possibility of off target hits.

These target run practice flights took place at AAA range finding posts, with the pilot of the fighter plane initiating the txxx attack by the composite team consisting of an Me-109 fighter and a Ju-88 plane, setting course and slopewith due regard for lead factors, and then XXXXXXXX disengaging the two planes. The crew in the Ju-88 plane only took over control shortly before reaching the target aimed at, rising to fly over the target, and then landed the plane. Once the composite was properly adjusted, the crew cabin was removed from the Ju-88,in the same manner as the maneuver head is removed from a satisfactorily adjusted torpedo and replaced by its warhead, in this case the SH1-4000 hollow charge. For combat commitments, plans provided for the hollow charges to be stored at the tactical airfields and to only move in the aircraft when required, which could have been done within a few hours.

To test the proper aiming of the unmanned and combat armed aircraft as well as the proper functioning of the fuses, a number of exercises were carried out with live charges by planes taking off from Peenemuende and using the Danish island of Möen, opposite the island of Ruegen, as a target. The point of this island projects far into the Baltic Sea, forming a steep chalk cliff almost 100 meters in height, known as the Möens Klint, at approximately mid height of which a target triangle with shanks measuring 15 meters was suspended. In these exercises all planes released scored hits within 20 meters from the center of the target triangle, which amounted to 100 percent hits in an attack launched xxx diagonally ~~to~~ to at the longitudinal axis of a large ship. The surrounding sea in this region was easily kept under observation and the peninsula was easily closed to traffic temporarily, so that only small expenditures were involved in these tests.

Besides shots aimed to strike the target at right angles, some were aimed to strike at an angle of less than 30°, so that the wings of the Ju-88 [illegible] contact the target and even in these cases the igniting contacts of the six No.66 electrical impact fuses in the nose of the SHl-4000 hollow charge functioned satisfactorily. Even if a wing broke off, the automatic pilot kept the Ju-88 firmly on course. The moment of impact was recorded photographically not only from the sea but also by a ~~xtsxskx typsxlixixaxxyixxz~~ vertically installed camera in a Storch type liaison plane flying overhead.

28 In mid-March, and thus barely three months before the Allied invasion in Normandy a final test series was carried out with the SHl-400 hollow charge, ~~in thexfsxtsxxrsxdxtsxx~~ in which the attacking planes took off from Marignane (Marseille) to attack the battleship Océan in the Toulon roadstead.

The first test involved exploding an SHl-400 charge alone against the two forward 305-mm gun turrets in order to test the piercing capability of the hollow charge on this part of a ship.

28a Photo

A SH1-4000 Hollow Charge Placed in Position
for Blasting

28a Photo

Hole 400 millimeters Wide in Turret Wall

28a Photo

25,000 ton Battleship after Bombing
with a SH1-400 Hollow Charge

28c Supplementary to page 364.

Diagram

Legend:

Abwurf und Sprengung SHl-4000 gegen frz. Schlachtschiff Océan (Maerz 1944,Toulon = Detonation of air-delivered and hand-placed SHl-4000 hollow-charge on French Battleship Océan (March 1944, Toulon)

M. 1:1000 = Scale: 1:1,000

Einschlagwinkel = Impact angle

aufgebaute Sprengung = Detonation of placed charge

Totale Zerstoerung trotz Verstaerkung Schiff auf Grund gegangen = Total destruction in spite of reinforced armor plate protection. Ship settled down to ground.

Beide 30,5 Tuerme "A" und "B" wurden durchschlagen und darin die Kartuschen entzuendet = Hollow-charge blast pierced through both gun terrets "A" and "B" and exploded the shells stored there.

"Wandstaerke"423 mm. = Turret walls of 423 mm steel.

Océan = Data on Battleship Océan

Baujahr: 1911 = Year constructed: 1911

XXXXXXX

Bestueckung: = Weapons:
12 x 30,5 cm = 12 305-mm guns
22 x 13,8 cm = 22 138-mm "
7 x 7,5 cm = 7 75-mm "

Geschwindigkeit: 20 Kn = Speed: 20 knots

In contrast with a normal explosive bomb, a hollow charge does not carry explosives to detonate below decks. On the other hand, its highly concentrated jet of combusting gases, carrying particles of metal at white heat is well capable of igniting gunpowder and causing it to explode. For this reason, iron powder cases were placed behind the turret walls in the line of the hollow-charge fire, and these immediately exploded.

The hollow charge pierced both 425-mm wall and the gun cradles and penetrated to a depth of 25 meters until it finally came to rest inside the side armor plating after piercing through 2 meters of steel. The hole caused had a diameter of 40 centimeters, with the hollow charge exploding roughly 2.5 meters from the first turret.

The second test involved a launching as it would occur in actual combat. The Ju-88 struck the target ship's stern at an angle of less than 20° to its center line and approximately the same angle to the horizontal, causing a hole about 20 meters across in the ship's side and piercing through and blasting out one armor plated lateral bulkhead (270-mm steel). Presumably, the shot went through the bottom of the ship, which sank in the shallow water.

Naval experts confirmed the results, namely that the ship was completely destroyed and sunk.

However, the Air Force General Staff was no longer interested in this new weapon, since it was not anticipated that the enemy in the expected invasion would use large naval units but hundreds of small landing craft instead, with a tonnage of only 125 tons. In the final event, battleships did participate in the invasion operations, their guns firing far inland. When this happened, orders were immediately given to prepare 300 SHl-4000 hollow charges for use against these battleships, but this measure came too late, as was the case with so many other measures.

Another type of airborne hollow-charge weapon was under development in 1944, namely the SHl-6000. This was a new departure in the field of weapons and was designed for use in Operation Eisenhammer, a grandiose plane for attacks against all power stations situated in European Russia.

The SHl-6000 had an overall weight of 6 tons and, as in the case of the SHL-4000, was to be placed in the nose of an aircraft, the He-177, a four-engine dive-bomber. Several hundred of these were still held in stock and were entirely unsuitable for the originally intended purpose. This enlarged composite plane team was to consist of an He-177 steered to the target by an attached FW-190 fighter.

The explosive filling of the SHl-600 had a diameter of 2.5 meters and it was designed for use against targets such as trubines and generators; during the war the Russians had placed all such installations under concrete protection with thicknesses of 2 meters, which served to show how important they were for the wartime economy. In retrospect it seems astonishing that the Air Force General Staff conceived the plan to destroy these targets only as late as in 1944, but apparently the hope had still existed of gaining possession of them in an undamaged state and using them to exploit the Russian military potential.

While plans provided for the use of new types of large drift mines, which will be described in the next chapter, to put the Soviet hydraulic power stations out of action, the machinery installations were the target for destruction in the steam driven power stations using peat as fuel in the northern regions of Russia. Experience had shown that only large bomb fragments could put heavy machinery of this type out of action, but it had meanwhile become necessary to reach these targets in their thick concrete protective coverings.

After preliminary trials with small caliber ground weapons using a hollow charge to obtain a concentrated fragmentation effect in one direction (the Diskus and Faustkartaetsche) a flat-dish shape was adopted for the explosive filling, the lining, consisting of approximately 800 steel fragments each weighing 2.5 kilograms arranged honeycomb-wise in 6 centimeter long 8-cm iron hexagons, weighed

Anlage BII
Seite 29

Supplementery to page 367-368.

Diagram

Legend

Schematische Darstellung der Wirkung von SHl-6000 auf Dampfkraftwerk unter Betonschutz = Diagram presenting effect of SHl-6000 hollow charge on steam-driven power station under protective concrete covering

M. 1:1000 = Scale 1:1000

Maschinenhaus = Machine house

2 m starke Betondecke = Protective concrete covering 2 meters thick

800 splitter zu 2,5 kg = 800 2.5-kilogram fragments

Rumpfvorderteil He-177 = Nose section of He-177 plane

Anlage B II
Seite 29

Supplementary to pages 367-368.

Legend:

Diagram

Hohlladung SHL-6000 mit gerichteter Splitterwirkung fuer Anwendung mit He-177 = SHl-6000 hollow charge XXXXXXX with one-direction fragmentation effect for use with He-177 planes

M. 1:10 = Scale 1:10

Aerodyn Verkleidung = Aerodynamic surfacing

Gesamtgewicht: 6 to. = Total weight: 6 tons

Sprengladung ca 4 to. = Explosive filling aoproximately 4 tons

ca 800 Stueck sechskanteisen 80 ⌀, 80 lang zu 2,50 kg Gew. (punktgeschweisst auf 1 cm Einlage) = Approximately 800 8 x 8 centimeter iron hexagons each 2.5 kilograms in weight (spotwelded to 10-mm lining).

Initiierung = Detonating fuse

Zuendabstand ca 2.50 m = Explosion distance from target surface approximately 2.5 meters.

30 altogether roughly two tons.

A test detonation on the ground proved the feasibility of achieving [illegible] results with a weapon of this kind against the targets discussed above, but after the turn of the year 1944-1945 there was no longer any possibility to carry out airborne tests do to use the new weapon in actual combat.

As previously mentioned, the development of a small bomb for antitank action had become just as important a matter as the development of air-carried hollow charges to repel an invasion by the Western Powers. It is necessary at this point to discuss the situation in the matter of antitank air combat.

During the first years of the war fighter planes xxx with their xxxx weapons fire and/light dive bombers with 110-pound explosive bombs had quite frequently destroyed smaller types of tanks. Meanwhile, however, stronger and faster tanks had come into service.

Lieutenant Colonel Rudel used a Ju-87 plane in running up his large score of destroyed tanks; this plane had two 37-mm antitank guns mounted in the undercarriage cowlings, which fired special ammunition with a 20-mm wolfram core. Attempts had also been made at using 50- and 75-mm antitank guns suspended under the Ju-88 plane; the disadvantage here, however, was the slow rate of fire of these guns, which

31 permitted the firing of only one round on each target run.

Using 550-pound explosive bombs armed with non-delay fuses dive bombers and fighter-bombers definitely could put a tank out of action--provided they were able to aXXXXXXX place the bomb close enough to the target. However, just as it is easier for the hunter to bring down fowl on the wing with a round of shot rather than with rifle fire, the problem here was just how small a bomb could be to still be sufficiently effective and how many of these small bombs should be combined in order to obtain a greater probability of success with a salvo of small bombs than with one large bomb.

To be adequately effective against a tank a weapon must set the tank on fire, cause its explosion, or kill the crew. To compel the crew to leave the tank because of damage to its tracks cannot be regarded as adequate, unless the tank is captured later. Generally speaking, a tank can only be exploded or set on fire by a hit in its ammunition or fuel tanks, XXXXXXXXXXXXXXXXXX and this is possible only in certain parts of the tank making up approximately one-half of its entire surface.

The first step was to secure the tanks necessary for experimentation, for which purpose what might be described as an expedition had to proceed to the eastern front. Finally,

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32 roughly ten T-34 plus one Sherman and three Churchill tanks were available for the purpose and were set up in the training ground of the new Udet bomb proving range in Upper Silesia.

First detonations of SC-250 bombs served to show the greatest distance [author here says "*mindestabstand*" meaning smallest distance] at which the blast destroyed the tanks, which contained test animals and fuel. The Churchill tank was only protected by rivetted steel plates and came apart when the SC-250 exploded at a distance of 5 meters. The Soviet T-34 and the American Sherman tanks were about equally resistant against outside explosions; they still remained intact when a SC-250 bomb burst only three meters away, but the animals inside were killed and the diesel fuel in the T-34 tanks was set on fire by the air pressure of the blast.

The next task for bomb development was to so aim a container of hollow-charge bombs of the same caliber as the 550-pound mine-type bomb that the center of the resultant fragmentation field would be not more than three meters [here the author says "*mehr als*" i.e. greater than] from the tank and would destroy it.

The attack tactics in 1943 were those of the fighter-bomber:

> Approach at a slope of between 10 and 20°; speed roughly 300 miles; bomb release altitude at least 1.650 feet since enemy tank formations at this stage of the

war generally included special antiaircraft artillery tanks for protection against low-altitude attack.'

The antitank weapon had to have an armor-piercing capability of at least 100 millimeters and this could have been achieved with a hollow-charge weighing only 2.2 pounds. However, large bodies of infantry usually accompanied the Soviet tanks,so that it seemed advisable to combine fragmentation effect with the armor-piercing capability, such as shown for the SD-4-Hl bomb in the hollow-charge table.

In order to be able to pack as many of these bombs in the available types of containers, the SD-4-Hl was given a relatively thick gray cast iron nose section, which shifted the center of gravity forward and thereby reduced the length required in the stabilizing vanes and of the entire bomb. The fuse vent had a diameter of 25mm and could take the No. 66 electrical impact fuse (eAZ No (66) which at impact sent an electric current from point to the base of the hollow-charge by means of a cable. This fuse was made completely of artificial materials and offered little resistance to the directed jet of the combusting gases.

The diameter of the SD-4-Hl resulted logically from the required armor-piercing capability of 100- millimetersand the thick walling~~xof~~ given to the bombto produce fragments. In test detonations the bomb pierced through 130 millimeters of steel, 33 a thickness found at the gun aperture of the Sherman tank turret, and the hole created was 20 millimeters in diameter at the entry and roughly 10 millimeters at the exit of the blast.

Shortly before the SD-4-Hl bomb went into mass production it unfortuantely became necessary to give it longer stabilizing vanes than had been planned in order to prevent to wide dispersal of the bombs making up a salvo under the existing circumstances.of bombing. This meant that the AB-250 container could hold only 40 of the new bombs instead of 50.

34 The Sobiet Type T-34 tank had a surface of 18 square meters, but tests with live bombs showed that only roughly one-half of this surface was vitally vulnerable to hits with the SD-4-Hl, namely those parts of the tank in which the ammunition and fuel would be exposed to the bomb's blast.

Assuming an equal distribution of the bombs of a salvo at impact, two bombs of this size would at least have ~~been~~ had to hit the tank to insure destruction.

The fourteen captured Soviet tanks previously mentioned were so arranged on the target range, namely spaced 6 meters apart, that theoretically one SC-250-non-dely bomb would destroy at least one of them. A group of 4 tanks thus exposed a total target area of 18 x 24 meters = 432 square meters which the SC-250 had to strike to destroy at least one of them. The important thing now was to place forty SD-4-Hl bombs within the same area so equally distributed that at least two tanks would be struck by each two bombs.

All aiming tests were carried out by an experimental air squadron specially activated for the purpose and the tests took up almost an entire year. Because of the unavoidable dispersion which occurred when the bombs left the container, it was decided to adopt the AB-500 container, holding 78 SD-4-Hl bombs as standard antitank bombing equipment.

Tank specialists of the Army considered the effectiveness of the ~~XXXXX~~ SD-4-Hl adequate. The T-34 tank had a surface angle of roughly 30° and the SD-4-Hl when striking these surfaces at an angle of only 20° degrees frequently pierced thicknesses of 45 millimeters. Events showed how right it had been to plan a piercing capability of 100 millimeters of armor steel for the bomb, since a bombs striking a 45-mm steel plate at an impact angle of 20° must pierce through roughly 110 millimeters, which the bombs often actually did in trial bombings.

However, it was too late for any large scale use of these bombs in actual combat and owing to the fluid situation in the summer of 1944 it was rarely possible to check the results reported by the troops.

The troops held a high opinion of the new bombs, but complained about the containers. The bomb containers, originally intended for incendiary bombs, consisted of two shell-like parts which opened apart to release the small incendiary bombs, and the authorities responsible for development realized that they were not very well suited to obtain the desired "shot-gun-fire" effect. However, it was not possible to halt production of the AB containers and small modifications could not serve to solbe the problem of dispersion.

In order to further improve on the composite plane method, a series of fast composite plane teams were taken under development, in which the piloting plane was a jet fighter Me-262 and Me-163). The plane carrying the hollow charge was a plywood structure powered by a ram jet unit (<u>Staustrahltriebwerk</u>). Striking ranges up to 1,200 miles were possible, since the piloting aircraft during the approach flight could take fuel from the bomb-carrying plane and for its return flight carried reserve fuel tanks. There being no question of the composite landing together, the lower (bomb-carrying) plane had an under carriage which was ejected after the take off, similarly to that of the Ar-234 planes. Booster rockets facilitated the take off.

5. <u>Naval and Drift Mines for Use with Aircraft</u>. In Germany, the development of naval mines to be dropped by aircraft was, prior to World War II, the exclusive responsibility of the Navy, where it was handled by the Sperr-Versuchs-K

Sperr-Versuchs-Kommando (Experimental Barrage Command) with headquarters at Kiel. This command produced the following types of airborne mines for the Air Force:

LMA: a ground mine with remote ignition; weight 1,100 pounds
LMB: " " " " " " " 2,200 pounds
LMC: " moored mine with 300 meters cable; " 2,200 pounds.

Of these three types of airborne mines only the LMB went into mass production. Mines of these types had to be dropped at a maximum speed of 210 miles. At release from the plane, a large parachute opened to insure that the mine, with its highly sensitized remote ignition gear would strike the water surface at a maximum falling speed of 30 meters per second.

The fuse systems used in airborne mines were practically the same as those used in normal naval mines. The remote ignition system initially used functioned magnetically; when the mine settled on the ground a compass needle adjusted itself to the local terrestrial magnetic field and if this magnetic field was disturbed ba an approaching ship, detonation took place. The explosive charge consisted of roughly 1,500 pounds guncotton comprising 60% trotyl, 24% Hexyl, and 16% aluminum; it was estimated that the blast effect would sink a medium sized ship (10,000 tons) at a distance of 66 yards. This was also the operating range of the fuse system in the case of targets of this size. The mine casing was of an alloyed aluminium proof against seawater.

37 Later in World War II acoustic fuses as well as combined acoustic-magnetic fuse systems were used in LMB airborne mines, once these systems had been developed, and were laid by aircraft in areas designated by the Naval Operations Staff which naval surface craft were unable to reach.

Owing to their slow rate of fall, it was not possible to aim parachuted mines accurately; consequently, theycould only be used to
be used to mine very large areas, such as the mouth of the Thames River or the sea routes along the east coast of England, but not to block harbor entrances at which sea traffic converged.

Besides other already known mechanisms, such as count contacts, time control units, and devices to safeguary secrecy, the airborne mines had the characteristic that they exploded after 30 seconds if they fell onto dry ground or into shallow water, or if they were heaved up from any considerable depth.

Certain air units used the LMB mines without remote ignition mechanisms, as immediate-detonation bombs. This was because during the first stage of the Air Battle for Britain Germany had no bombs of this size except those with delayed action fuses. This is the origin of the term "air mine."

In order to enable units operating at great altitudes to also mine such areas as port entrances and canals, the Air

37 Force immediately after the outbreak of war commenced de-
38 velopment of a suitable missile under its own responsibility. Missiles of this type were designated bomb-mines (bombenmine) The BM-1000 bomb mine was released in the same way as a conventional explosive bomb, and its deflection in water, which was so undesirable in normal bombs and was caused by its ogival nose section, served in the case of the bomb mine to limit its penetration depth. The xtxxxixx stabilizing element was of artificial resin in the BM-1000 and broke off on striking water.

The length and diameter of the BM-1000 corresponded to the dimensions of the SC-1000 mine-type bomb, but the casing of the bomb mine was of non-magnetic steel and consisted of a number of sections welded together. The weight of the explosive charge was the same astthat of the LMB airborne naval mine but contained 70% trotyl, 15% hexogen, and 15% aluminum, and was known as trialen 105.

With support from a naval mine development sub-section established in the Bombs Branch of the Air Ministry Technical Office at the beginning of the war and which cooperated closels with the AEG (General Electric Company) in Berlin, the first BM-1000 bomb mines from serial production reached the troops already towards the end of 1940.

What was initially a great improvement was the fact that

38 the new bomb mine could be dropped from an altitude of 6,[illegible]0 feet, the required minimum depth of water being only 8.8 yards. Previously aircraft had only been able to lay mines at night.

Howeher, the Air Force Operations Staff planned daylight mine-laying operations by aircraft operating at great altitudes and in 1941, in time for this purpose, new variants of the BM-1000, namely Models H and M, made their appearance. These could be dropped from any altitude and rendered excellent service in the campaign in northern Africa. Owing to the steeper angle at which these new bombs entered the water, however, the minimum water depth requirements had to be increased to 33 feet. Furthermore, it proved essential to reduce the fall speed to approximately 220 meters per second 39 by means of a small brake-parachute, since otherwise the stability of the mine casing and the shock-proof properties of the explosive charge would have been impaired.

Besides the AEG, other firms specializing in electrical apparatus, as well as various institutes, were invited to participate in the ~~development of~~ further development of remote ignition devices required by the expandin conduct of mine-laying warfare. Consequently, the following ignition devices reached the troops successively for installation in the BM-1000 and the new variants of that bomb mine:

M 101 : magnetic ignition
A 105 : acoustic ignition

39 AD 104 : acoustic arming, detonationby means of a pressure cylinder (hydrostatic)

DA 102 : arming by means of a pressure cylinder, detonation by means of guided acoustic

MDA 105: As in A 105, above, acoustic ignition but requiring simultaneous magnetic and hydrostatic impulses to arm the fuse

AA 106 : arming by uncontrolled acoustic, detonation by guided acoustic

AJ 102 : guided acoustic arming, inductive detonation

JDA 105: acoustic detonation, fuse arming by simultaneous inductive and hydrostatic impulses.

The supplementary devices customary in other naval mines were also included in the bomb mines; such as count contacts which could be xxtXXXXXX as desired for between two end twentyfour ships to cross over the mine before it exploded, and which were usually set by probability factors; time switches, which insured that the mine would only detonate at specific times, for example only at night; delayed action devices, so that the mine would explode under midships; light fuses, which exploded the mine when the cap covering the ignition apparatus was removed and a faint ray of light penetrated to the element built into the ignition circuit.

All ignition devices were proofed against the shock occurring when the bomb mine struck water at a fall speed of 220 meters per second. If the mine fell on shore it exploded immediately at a stress equal to more that 800 times that of gravity acceleration.

4[illegible] On the first day of the campaign against Soviet Russia, a regrettably faulty use of the BM-1000 bomb mine occurred, which can serve to show what results exaggerated secrecy requirements can produce. The 806th Bomber Group received the mission of closing the Stalin Canal leading from the Leningrade region to the Arctic Ocean by destroying the gates of t the highest lock of this waterway and thus causing the lock to run dry.

Instead of consulting weapons specialists in the planning for this attack, the choice of the most suitable weapon to destroy the lock gates was left to the unit commander. On the basis of the available tactical regulations compiled by the Air Force Operations Staff, the commander of the attacking unit selected the BM-1000 bombs for the purpose, from which all ignition devices were removed with the exception of the water pressure switch ignition. Plans provided for the individual Ju-88 aircraft of the unit to approach in a flat dive and from a very low altitude drop their ~~kxxbx~~ bomb mines on lock basin, which had a length of approximately 220 yards a breadth of roughly 13 yards and a depth of only 3.3 yards. The water-pressure ignition was set to detnoate the bombs after a delay of a few seconds.

However, the tactical regulations issued by the Air Force General Staff regulating use of the BM-1000 provided

40 only, for high-altitude bombing and made no mention whatever of low-altitude bombing, since the LMB airborne mines with parachutes were available for such purposes. This fact alone should have resulted in an inquiry addressed to the technical

41 agencies in the Air Ministry, but owing to the secrecy to be maintained concerning the planned campaign against the Soviet Union such inquiries could not be made.

The air unit took off from the Koenigsberg (Eastern Prussia) area, to load the bomb mines at a Finnish airfield, where they had been prepared according to plan.

The attack achieved its purpose but at the cost of a number of aircraft destroyed, including that of the unit commander leading the attack because on striking the lock installations, namely the gates and concrete walls, the shock-sensitive trialen exploded by selfignition , destroying the aircraft and crews flying at an altitude of only 60 to 100 feet. The impact velocity of the bomb mines was [illegible] about 150 meters per second and such large charges of explosives cannot withstand impact on a hard surface unless specially phlegmatized, as is done with the explosive charge in antitank ammunition.

If the development sections in the Office of the Chief of Air Force Special Supply and Procurement Services had been consulted in time, they would have advised for this purpose

41 the use of SD-1700 multi-purpose bomb, with impact plates attached to the bomb nose to take up the force of the impact on the surface of the water in the canal, and the explosive charge of the bomb would have been of phlegmatized trotyl. It is selfunderstood that the bomb thus prepared would have been tested against an appropriate target installation to insure proper functioning before its release to the troops.

42 An outstanding example of good cooperation between the command, technical agencies, and troops is that of the XIXXXX XIXXXXXXXXXXXXXXX development and use of the British Dam Buster 4 t rotating water bomb intended for the attack against the Moehne and Weser River dams in Germany. The flight was practised long beforehand by the well-known 617th Experimental Squadron without anyone except the commander knowing the intended target.

The rotating water bomb had the shape of a cylindrical drum and was suspended under a Lancaster plane at right angles to the plane's longitudinal axis. Shortly before release, at an extremely low altitude, the drum was set rotating (opposite to the direction of flight) by an oil pressure motor, producing a Magnus effect which carried the drum a few hundred yards on the water surface. After this it sank at the inner surface of the dam wall and its explosive charge of 2.6 tons of trialen detonated at the bottom of the dam.

42 The attack came as a complete surprise to the German side after low level attacks against hydrating installations had resulted in a temporary removal of barrage balloons from the important area to protect the hydrating installations; it succeeded, although a number of the attacking aircraft were shot down.

To return to the subject of airborne marine mines: a new ignition device was introduced whenever the mine clearing methods of the enemy had been adapted to the devices in use up to then. However, it was practically impossible to clear the mines detonated by the hydrostatic pressure cap system, which the British called "Oyster Mines."

43 After the Allied landing in Normandy the German Air Force then used normal mine-type bombs of 550 pounds armed with the extremely simple AD-103 fuse device. Fighter aircraft dropped these bombs, designated as BM-250 (bomb-mine 250) in the English Channel and other shallow waters and in rivers, where they seriously hampered enemy seaborne supply operations. They were effective at depths as great as 22 yards.

Bomb mines were dropped in the same way as normal explosive bombs, with the use of normal aiming and bombing equipment. The fuse was armed by a "fuse arming head" (Ladekopf) on the side of the bomb, as was the case with the normal electrical fuse, so that their use required no speciall

Supplementary to page 385 .

Diagrams

Legend:

Lancaster Bombenflz. = Lancaster plane

Fl. R. = Direction of flight
M. 1:50 = Scale 1:50
Antriebsmotor = Propelling motor
60 PS = 60 horsepower
Gesamtgewicht: 4 t = Total weight: 4 ton
Sprengladung: 2,8 t = Explosive charge: 2.8 ton

M. 1:20 = Scale 1:20
V = 100 m/s = Velocity 100 meters per second
U = 150 m/s = Revolutions = 150 meters per second
Magnuseffekt 4 t = Magnus effect 4 ton

M. 1:1000 = Scale 1:1,000
Flugweg, Hoehe 10 m = Direction of flight, Altitude 10 meter
1) Aufschlag = 1) Reaches water surface
2) Anprall = 2) Impact on wall of dam
Torpedo Schutznetge = Protective torpedo nets
3) Detonation mit Wasserdruckzuender = 3) detonation by water pressure fuse

Staudamm = Dam Wall

trained personnel at the airfields, as was the case with the airborne marine mines of the Navy.

The German Air Force also developed equipment to clear remote ignition mines. This equipment could be operated by aircraft. To clear magnetic ignition mines, coils with a diameter between 10 and 14 meters were mounted in Ju-52 and Do-23 aircraft; these coils produced a magnetic field directed downwards which caused the magnetic mines to detonate. To clear mines with acoustic ignition, salvos of small detonators were dropped by aircraft into the water, where they produced sounds similar to those of the propeller of an approaching ship.

Mine-clearing aircraft had to fly very low over the minefields laid by the enemy, and losses occurred when, besides the mines set to explode with a delay of a few seconds, so that they would strike the engine room of a ship, a minefield included a few mines set for immediate detonation. The columns of water thrown by such mines caused nearby aircraft to crash.

44 The German Navy, in turn, used what were called "rip buoys" (*Reissbojen*) to protect its minefields. These were also dropped from aircraft and served to destroy the mine-search cables of enemy naval minesweepers attempting to clear anchored German mines. The German Navy lost a number of "Blockade breakers", ships equipped with all types of mine-clearing apparatus and travelling ahead of convoys in mine

waters, when the Royal Air Force unexpectedly dropped XXXXX XXXXXXXXXXXXXXX mines with phlegmatized (stumpfe) acoustic ignition devices, which did not respond to normal propeller sounds but only to the submarine sounds of the XXXXXXXX barrage breaker ships.

The above examples have been quoted to indicate the diversity of marine mine warfare and the expansion of this warfare introduced by the use of aircraft.

In the development of marine mines, Germany at all times adhered to the international laws of naval warfare. For example, all remote ignition fuses were operated by batteries with a servicable duration of not longer than two years, so that after this period elapsed the mines represented no hazard to ships. Britain, in contrast, used mines with induction ignition, in which the electric current is produced by the ship passing overhead and which will still remain effective for many years. According to Skandinavian estimates, roughly 2,000 of these mines are still present in the North and Baltic Seas, so that in these waters ships can only travel by precisely prescribed courses.

Germany only commenced developing drift mines in 1944, when the Air Force General Staff planned a large-scale attack against a number of large electric power stations situated in European Russia, because the Soviets had in the meanwhile rendered these stations proof against the effects of normal ~~[illegible]~~ bombing. The SHl-6000 airborne hollow charge developed for this purpose has been discussed in the previous chapter. It was intended for use against the steam-driven electric power stations , some situated in the ~~[illegible]~~ coal region of the Donets Basin and others, burning peat, in the regions farther north. Against the hydro-electric power stations which, as was the case at Volkhovstroij, operated with a slow flow of water, it appeared simpler to use large drift mines to be dropped by aircraft into the dams.

Air reconnaissance had established that the intake ducts to the turbines were protected by torpedo nets, as was also the case with the German dams in the Moehne and Eder Rivers. Whereas the British overcame the German obstacle by means of rotating water bombs which rolled over the nets, the German plan was for the mines to pass under the nets. This was the purpose of the mine known as the "water balloon (Wasserbal-

The water balloon was an SC-1000 mine-type bomb with a trialon 105 explosive charge and fitted with an empennage of artificial material and taken from the BM-1000 bomb mine. When dropped from a high altitude, the empennage brok off on striking the water and the bomb, after changing its position, settled downwards to lie flat on the bottom. Then a rubber balloon with a diameter of approximately 1.4 meters and folded in at the base of the bomb, was filled from a

45 small compressed air container, causing the bomb to float.

However, the water balloon had a slight downward deflection, so that ot did not rise to the surface, where it could easily have been exploded by gunfire, but floated just above the bottom of the dam, where it drifted along. Experiments to determine the flow of water in the Soviet dams were carried out by the Canal Research Institute (*Kanalforschungsamt*), Lake Walchensee, Upper Bavaria, with scale 1:50 models and showed that the originally designed water balloon mine bomb would drift along the ground at 0.1 meter per second.

It was hoped that in this way the bomb mines would drift under the torpedo nets and with their explosive charge reach the intake ducts of the water turbines. Plans were also considered to destroy the torpedo nets by means of drift mines shortly before the actual main attack, but this plan was dropped for fear of alerting the Soviet defenses. Units participating in Operation Waterballoon were also to bomb the machine house in order to divert the attention of the defenders from the actual dam.

An ignition system operated by the flow of water was intended for the water balloon mines but tests showed them to be unsatisfactory. Finally electrical shock fuses were built into the body of the mine but with a relatively "hard" contact. However, some of the mines were provided with

75a **Supplementary to pages 389-390.**

Legend:

Wasserballon und Winterballon	= Water Balloon and Winter Balloon airborne mines
Ballon ∅ 1,40 m (Wasserballon)	= Balloon diameter 1.4 meters (Waterballoon mine)
Ballon ∅ 1,60 m (Winterballon)	= Balloon diameter 1.6 meters (Winterballoon mine)
Leitwerk aus Kunststoff bricht beim Aufschlag ab	= Plastic stabilizer, breaks off on entering water
Druckluftflasche mit Aufschlagventil	= Compressed air cylinder with valve to open by shock
Ballon, verpackt	= Packed balloon
L. Zt. Zdr (17) oder El. Zt. Zdr (50)	= Long delay fuse (17) of electrical (clock) time fuse (50)
Uebertragungsladungen aus Hexagen	= Hexagen primer charges
Aufhaengewarze	= Suspension lug
Gesamtlaenge ca 3,50 m	= Overall length approximately 3.5 meters

45b Supplementary to pages 389-390.

Diagram

Legend:

Lageplan des sovietruss. Wasserkraftwerkes Wolkowstroij = Plan view of Soviet hydro-electric power station Volkhovstroij

Wolchow See = Lake Volkhov

0,1 $\overset{m/s}{\cancel{x}}$/Stroemung = Flow 0.1 meter per second

Torpedonetz = Torpedo net

Betondamm = Concrete wall of dam

1 m/s, 2 m/s, 5 m/s = Flow 1, 2, 5 meters per second

Neubau = New structure

Turbinenhaus = Turbine house

Transformator-Station = Transformer station

Abgehende Hichspannungs-Leitungen = Outgoing high tension wires

Bemerkung:

Die Stroemungsge~~r~~~~xxxxxxxx~~schwindigkeiten wurden bei Modelversuch 1:50 ermittelt = Flow velocity determined in experiments with scale 1:50 model

46 clockwork ignition fuse Nr. (17), the idea being that they would cause the simultaneous explosion of all the other drift mines gradually accumulating at the turbine intake ducts.

47 Since the attacking units were to deliver 100 Waterballoon mines on target at each power station, the entire explosive charge would have been roughly 60 tons, so that satisfactory results could have been expected in view of the short distance between the dam and the power station installations.

Owing to the approach of winter in 1944-45, a parallel project was that of the development of a similar mine, the Winter Balloon mine (Winterballon), so that the timing of the operation would not be dependent upon the presence of open water.

The Winter Balloon (Winterballon) was made from an SC-1000 mine-type one-piece casing; released from a high altitude it was capable of piercing the thickest ice cover encountered on any of the artificially dammed up lakes in northern Russia. At impact the plastic stabilizers broke off and the drift mine settled to the bottom. Then the rubber balloon filled with air, giving the mine a slightly greater degree of buoyancy than that of the previously discussed Wasserballon (Water Balloon) mine because of the slightly greater size of the balloon.

Appropriate tests had shown that the mine would drift

Supplement to pp. 392-393.

Diagrams

Legend:

Die verschiedenen Phasen bei Anwendung von Wasserballon = Various phases in use of a Water Balloon mine

M. 1:100 = Scale 1:100

1) Hochabwurf "Wasserballon" wie SC-1000 = 1) High altitude release of Water Balloon mine; same as release of SC-1000 mine-type bomb

Wasseroberflaeche = Water surface

Torpedoschutznetz = Protective torpedo net

2) XXXXIIIXXXXXXIXXXXX Leitwerk geht ab; Bombe wendet sich innerhalb 6-7 m und legt sich flach auf Grund = 2) Stabilizer element breaks off; within 6-7 meters the bomb-mine topples and comes to rest on the floor of the lake

Mindestwassertiefe 8 m = Minimum water depth 8 meters

Stromung 0,5-1 m/s = Rate of water flow 0.5 to 1 meter per second

3) Auftriebsballon fuellt sich = 3) Balloon is inflated

4) Wasserballon treibt auf Grund = 4) Waterballoon bomb mine drifts along lake floor

M. 1:500 = Scale 1:500

5) Zuendung mit Uhrwerkszuender nachdem etwa 100 Stueck Wasserballon mit Erschuetterungszuender sich am Turbineneinlauf angesammelt haben. = Detonation by means of clockwork fuse after roughly 100 Waterballoon mine bombs xxxx with shock fuses have accumulated at turbine water intake duct.

47 along the undersurface of the ice, which is always completely smooth and has no protuberances on which the balloon might have been caught.

The protecting torpedo nets were removed from the water in winter, so that the Winter Balloon bomb mines in this way could have drifted close to the turbine water intake ducts, where devices the same as those used with the Water Balloon bomb mine would have detonated them simultaneously.

Much effort was expended so late in the summed of 1944 on the development of these drift mines, and it was only possible to test the individual elements separately, but not

48 the complete bombs. However, procurement presented no difficulties, since the mines in actual fact were nothing but modified forms of existing bomb types. All in all, approximately 1,000 Water Balloon bomb mines and Winter Balloon bomb mines were produced, which were to be used by the 100th Bomber Wing in execution of the planned <u>Operation Eisenhammer</u>.

However, it was not possible to execute this last large-scale operation planned by the German Air Force in the Eastern Theater, because the seriously critical military situation in the last winter of the war made it imperative ~~fax~~ to concentrate all energies and all forces on the defense. Local, small-scale attacks with the new weapon were prohibited by

XII C
47a

Supplementary to page 395.

Diagrams

Legend:

Die verschiedenen Phasen bei Anwendung des Geraetes "Winterballon"	= Various phases in use of Winter Balloon [illegible]
M. 1:100	= Scale 1:100
ca 1 m. dicke Eisdecke	= Ice cover approximately 1 meter
1,Hochabwurf von SC-1000 als Winterballon	= 1) High-altitude release of SC-1000 adapted as Winter Balloon bomb mine
2)XXXXIIXXXXXEXXXXXXXXXX Leitwerk bricht ab;Bombe wendet xixx innerhalb 6-7 m und legt sich auf Grund	= 2) Stabilizer elements breaks off; bomb mine tumbles within 6-7 meters and settles at bottom
3)Auftriebsballon fuellt sich	= 3)Balloon is inflated
4) Winterballon treibt unter der Eisdecke	= 4)Winter Balloon bomb mine drifts along under ice
Mindestwassertiefe 8 m	= Minimum water depth 8 meters
Stroemung 0,5 - 1 m/s	= Flow of water 0.5-1 meter per second
M. 1:500	= Scale 1:500
5) Zuendung wie "Wasserballon"	= Detonation same as Water Balloon bomb mine.

48 the Air Force General Staff in order not to disclose its existence.

At the beginning of 1945, however, use was made of Summer Balloon (Sommerballon) bomb mines in the Western Theater. These were developed within a few weeks on the basis of experience with the weapons just described above, and were designed to destroy bridges over the Meuse River and the lower reaches of the Rhine River, which enemy forces had [illegible].

The technical background to the above weapons is as follows:

An experimental station established by the Air Force for research on the physics of explosions had found in carrying out underwater detonations that for each individual explosive charge there is a specific depth of water at which it will throw up a maximum quantity of water, a phenomenon known from the effects of xxxaxxxxxx depth charges. However, it is to the credit of this experimental station that it how great the kinetic energy in these occurrences was and that it submitted recommendations for the exploitation thereof.

In the past only the pressure and thrust of underwater explosions had been taken into account.

49 If high-capability explosives are used the force of the masses of water hurled into the air is so great that it can destroy bridges overhead.

49 In one blasting test, only 11 pounds of hexogen detonated at a depth of approximately 2 meters caused the collapse of an iron bridge spanning a 12 meter wide canal at a height of 4 meters.

Using slow motion photography it was possible to observe how the rising fountain of water first raised the steel girders of the bridge about 18 inches; when falling back, the girders snapped and the entire bridge collapsed into the canal. A demolition charge placed by engineers under the bridge definitely would have caused far less damage.

According to the results obtained in test blastings, a 1,650-pound charge of high-capacity explosive xxxxxxxxx exploded at a depth of 12 meters was needed to destroy a bridge 30 meters above the water surface.

The Western Allies had in the meanwhile placed torpedo nets to protect the Meuse and Rhine River bridges designated as targets against drift mines. Prior to the attack with Summer Balloon bomb mines, a few drift mines with clockwork xxxxxxxxxxxxxx time ignition were therefore dropped into the rivers to destroy the torpedo nets.

The Summer Balloon bomb mine consisted of a BM-1000 bomb mine casing with an explosive charge containing 70% hexogen. The bomb release altitude was immaterial, but the minimum water depth had to be 10 meters, as required for

49a Supplementery to page 398.

Diagram

Legend:

Sommerballon = Summer Balloon bomb (drift) mine

Ballon ⌀ ca 1,5 m = Balloon diameter approximately 1.5 meters

Leitwerk aus Kunststoff bricht beim Wassereintritt ab = Plastic stabilizing element breaks off on entering water

Fernzuendung = Remoteignition fuse

Aufhaengewarze = Suspension bulge

Gesamtlaenge ca 3,5 m = Overall length approximately 3.5 meters

Platz fuer verpackten Ballon = Space for packed balloon

Elektr."Auge" auf dem Wasser = Electric "eye" at water surface

Wasserdruckzuender = Water pressure detonator

Uebertragungsladudungen aus Hexogen = Primer charges of hexagen the "[illegible]" series of the EXIES BM-1000 bomb mine. After changing its position on entering the water, the Bommer Balloon bomb mine sank to the bottom. Where the stabilizing vane detached from the bomb mine, after a bolt made of salt had dissolved, and a rubber balloon was suffiently inflated to just allow the bomb mine to drift off the ground. The only above-water contact was by means of an electric cable carried by a float, which was disguised with twigs and carried an "electric eye" for remote detonation.

Tje Bummer Balloon bomb mine had two separate systems for ignition. The one was "passive" and functioned only during daylight . It consisted in principle of a photo-sensitive cell, the "electric eye" in an optically vertical position. If this eye drifted under a bridge girder the shadow released the ignition, which first caused the balloon to burst. The mine thereupon sank to the botton, where it was detonated bxx xxxxxxof at the most effective depth by means of a built in pressure detonator set at a certain water depth.

The bomb mine functioned similarly with an "active" detonator, the only difference being that here a shortwave transmitter was built in, which functioned independently of daylight, and undistrubed by the presence of dummy girders, and caused the ignition by radar principles.

The enemy had such pronounced air superiority in the

50a Supplementary to page 400.

Diagram

Legend:

M. 1:50	= Scale 1:50
Die verschiedenen Phasen bei Anwendung des Geraetes "Sommerballon)	= The various phases in the use of the Summer Balloon bomb mine
1) Hochabwurf BM-1000-H	= 1) High-altitude release BM-1000-H bomb mine
2) Leitwerk bricht ab; Bombenmine wendet sich und legt sich auf Grund	= 2) Stabilizer unit breaks off; bomb mine changes position and settles to bottom
3) Auftriebsballon fuellt sich	= 3) Balloon is inflated
4) Sommerballon schwebt und treibt im Strome	= 4) Mine bomb suspended and drifts with current
5) Das "Electrische Auge") zuendet unter der Bruecke	= 5) The "Electric Eye (Photosensitive Cell)" ignites under bridge
6) Ballon wird abgesprengt	= 6) First phase of bomb detonation: Balloon is deflated
7) Mine sinkt	= 7) Second phase of detonation: bomb mine sinks
8) Mine zuendet durch Wasserdruck in 10-12 m) Tiefe	= 8) Third phase of detonation: mine bomb itself detonated by water pressure at depth of 10-12 meters
Wasseroberflaeche	= Surface of water
Stroemung 1-2 m/s	= Flow of water 1-2 meters per second

50 west in the xxxxx spring of 1945 that German aircraft were unable to use the German Balloon bomb mines; instead these were dropped from rafts poled to as close as possible to enemy held bridges. Apparently these operations did not produce any appreciable results.

Finally, the example of the 110-pound drift mine is quoted here to illustrate how quickly the individual elements of various mines could be assembled to produce a weapon for a purpose differing completely from the originally intended use.

The 110-pound drift mine was also intended for laying by aircraft and went into development just prior to the invasion in Normandy; owing to generally reduced production, however, it was not placed in mass production.

Plans provided for fighter-bombers to lay a barrier of small drift mines between the Allied troop transport ships and the shore as soon as the Allied troops began disembarking. Naval experts considered that a floating barrier of this kind, to support bombing with LM-250 bomb mines, would prove more effective than direct attacks with weapons fire and bombs against the ships with their strong antiaircraft defenses.

It should be noted here that at this juncture every means that could be used to repel an invasion was pressed into service, even if the chances of putting plans into effect

51 effect were relatively remote.

As a first step in development of the new weapon, the Air Force weapons proving station at Travemuende tested the effectiveness of weapons fire with the 14- and 20-mm guns carried by aircraft on an original "Landing Craft 250 t" captured in the Canadian "invasion exercise" at Dieppe in August 1942. However, the [illegible] of these guns failed to produce satisfactory results. The next test was with fragmentation bombs, starting with the SD-1 (2.2-pound) and working through to the SD-15 (33-pound) caliber, which would have caused considerable casualties among the men on a landing craft but would not have sunk the landing craft itself, which was the effect to be achieved according to the instructions received by the weapons development specialists.

Under-water detonations proved considerably more effective, an explosive charge of only 10 pounds detonated at a depth of only one meter and at the same distance from the landing craft causing its immediate sinking in spite of its strong watertight bulkheads.

To produce a drift mine, use was made of the casing generally used for the SC-50 mine-type bomb. However, the casing was longer than usual, namely, 1.1 meter (roughly 3' 6"), the nose was swaged on and the base piece was welded in.

52 The mine version thus had no stabilizing vanes but, instead, had an air space at the base. The explosive charge filled

52 into the nose section shifted the center of gravity so far forward that the mine floated upright in the water, only sufficient buoyancy being allowed that the base projected a few centimeters above the surface. This made it possible to give the mine an explosive charge weighing between 15 and 16 1/2 pounds if completely filled.

Similarly to the Bd-4-C-10 containers for each 4 22-pound fragmentation bombs discussed previously in this study, the troops had meanwhile received the Bd-4-C-50 container to carry either 4 110-pound explosive bombs or 4 LC-50 flare bombs, and which could be used with the bombing equipment for 55- and 1,100 bombs. These containers could also be used to release 4 drift mines simultaneously, each weighing 110 pounds.

The new mines, designated TM-50, were armed with the No. (50) percussion or shock fuse which had proved so satisfactory in use and which will be described in the following chapter. However, the arming time was reduced to two minutes and in the tests the percussion contact was so set that it would function at impact on metal but not through the shock of heavy seas or underwater explosions.

The 4 drift mines making up a container were connected by floating cables 165 feet long with a cloth drift anchor attached to the end of the last cable. Wind and the motion of the water extended the cable holding the mines to its full

52 length, producing a mine barrier 300 yards long. The length of the cable sections was just double the length of the "Landing Craft 250t", so that at least one mine would strike the target of the craft ran into the barrier.

Any fighter aircraft would have been capable of laying drift mine barriers of this type. However, complete German inferiority in the air over the Allied beachhead areas made it impossible at the time for German fighter-bombers to operate there, so that the 110-pound drift mine also did not find use in actual combat.

52a **Supplementary to pp. 403-405.**

Diagrams

Legend:

Flugzeug-Treibmine TM-50 und Anwendung gegen Landungsfahrzeuge	= Air-carried TM-50 drift mine and its use against landing craft
Landing Craft 250 t in Fahrt	= Landing Craft 250 t in motion
M. 1:1000	= Scale 1:1000
Vom Flugzeug ausgelegte Treibminensperre	= Drift mine barrier laid by aircraft
TM-50	= TM-50 mine
Treibanker	= Drift anchor
Detoniert	= Explodes
M. 1:10	= Scale 1:10
Wasser	= Water
Auftriebsraum	= Air space
Schwimmende Leine	= Floating cable
Beruehrungszuender Nr.(50)	= Contact fuse No. (50)
7-8 kg Sprengladung	= 7-8 kilogram explosive charge
Buendel aus 4 Stck.TM-50 aufgehaengt wie 250 kg Bombe; oeffnet sich nach Abwurf	= Container of 4 TM-50 mines, suspension same as 550-pound bomb; opens after release from aircraft.

CHAPTER III

1

THE DEVELOPMENT OF BOMB FUSES

1. Basic Principles and Requirements. That a major air power in World War II made almost exclusive use of electrical ignition systems for its bombs was due not only to the technical advantages of electrically functioning fuses but also to a large extent to the ruling xixxxxxx tactical views on the operations and command of large bombing forces.

Another contributing factor is that the reestablished German Air Force was untrammelled by old stocks of ammunition, which in the case of other air forces hampered every effort at conversion from one system to another, but could choose without let or hindrance just what was considered most suitable.

However, in comparison with the other xxxxxx branches of the military, the Army and the Navy, whose technical branches had continued to function without any considerable interruptions after the end of World War I, the program of air rearmament made such a late start in weapons development that one of the most important reasons for the choice of principle of electrical ignition in air-carried bombs stemmed from the procurement situation.

All artillery ammunition used by the German Army and

2 Navy has mechanical ignition devices, only marine mines being armed with electrical ignition, and all available manufacturing capacities in the precision instruments and watchmaking industries required for such purposes were allocated to the Navy and Army production programs in the event of any mobilization. The term "mobilization" is used here to mean the moment industry was required to convert to wartime production.

From the outset the estimated requirements in antiaircraft artillery were so high that the Air Force could not even expect any allocations from any planned expansions of existing
3 or establishment of new factories in these lines. Furthermore, the Army handled the procurement of antiaircraft guns and the requisite ammunition.

In contrast, the industry engaging in the production of low-voltage electrical instruments and particularly those branches specializing in the manufacture of radio instrument parts was established on a very broad basis in Germany and the military requirements in electric communications facilities at that time, namely, in the 1930-33 period, were relatively small.

In 1927, the Rheinmetall Weapons and Ammunition Factory in Duesseldorf had registered a patent for an electrostatic artillery shell igniter (diagram 1), but the ordnance offices

3 of the Army and Navy had evinced very small interest in this development.

The expert engineer personnel of the new German Air Force, however, adopted a completely unprejudiced approach to this interesting problem which, on closer examination, appeared predestined for air-carried bombs. In contrast with ammunition to be fired from guns, the arming of the fuse at the moment of release of the bomb from an aircraft presented no fundamental difficulties.

However, a few tactical requirements had to be met, which the Air Force Operations Staff had specified on the basis of experience gained in World War I and on the basis of publications concerning the opinions ruling in the air forces of foreign powers.

The requirements specified for a modern bomb detonator were extraordinarily comprehensive so far as their use was concerned and it is necessary in this respect to differentiate between the requirements concerning results obtained and the requirements relating to safety measures:

3 1. At the take off of an aircraft, the ~~bombs it carried~~ fuses of the bombs it carried had to be unarmed, so that any bombs which might be lost during the take-off run or immediately after the plane lifted from the ground would not constitute a hazard for the plane itself or for its

3

surroundings.

In the event of an unsuccessful take off it had to be possible for the plane to jettison its bombs, meaning that any plane in an emergency could get rid of its entire bomb load without those bombs causing damage by exploding.

The possibility had to exist for a plane to bombs blind over friendly territory from any altitude.

Bomb fuses were only to be armed over enemy territory.

2. In order to insure proper results in each individual case, the possibility was required to set the fuse to detonate the explosive charge with or without delayed action according to current circumstances, and it had to be possible to so set them even very shortly before release of the bombs.

3. Proper functioning of the ignition had to be insured in any method or direction of attack.

4. Bombs and fuses had to be constructed and set that the bomb would only explode ~~xt~~ when dropped from so-called safety altitudes, meaning the altitude at which the bombing plane was beyond the rage of blast and fragmentation effect of the exploding bomb.

5. When dropped from a low altitude, and thus in low-altitude attack, the bombs were only to explode at a safe distance behind the bombing plane; this delay of a few seconds was called "delayed ignition (Verzugszuendung)" since it was necessitated by the method of attack, whereas the normal delay of a fraction of a second served only to influence the effectiveness of a bomb.

The re-setting from non-delay (ohne Verzug) or with /normal/ delay to delayed ignition was to function automatically, since it was impossible for the aircraft crew

4 when descending through clouds or in difficult combat situations to estimate accurately the safety release alti- ~~XXXXionsXtoXestXXXX~~ tudes for the various types of bombs.

6. For use against specific types of targets combined effect fuses were required; for example, the requirements for an SC-500 bomb dropped on a large warship were

a. if it landed on strongly armored decks, to detonate immediately on impact;

b. if it penetrated into the target without risk of the casing bursting, to detonate with delay;

c. if it entered the water, to detonate at a certain depth, in order to achieve results by water pressure against the unarmored parts of the target ship.

All bomb fuses in use by other air powers were of the mechanical type; in most cases the ~~XXXXXXXX~~ firing pin was released by a small propeller friven by the slipwind within a fraction of a second after the bomb left the releasing plane. In mass bombing it was necessary to prevent the detonation of bombs by their knocking together at release. For this purpose, the USAAF introduced an impact fuse with trajectory safety; a tooth-wheeled gear was inserted between the ~~xxxixg~~ fuse arming propeller and the shaft of the firing pin to slightly delay release of the pin. However, this made no allowance for safety bombing altitudes.

5 For use in low-altitude attack, foreign air powers inserted special delayed-action fuses into the bombs prior to take off of the aircraft.

Supplementery to pages 403-411.

Legend:

S = Stromquelle	= S = Source of electric current
M = Masse	= M = Mass
K_1 = Speicher- K_2 = Zuend- } Kondensator	= K_1 = Accumulator- K_2 = Ignition- } condenser
W = Umladewiderstand	= W = Transfer resistance coil
A = Aufschlagkontakt	= A = Impact contect
Zdm = Zuendmittel	== Zdm = Ignition medium
E = Aufladespannung	= XXXXXXX Supercharging voltage
E_A = Ausgleichspannung	= Compensating voltage
Beispiel: Zum Zeitpunkt t_1 hat der Zuend-Kondensator K_2 die Spannung E_1 erreicht	= Example: At t_1 the Ignition-Condenser K_2 will have the same voltage as E_1

For safe handling and transportation the mechanical type fuses had a protective cap which prevented any unintentional release of the propeller. In actual bombing, a remote control fastening and a long brass wire served to remove this protective cap.

In an emergency bomb release and at plane take off the fastening remained at open so that the bomb would fall together with the protective cap and the wire, thus preventing its detonation.

Because of the large number of bombs carried, modern bomber aircraft usually had electrical equipment, using numerous electromagnets , to ready the fuses.

The method of selecting impact ignition with or without delayed action was by means of each bomb having an instant ignition nose fuse and a delayed action base fuse. If the protective cap was removed from the nose fuse, the bomb exploded immediately at impact, if it was left on only the base, delayed-action, fuse functioned, from which the cap was always removed at bomb release except in the case of an emergency release.

If it was necessary to have an electric cable leading to each bomb carried by an aircraft in order to activate the mechanical ignition system, it appeared only logical to use the electric current itself for the functioning of the fuse, 5 and lead the current into the fuse directly instead of through the medium of a mechanical intermediary element.

6 The electrical fuse not only made this simple solution possible, but was also the only ignition system which received its igniting energy only at the moment of bomb release and not before, and which ~~XXX~~ could be considered absolutely safe in transport until that moment, even if the primer charge was already loaded.

This was a great advantage in ammunition supply operations and storage, since the fuses could now be built into the bombs at the ammunition installations far in the rear and delivered to the troops ready for instant use.

In foreign air forces, bombs were usually delivered to the troops in separate sections, i.e. the casing, the stabilizer section, the fuse, and the primer charge, and usually the parts were only assembled in position under the bomber plane. For safety reasons the fuses were often only built into the bomb when it was already suspended under the aircraft. This method requires large numbers of ground and specialized personnel, takes up a lot of time, and can lead to operational delays if any single part of the bomb should be missing, quite apart from the possibilities of errors in assembling the various parts under field conditions.

In the swift campaigns in Poland, France (in 1940

6 In the Balkans (1941) and at the opening of the campaign against Soviet Russia, the advantages of the electrical fuse in point of transportation safety in many cases proved more important for tactical purposes than the number of aircraft available, since it enabled each individual aircraft to fly a multiple of missions instead of losing the time required to ready ammunition with mechanical type fuses.

However, it must be admitted at this point that when conditions were unfavorable the storage durability of the ammunition held ready for use sometimes suffered seriously if it was not properly handled and left for months exposed to rain or snow.

Thus, British statistics on unexploded German bombs in the winter of 1940-41 show a clear increase during the 7 major offensive against Britain: whereas the count for the autumn of 1940 was less than 5 %, a quite normal percentage, it increased in the spring of 1941 to more than 10 percent.

The electrical fuse is sensitive to moisture, which reduces the capacity of the condensers and disintegrates the primercharge, quite apart from the harmful effects of corrosion on wire and other contacts.

The cables installed within the aircraft leading from the generator to the fuse were less sensitive to the effects of corrosion or weapons fire, as tests carried out prior to

7 World War II had shown, in which the aircraft carrying a bomb load had frequently been subjected to weapons fire.

Each time a bomber was to receive a bomb load, its wiring system for bomb ignition was first checked with simple instruments to insure its proper functioning. In cases where there was a high percentage of unexploded bombs (and it might be worth mentioning here that the percentage was higher for enemy bombs) the only possibility for the failure was that the electrical fuses themselves had become corroded, unless the aircraft crew had forgotten to switch on the fuse switch box. As early as in the late autumn of 1940 personnel carrying out surprise checks at the various tactical airfields found very badly neglected bombs held in stock: rust-seized fuses in the bomb sockets, bombs stored with the nose fuse downwards, under water, instead of on wooden lathes with the fuses sideways and covered with tarpaulins as they should have been.

The efforts of ammunition supply installations to first use up their poorest quality ammunition in order to be able to show only perfectly sound ammunition in stock at regular inspections also had an effect on the percentage of unex-
8 ploded bombs, for which no blame can be attached to the flying personnel.

All of this happened in spite of the fact that the output in fuses was at all times twice that of bombs, so that even the poorest quality bomb would always have had a new fuse if only the personnel at ammunition installations had been more reasonable.

Even in the fairly well regulated conditions of the Western Theater it proved difficult to insure that the flying units would always receive only sound ammunition, so that in the Eastern Theater these efforts were bound to fail. In the end it was found that responsibility could only be accepted for the supply of readied ammunition to the theater in Northern Africa, and there only because of supply and climatic conditions; at stabilized fronts methods had to be devised to insure that fuses were built into the bombs only shortly before their use.

In the German Air Force bombs up to a caliber of 550 pounds were stored and transported in wooden cases; as was the case with detonators for hand grenades, it was a simple matter to include the electrical fuses for bombs in the case, packed in airtight bakelite containers developed for the purpose; this insured that the fuses would not be forgotten or wrongly dispatched but would be delivered together with the bombs.

All that was necessary when putting in the fuse was to remove and then replace a screw ring, a process requiring

8 a very small effort compared with the readying of British and American bombs.

Attention must be drawn here to the hazards inherent in the use of electrical bomb fuses. Because of the extremely weak current required for the functioning of the fuse, care
9 had to be exercised to insure the utmost stability of all electrical factors involved, since even the minutest deviation could produce disastrous results. During almost ten years of practical use, involving thousands of bomb releases, no accidents of any kind occurred with fuses, and the contact system within the fuse itself as well as the safety devices in the ignition wiring system in the aircraft theoretically excluded all possibilities of hayards.

Immediately at the opening of the campaign in Poland the troops developed a critical lack of confidence in the electrical fuse because bombs had been observed to explode immediately under the releasing aircraft, causing its total loss. Investigations proved, however, that in such cases the machinegunner in the Do-17 (and later also in He-111) aircraft concerned had, in the excitement of battle, hit their own bombs while these were passing the muzzles of their guns. (With their unrestricted field of fire it also occurred that the machinegunner in the upper turret set the fuel tanks of his own aircraft on fire by firing into them).

These are examples of faulty training of crews in the German Air Force, which, in its rapid build up simply had not found time to carry out combined bombing and weaponsfire exercises.

Two similar cases were reported to have occurred during dive-bomber attacks at Sevastopol in the spring of 1942. Although these two incidents could also have been due to full hits by antiaircraft gunfire from the ground, a comprehensive check of all stocks of fuses was carried out in the Eastern Theater. Special staffs from the firms manufacturing the electrical fuses spent a number of weeks checking fuses from old deliveries, using special supercharging and testing instruments for the purpose. Out of 20,000 fuses thus tested one normal impact fuse No. (25) was actually found which ignited immediately on being supercharged and thus without the safety delay and without impact.

A thorough examination at the factory established that this was due initially to faulty structure, one of the insulating sides in the nose section being found to have been porous. This alone could not have caused any disastrous results, but an additional factor was that if stored in a damp place the so-called swelling factor of the electrical ignition medium could become smaller, meaning that the fuse would function with a smaller current than that used in delivery acceptance tests at the factory . In the past all "aging" tests had indicated precisely the opposite of these findings.

It can be assumed that excess voltage produced by the ignition current generator during the divebombing can also played a role as a third hazard factor.

Although it only seemed possible to explain any hazard by the occurrence of three different causes, each possible source of hazard was examined and removed by means of severer factory and stockpile controls as well as by the development of voltage stabilizers.

Chapter III
p. 11

2. Sources Adopted to Meet Fuse Requirements. In the development of electrical bomb fuses, no difficulties were encountered in meeting Point 1-3 of the specifications enumerated in the preceding chapter, but it proved all the more difficult to meet Points 4-6.

Point 1 was eliminated by the inherent characteristics of the ignition system itself. Compared with mechanical fuses the electrical fuse could be considered absolutely safe, since the current required to initiate ignition was not present at all up to the moment of bomb release. In contrast, accidents occurred frequently in foreign countries in the case of unsuccessful take off or if bombs with secured mechanical fuses were inadvertently dropped, since the heavy mass of the bomb compressed the fuse and the firing pin struck the percussion cap.

Point 2 could easily be met by means of a twin line and an appropriate wiring of the ignition current conducting circuit and within the fuse itself. (see Diagrams 2 and 3).

Two separate circuits were installed, one each for the non-delay and the delayed-ignition; as was the case in artillery shells, delayed ignition was insured by the burning of a powder grain. Numerous bombing tests against appropriate targets had to be carried out to determine the proper quantity of powder grain to be used. In bombing shore targets

11 with mine type bombs the best results were secured with a detonation delay of 0.08 second, after completing approximately one-half of its penetration capability in soil, the factors used in calculations being a normal bomb release from an altitude of 15,200 feet and the mean penetration capability for 110- and 550-pound mine type bombs.

The SC-500 1,100-pound mine-type bomb was intended initially only for use against ships and was given a delay of 0.15 second; the ultimate plan was to give this bomb a triple fuse as specified in Point 6.

Point 3, requiring that the fuse must function at any impact angle or direction was met satisfactorily by the use of several hose springcontacts placed in the several fuse surfaces. The hose springs provided a longer contact duration than the ball contacts first used as well as a safer flow of current. In the highly sensitized fuses (No. (26)) the impact contacts and the membrane contacts were arranged on the bomb nose or on a spacer spike; in the case of the (55)-A fuse they were arranged parallel with the inertia contacts.

Point 4, stating the requirement for safety bombing altitudes could be considered as an unnecessary relic from World War I. More as a matter of chance than by design the fuses of the rotating bombs used at that time hade become activated after a fall distance increasing with the caliber

12 of the bomb, since the same fuse parts --centrifugal arming device and flap springs--were used in all bombs for purposes of simplification.

With a 4-meter rise of the stabilizer vanes (in a fall of 4 meters the bomb rotatet once around its own longitudinal axis) the safety bombing altitude coincided more or less with a 300 meter fall for the 110-pound Fu/ bomb, of 500 meters for the 660-pound and of 700 meters for the 2200 Fu/ bombs. However, this applied only to the aircraft speeds of those times, which ranged between 90 and 133 miles; in bombing at greater speeds the forward travel of the bomb, and thereby the distance at which the fuse became armed, increased progressively, so that finally the fuse arming altitude was no longer adequate to allow the aircraft time to leave the zone endangered by the detonating bomb.

No other air power adhered to any such concepts of safe fuse arming altitudes, concepts which very seriously

13 complicated matters for the designers of the electric fuse although it seemed a relatively easy matter, initially, to so select and arrange the elements of the fuse, namely, the condensers, resistances, and ignition medium, that the time for supercharging from the accumulator to the ignition-condenser would correspond to the safety time of fall required (sketch).

In view of the significance which dive bombing tactics

13 gained in the German Air Force shortly thereafter, it necessarily became essential very soon to give consideration to even shorter drop times than those occurring in high-altitude bombing. In flattening out after its bomb release the dive-bomber often reached an altitude lower than that at which the bomb had been release.

The necessary accelerated supercharging was achieved by giving the fuse, at release in the dive-bomb attack, a 240 supercharge voltage instead of the 150 volt used hitherto in high-altitude bombing.

In low-level attack, which was understood to mean altitudes of between ten and one hundres meters (33 to 330 feet) however, a voltage of 150 had to be adhered to and the fuse had to be set at "delayed action" to avoid any danger of ~~xaxixgxkslexxthe~~ too quick supercharging.

The fuse was set for dive-attack or for horizontal bombing in the same way as the setting for "non-delay" or for "delayed action" by means of a special switchbox, the ZSK-241 (see sketch), placed within easy reach of the pilot or bombardier. At take off of the plane the switch was set at "off -(Aus)" and only changed to "on" over enemy territory, at which time the type of attack was also set. The actual fuse timing was only set when the target was within sight.

Graph

13a Supplementary to pages 422-423.

Legend:

Schematische Umladekurven im Verzoegerungskreis des elektr AZ (25) = Graph of supercharging curves in delay-setting circuit of the electrical elekt. AZ (25) bomb fuse

Hochangriff = High-altitude bombing

Sturzflug bezw. Tiefangriff = Dive bombing or low-altitude bombing

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13b Supplementary to pages 422-423.

Diagram

Legend:

Schaltung des Zuenderschaltkastens ZSK 241 = Wiring of the ZSK-241 fuse-setting switchbox

Als Stromquelle entweder FT-Anodenbatterie oder Umformer = Current supplied either from FT-Anode battery or transformer

Hauptschalter = Main switch

Kontrollampe = Control lamp

Wahlschalter = Selecting switch

Sicherheitswiderstand = Safety resistance

Masse = Body (of bomb)

o.V = Non-delay

m.V. = Delayed action

zum Zuender = To fuse

14 Point 5, the specification that in the case of a short bomb drop the fuse must automatically set itself at 14 seconds delayed action was only stipulated later, in 1938, by the appropriate xxtxaritiex command authorities. The object was to obtain a bomb fuse which could be used uniformly against all shore targets. This fuse was designated No. (25) and was also called the "thinking" fuse.

To anticipate a final appraisal, let it be said here that xhisxxxskingxforxtxsxxnxx exaggerated demands have never produced a usable weapon, starting from the World War I all-purpose shell of the German field artillery which was to be equally effective as a high-explosive and as a shrapnell missile, to the World War II multi-purpose bomb.

The "multi-purpose" (25) bomb fuse was indisputably an exaggerated demand. Success was admittedly achieved in meeting the diversified and in some cases overlapping desires of the Air Force Operations Staff, but at the cost of an exceptionally large percentage of rejects, because exceedingly severe standrads had to be set for the electrical properties of the individual parts. Although the quality of the electrical fuses coming from mass production improved over that of the models used in prior tests (for example, the inulation and the capacities improved progressively), external influences were underestimated, which could arise from inappropriate

19 storage and manifested themselves not only in fuse failures but also in the hazards of premature detonations of bombs.

The condensers were wound one over the other, proof against damping and induction, so that there was no greater counter capacity than 15 centimeters, and in this work insulation~~s~~ capacities of 3,000 megohm/microfarad had to be achieved.

The resistances in the (25) fuse had coefficients between 11 and 50 megohm at 1/2 Watt, tested for a precision of from 20,000 to 30,000 ohm at temperatures varying by more than 100° Centigrade.

Because of the very small space within the fuse the resistances were constructed by steaming collodial carbon on to the spirally incised surface of the porcellain base, after which a waterproofing varnish was applied.

However, the severest demand was that made on the electrical ignition medium.

Each of the three ignition condensers had a capacity of 0.2 MF: with an ignition tension of 28-35 Volt and an allowable ~~a~~ maximum ignition delay of 10 -5 seconds, the so-called liminal ~~value~~ factor (Schwellwert) was only 0.2 milliwattseconds. Such a high degree of ignition sensitivity could only be achieved with very short and exceedingly thin bridged incandescent chrome-nickel wires of less than 1/100th millimeter in dia-

14a

Diagram

Supplementary to pages 426-428.

Legend:

Zm o.V. = Ignition medium; non-delay

Zm V.Z 14 s. = Ignition medium; retarded ignition 14 seconds

Einbausicherung = Accessory safety fuse

o.V. m.V zum ZSK = non-delay; retarded ignition to ignition switchbox

a = Impact contact

15 diameter, the "bridge" was dipped ~~frequently~~ repeatedly in plumbous trinitroresorcinate (Bleitrinitror sorcinat) to form the igniting pill which had to transfer the requisite ignition energy to the percussion cap and primer charge.

In Germany this type of high-precision work was done not only by one but by quite a number of ~~xxxlk~~ firms which, though small, were under excellent technological management.

However, the (25) fuse in point of space and wiring was so complicated in structure that errors frequently occurred in firms constructing them under licence, errors which only became apparent in use.

In spite of all complications and difficulties, however, the suitability of the electrical bomb fuse was never doubted. The fundamental flaw in the whole system was in the exaggerated demands made in specifications, which were just as harmful in the case of a small item like a fuse as in large projects, for example in the demand for a 4-engine dive-bomber plane, which resulted in the monstrous He-177 dive-bomber.

In anticipation of future procurement difficulties, the Air Force authorities responsible for weapons development already prior to the war developed what was called a substitute fuse, the No. (55). This fuse had only impact ignition with retarded and with delayed-action ignition. It was constructed of parts exceeding the tolerance limits

16 of use in the No. (25) fuse. The casing was of welded sheet metal, xxixx and its mechanical parts were all stamped out; the wire contacts were all welded, so that the labor required in its production was practically nil.

The mere fact that a fuse is named a substitute item denotes that if the event should arise it would be the only type of fuse produced. This event arose when, shortly prior to the outbreak of World War II the demand for supplies suddenly mounted tenfold (to a requirement of 1,000,000 electrical bomb fuses per month), due to the increased current output in substitute types of bombs with welded and with concrete casings.

In this situation the Air Force General Staff ordered that the axxpxx monthly output of No. (25) fuses was to be increased to the envisaged maximum of 100,000 and that No. (55) fuses were to be produced to meet the remaining requirements. This was not only a technological absurdity but also faulty from the command viewpoint, since it was not possible to so direct supplies to the fighting front all around Germany that the proper bombs with the proper fuses would always be available XXxXXx in the comabt areas where they were required.

17 Another point deserving mention here is that, owing to its simplicity, the No. (55) bomb fuse was also more

17 reliable in its functioning than the No. (25).

If it is accepted that each type of bomb should have the fuse with which it would achieve its maximum performance, then it was wrong to differentiate between a normal and a substitute fuse.

It was impossible to produce 1,000,000 No. (25) fuses per month, so that it would have been a sounder policy for the time being to manufacture only No. (55) fuses, since the non-delay effect is the more important in mobile warfare and since the delayed-action ignition xxxlxxpxoxxxx in use against inanimate targets would produce results equivalent to those of the retarded ignition effects.

The only point which had to be dropped from the list of specifications was Point 5, with its demand for automatic re-switching. In practice, however, the order was valid that any aircraft going over to a low-altitude attack was to set the fuse switchbox at "retarded ignition" and "horizontal bombing."

Just as the (55A) fuse with a highly sensitive membrane contact was developed later from the (55) fuse as soon as xx the horizontal bomb suspension became possible, a (25B) fuse xxxlxxxxx with selective "retarded ignition" or "delayed-actionxXIgXIXXXX (0.8 second) ignition would have developed from the No. (25). This fuse could have replaced all other fuses in bombs to be used against shore targets and would have made it possible to avoid the difficulties encountered with the No (25) fuse.

The attached table of fuses contains the significant data on the more important types of electrically operating impact and time fuses used by the German Air Force. A supplementary sheet illustrates by means of diagrams the somewhat complicated arming process of the (25) bomb fuse.

The electrostatic impact fuse also provided the basis for the development of electric time and proximity fuses.

The No. (9) electrical time fuse, of which a wiring diagram is presented on page 432, was used in flare bombs, in chemical bombs with a filling of viscous mustard gas, and in bomb containers types AB-500 and AB-1000 for small caliber bombs. The basic scheme of this time fuse is practically the same as that of the impact fuse, the only real difference being that the impact contact is replaced by an oscillating lamp (Ueberschlaglampe) which allowed the current to flow through to the ignition medium as soon the point of rectfied voltage was reached.

The so-called extinction tension of the spark line was 190 Volt. In serial production this voltage had to be insured with a plus-minus tolerance of 4 Volt, in order not to allow the running-time deviation to exceed that of

18a Supplementary to pages 430-431.

Diagrams

Legend:

Grundschaltung des elektrostat. Bomben-Zeitzuenders (9) = Basic wiring of No. (9) electrostatic time fuse for bombs

Aufladespannungen: + 500 V = Charging tensions: + 500 Volt

veraenderlich zwischen ± 500 V = Alternating between + 150 and - 150 Volt

Glimmlampe 190 V (± 4 V) = Glowlamp 190 Volt (plus-minus 4 Volt)

K_1 = Speicherkondensator = K_1 = Accumulator condenser

K_2 = Zuendungkondensator = K_2 = Ignition condenser

Bemerkung: Ausgleichsspannung 5 V unter der Zuendspannung = Remark: Rectified voltage 5 Volt less then ignition Voltage

18 the S-30 clockwork time fuse in use for antiaircraft shells, which had a maximum time deviation of 0.15 second.

In order to obtain the desired time setting between a minumum of 5 and a maximum of 50 seconds, the ignition condenser in the No. (9) fuse was given an initial bias tension at bomb release, the voltage being regulated by a potentiometer with seconds calibration in the auxiliary time-fuse switchbox. For the minimum transmission time the initial bias tension was approximately + 150 Volt, for the maximum transmission time approximately - 150 Volt. In contrast the accumulator condenser was always charged at 500 Volt. The rectified tension of the two condensers was about 5 Volt below the extinction voltage of the vacuum tubes.

For the bomb containers AB-50 and AB-250, which had fillings of 2.2 to 33-pound fragmentation bombs and were used chiefly by ground-attack aircraft in low-altitude or dive-bombing operations, a continuously adjustable time fuse was unnecessary. They were used with Nos. (59), (69), and (79) powder-train fuses. These had been specially developed for the purpose, and with their two time settings in the non-delay and retarded ignition circuit were adequately adapted to tactical requirements.

19 For the SD-50 multi-purpose bomb an electrostatically controlled proximity fuse, No. (39) was developed already

19 prior to the war, with a circuit system the same as that shown in the attached Proximity Fuse diagram for antiaircraft artillery shells.

Regardless of the bomb release altitude, 110-pound bombs armed with this fuse detonated 0.5 to 1 meter above ground and thus had a fragmentation effect at least 25 percent greater than that achieved by detonation at impact with a non-delay fuse setting. However, this fuse was not introduced for use because a program of simplification of types was carried out at the beginning of the war and the SD-70 bomb, a consolidation of the SC-50 and SD-50, produced approximately the same results.

Later, the SD-70 was given the No.(55A) fuse with a highly sensitized membrane contact screwed either into the nose of the bomb or even into a nose spike which could be fitted to the bomb and thus raised the burst point to above ground level. In any case, this solution was more simple than a solution involving anew fuse would have been.

The fuses for bombs to be used against ships had a circuit system no different from that of bombs for use against shore targets, the only difference being that their retarding or delay elements were different and that the fuse arming times were adapted to the special tactical conditions involved.

19 [illegible]ere, a special advantage of the electrostatic fuse system became evident; without any necessity for the production and testing of new mechanical parts, it was possible after laboratory experiments to use condensers and resistance elements with other potentials plus appropriate powder grain delay elements and put the new type of fuse together.

20 Initially, 150 and 240 Volt anode batteries were used to charge the fuse at bomb release; the 500 Volt tension required for the No. (9) time fuse was taken from a transformer in the Z[illegible]K-501 time-fuse switchbox.

In order to eliminate the effects of cold temperatures on dry cell batteries, a~~n~~ trans[illegible] [illegible] introduced also for normal fuses [illegible] possible to [illegible] secondary tension circuits functioning independently of ~~XKE~~ variations in the load placed on the general electrical circuit of aircraft.

Tests in which fully equipped aircraft were taken under fire with 88-mm shells showed that even in the case of hits in the distributor boxes the current was cut in only 5 percent cases, while no short circuits occurred. In order to reduce these interruptions to a minimum, the fuse electricity circuit in aircraft was installed as a ring cable, so that the fuse received its charging current by two ways from the charging circuit. A parallel contact with the voice-radio

20 battery provided a reserve source of electricty, which could be switched on if the control lamp on the fuse switch box failed to register.

Each time an aircraft received a load of bombs, the functioning of the fuse ignition circuit was first checked by means of a small testing apparatus.

The electricity charging plugs, which formed part of the standard bombing equipment and were plugged into the fuse heads when the bombs were loaded, were so formed that when the bombs were suspended they connected the condensers of all fuses with the body of the plane (earth) in order to prevent unintended charging, for example, by lightning. At release of the bombs the charging plugs remained inserted long enough to insure that the suspension lugsof the bombs definitely were clear of the suspension equipment; experience showed that a drop of 25-30 centimeters was adequate for this purpose.

Only then, and thus after the bomb release, did the charging plug establish contact and the accumulator condensers in the fuses received their necessary voltage; the plugs then disengaged from the fuses, the transmission from the accumulator condensers to the ignition condensers commenced, and the runnining time was initiated.

21 In efforts to eliminate the possibility of non-detonation of bombs due to causes inherent in the ammunition used, a simple fuse testing instrument was used to check the functioning of the fuses in all ammunition held in storage ready for use from time to time.

The fuse heads were provided with a protective capxxxix, similar to a bottle cap, with a mipol sealing (Mipolam = a type of synthetic rubber--Note by Translator).

In the Eastern Theater it was found advisable to give all ammunition stored ready for use another check shortly before use. It had been found in a number of cases that Partisans had tampered with poorly guarded ammunition, removed the fuses, and replaced them with fuses from which the supercharging/ resistances had been removed. These "sabotage" fuses detonated the bomb at the moment of release, destroying the releasing aircraft and its crew.

Under field condition, also, it is necessary to keep all fuses, electrical or mechanical, under lock and key.

To meet the requirement of Point 3 of the list of specifications (detonation from impact on any part of the bomb), No (55A) fuse, in addition to the highly sensitized membrane in the dome nose or the attached nose spike, also had an "all-around" non-delay impact contact inside the fuse, and in the "delayed-action" setting circuit there were two such inertia contacts in two surfaces perpendicular to each other, which were activated by stoppage of the bomb fall.

Contacts of this kind were adequate in every respect to achieve the non-delay effect in mine-type bombs; initially, spherical springs were used for the purpose, later hose springs, which gave a longer contact duration.

When bombs were released at altitudes of 14,500 feet the explosive charge detonated with relative precision when the bomb nose had penetrated to a depth equal to roughly two-thirds of its diameter in a sand or loamy surface, the depths measured being 13 centimeters in the case of the SC-50 and 24 centimeters in that of the SC-250 bomb. The total delay at an impact velocity of 250 meters per second can be calculated by the formula $5 - 10 \cdot 10^{-4}$ second, so that a full blast effect was insured around the impact point.

The only factor which made it necessary to raise the burst point in order to improve the fragmentation effect was the deep snow encountered during winter in the campaigns in the eastern theater; this requirement was very soon met by fuse No. (55A) plus a nose spike.

Very comprehensive tests were needed to determine the proper delay factor when using a powder train in the fuse between the E/83 electrical ignition medium and the C/98x

22 primer charge. The fundamental rule is that a bomb with delayed-action detonation should explode at that point in time and space when it can be expected to produce maximum effects. In normal buildings this is the case when the bomb has penetrated into the house and its nose touches the cellar ceiling; explosion of the bomb at this point will shatter the cellar and also blow out the side walls of the building. If the bomb penetrates deeper, the explosion will only have a shock effect on the surrounding areas and the walls of the building will remain standing, except in the case of large caliber bombs. In the case of highly resistant targets, such as the concrete covers protecting industrial installations, consideration must be given to the hardness of the casings of mine-type bombs and the detonation must be set to insure that the bomb casing will not burst before explosion occurs. This was also realized by the forces opposing Germany in World War II, which is obvious from the fact that during the war both the British and the Americans used faster fuses in their 500 and 1000-lb General Purpose bombs in place of those used initially, which had given a delay of 0.1 second.

Armor-piercing bombs must burst immediately ~~behind the~~ beneath the deck of a ship if they are to produce maximum results.

For the purpose of determining the optimum delay factor

23 in mine-type bombs for use against ships precise data was available from test blastings on the optimum depth of water in relation to the size and composition of the explosive charge. Using this data from the Navy, the Air Force experimental station at Travemuende carried out a series of experiments with bombs suspended from buoys at various depths and thus exploded. A camera registered the height and shape of the column of water thrown up by the explosion, together with the duration of its initiation. Further tests then followed with bombs of the same caliber released from various altitudes. The results of these bomb releases were also photographed and the data on the various water columns was used to determine the optimum delay factor.

On shore, a multi-storey high house, partly of concrete and partly of steel framework structure served as an experimental target at the Jueterbog artillery firing range. However, 24 the building had no side walls, which were omitted in order to be able to photograph the moment of detonation in the various storeys of the fuses used in the practice bombs. These detonating experiments, which were carried out in 1933, resulted in introduction of an 0.08-second delay factor for fuse No. (25) with SC-50 and SC-250 bombs.

In 1936 the Inspectorate of Civilian Air Defense (*Ziviler Luftschutz*) constructed a series of real dwelling

24 houses at the bombing practice range of the Rechlin XXXXXX Proving Station. Test bombings here made it possible to determine precisely the effects of mine-type bombs and confirmed the suitability of the 0.08-second delay factor.

When striking natural ground, with the bombs released from altitudes between 7,200 and 16,500 feet, this delay factor corresponded roughly to one-half of the penetration depth capability of the bomb and the bomb crater formed was relatively open, meaning free of earth falling back. This is highly important in the bombing of enemy airfields if the runways are to be rendered unusable. The slope of the bomb crater must correspond as closely as possible to the slide angle of the type of soil concerned.

When bombing underground installations, however, it is at times desirable to have the bomb explosde at the greatest depth possible; this effect could be achieved with the No.(25) fuse by turning a sxtxxxxxx regulating screw at the end of the fuse to switch off the 0.08 second delay, so that only the regular delayed-action of 14 seconds remained in function.

Work continued also during the war on efforts to replace the powder grain delay element by a kinetic delay element, but 25 the war ended before the fuse No. (75), intended for this purpose, could be placed in service. The ignition acceleration of this fuse was tuned to the bomb behavior when penetrating

25 into earth, primarily a problem of cross-sectional tensions, or when crashing through house roofs and ceilings, depending more on the weight of the bomb itself. The purpose of the kinetic delay element was to insure that explosion would be delayed in the event of a full hit on a target and without xxix retardation if the bomb struck open ground, in order to secure maximum results in either case.

Point 6, the last requirement in the list of specifications, referred to what was called the triple-effect fuse.

In modern ships of that period the upper decks were of normal ship-building steel and only the armor protected decks were of alloyed steel.

According to data from gun-fired tests, the SC-250 and SC-500 bombs with one-piece casings had a hardness giving them a penetration capability of 50-mm of shipbuilding steel making it possible to bomb appropriately resistant targets with the fuse set at retarded detonation, with which the bomb could do considerably more damage inside a ship than if armed with a non-delay fuse.

This became clearly evident later when Soviet-Russian 220-pound mine-type bombs struck the German battleship Deutschland (Mallorca 1936) and when American 1000-lb demolition bombs struck the French battleship Dunkerque (Toulon 1944). In both cases the blast effect above the armor protected decks

25 extended from one side to the other of the ship, whereas bombs with non-retarded impact fuses only showed traces of fragmentation effect.

26 If a mine-type bomb struck the cover of a turret or any other particularly resistant part of a ship's superstructures, it could naturally do most damage by exploding before its casing fractured, so that it could damage radio installations, aircraft carried by the ship, or other vulnerable materials, thus reducing the battle value of the ship itself.

If the bomb entered the water alongside the ship it was to explode at a considerable depth in order to cause leaks in the ship. However, if the bomb struck a submerged submarine then, according to pre-war principles, it was to explode at impact, even if it was a depth-charge type mine with a fuse set for a depth explosion.

Development of the desired "Naval fuse" in the complicated form enabling it to meet all these requirements was not completed.

For this reason naval reconnaissance planes for the time being carried bombs armed with the normal impact fuse; without any risk they could drop SC-50 bombs thus armed on submarines. The retardation factor here was only 0.15 second and the running time of the fuse ignition system, using a 150-Volt supercharging tension, was only 3 seconds, so that proper

26 functioning was insured even in a down-sloping bombing run. The retarded ignition element intended for bombs used against shore targets was omitted in No. (28A) fuse; the non-retarded ignition element was retained so that seaplanes could also rely on blast and fragmentation effect when bombing seaplane bases, particularly seaplanes anchored at their buoy.

The Marine (No. 28a) fuse (Seezuender Nr. (28a)) was replaced already at the end of 1939 by fuse No. (38), which had three different retardation elements and was better suited to meet the requirements of attack against ships than the No. (28a) fuse.

27 The bombing of merchant ships with SC-250 and SC-500 bombs in the waters around Britain called for special tactics adapted to the target and the defenses encountered in the attack. These tactics were possible with the No. (38) fuse: if the target approach had to be at a high altitude, the fuse switch box was set at non-retarded, but in actual fact the bomb then exploded at a depth of 5-6 meters under water, since a short retardation element of 0-05 second built into the non-delay ignition circuit insured a detonation depth under water, when the bomb was released at altitudes of 13,200 feet, indicated as the most effective depth against medium size ships (maximum displacement 10,000 tons). At altitudes

27 around 3,300 feet a retardation of 0.2 second was found best, and for low-altitude attacks at around 165 feet, a retardation factor of 5 seconds was used. In the latter case consideration had to be given to the possibility that bombs might bounce off the water surface or off a ship and fly high up into the air before against striking the water surface.

Initially, the safety of the bombing aircraft was the determining factor in the selection of this delay factor for low-level attack, on the other hand, it was also found later that this delay produced the best results, namely, when the bombs were provided with baffle plates to prevent bouncing.

With a baffle plate attached to its nose, and intentionally dropped slightly ahead of the target, the bomb travelled along the surface for about 165 yards and then sank to detonate underneath the ship.

Combat experience fully substantiated the soundness of the retardation or delay factors determined in practice bombings, and the No. (38) fuse played its role up to the end of the war.

28 For the PC-1000 and PC-1400 armor-piercing bombs the No. (35) electrical fuse was developed, which had a 0.1-second retardation element in each of its two ignition circuits, the dual purpose being to exclude the possibility of unintended

28 [illegible] without [illegible] ignition circuits available for more secure functioning, since these valuable bombs had only one fuse each. The running time of the fuse release mechanism was shorter in the No. (35) fuse, so that these armor-piercing bombs could also be delivered on target in dive attack, which alone gave them the velocity required for their maximum penetration capability. The reason for the long fuse delay was that the impact velocity of the bomb when delivered in dive attack (roughly 180 meters per second) was smaller than when released in high-altitude attack (roughly 250 meters per second), while the armor plated decks of aircraft carriers are deep below the flight decks.

Both the No. (35) and No. (38) fuses could be simply put together from ready parts and supplied immediately in large numbers to the troops, which illustrates the wide adaptability of the electrical fuse to requirements suddenly arising at the front.

Armor-piercing bombs produce maximum results when they explode immediately after penetrating the greatest resistance, since the propelling machinery of a ship, as well as the ammunition and fuel supplies are just below the armor plated decks.

In spite of well placed bombings, the Royal Air Force failed to sink the German battleship Scharnhorst in attacks

28 at an [illegible] in the summer of 1941 because three armor-piercing bombs of the AP-2000-lb type were set with a too long delay, penetrated right through the entire ship, and only exploded in the mud below, where the under-water blast effect of the
29 176-pound explosive charge carried by bombs of this class is inadequate, particularly since it first has to shatter the thick bomb casing.

German Rocket-assisted armor piercing bombs were armed with the No. (49) electrical fuse which, after a burning duration of 2.7 seconds ignited the propellent rocket charge and at impact had a retardation of 0.045 second. The German PD-500 and PD-1000 armor-piercing bombs constructed later had the same retardation element built into the one ignition circuit, while the other circuit, with a 0.075 second retardation element, could be selected for bomb release at lower altitudes and against less resistant targets; the fuse used here was No. (48).

The work which commenced at the beginning of the war on the development of super-caliber mine type bombs created the acute necessity for introduction of a supplementary contact arrangement dependent on acceleration in order to fulfill part of the original fuse requirement stated in Point 6 of the list of specifications, since these bombs were to be used exclusively against warships.

29 Parallel with a powder grain retardation of 0.12 seconds, designed to detonate bombs delivered in dive attack at a depth between 33 and 50 feet under water, the new No. (28B) fuse was given a kinetic delay element adapted in each case to the bomb casing and the mass of the bomb concerned, which was activated by stoppage of the bomb at impact. Corresponding to these factors the (28B) fuse in SC-1800 bombs was set at 800 times gravity acceleration "g", in SC-1000 bombs at 2000 "g". The SD-1700 multi-purpose bomb, development of which was unfortunately abandoned later, would have been set at 6000 "g", since it was far harder than the mine-type bombs previously mentioned and, in the case of direct hits, would have penetrated deeply into a ship.

30 Experience showed that negative acceleration factors of this magnitude did not occur when the bomb struck water.

The use of bombs armed with these fuses in the bombing of houses during the missions flown against Britain in 1940 was, naturally, a completely wrong use.

In London, and particularly in the vicinity of the docks, the substrata consists of a mixture of sand and loam, which offered very little resistance against bomb penetration. With a fuse delay of 0.12 seconds, practically every bomb would have penetrated to its maximum capability; when unexploded bombs were dug out later, it was found that SC-1800 bombs had, on an average, penetrated to a depth of 16.5

30 lbs, on an average, penetrated to a depth of 1[illegible].5 meters. From this it is possible to compute an average acceleration of 235 "g", so that the bombs in question exploded with a delay of 0.12 second at such a great depth that they produced no blast effect but only a ground shock within a restricted radius. Air photos taken by German reconnaissance planes showed wide craters, at the edges of which the houses showed very little damage. From then on the super-caliber mine-type bombs, when used against shore targets, were given a non-delay impact fuse, so that they produced the same results as the air-land mines (marine ~~bombs~~ mines suspended from parachutes and armed with delayed action fuses for use against shore targets).

Initially fuse No. (26) was used, as a particularly sensitive impact fuse, in chemical and fire bombs, since even very slight penetration into the target greatly reduced the effectiveness of bombs of these types. The No. (26) was a normal electrical side fuse, the only difference being that an impact rod of electrometal conducted the shock of impact directly to the fuse and closed the non-delay ignition cir-
31 cuit. Since this complicated the construction of the bomb, the No. (26) fuse was soon replaced by the previously mentioned No. (55A) fuse which, owing to its membrane contact in the bomb nose, was far more sensitive.

The "deformation fuse", No. (24) which was developed

51 later, was similar in structure to the No. (2[illegible]) fuse. It was used in the [illegible] and [illegible]-2500 bombs, a strong horizontal rod carrying the impact shock from the bomb nose. Otherwise, it could have occurred that the front part of the bomb would have fractured before the fuse had slowed down sufficiently to establish contact.

Besides the impact and time fuses discussed, the German Air Force had a series of electrical fuses used only to initiate other functions, for example in remote control marine mines, or which consisted solely of a detonating head.

52 3. Development of Special Type Fuses. The attached list shows a number of special type bomb fuses, from the electromagnetic type of impact fuse, No. (66) for the so-called hollow or shaped charge bombs, to nuisance detonators (Stoerzuender).

Even when the latter, as long delay fuses, contained a clockwork mechanism or functioned chemically they were always switched on electrically, since the element for this purpose, the fuse switchbox, was mounted in the bombing aircraft. Only the fuses for small caliber bombs had a mechanical securing device, which in some cases functioned exclusively on the basis of mass inertia of the individual fuse parts. For the sake of completeness they will be discussed at the end of this report.

In connection with development of hollow-charge bombs it became necessary in 1942 to develop a fuse with a highly sensitive functioning and which would initiate detonation of the bomb from the rear end of the explosive charge, as was essential to secure the hollow-charge effect (Chapter II, 4). Allowances had to be made for very small caliber bombs, such as antitank bombs with an explosive charge weighing only a few hundred gramms, so that the electrostatic fuse, which required a relatively large space, could not be taken into consideration for this purpose.

After roughly one year spent in development work, the

32 No. (66) electro-magnetic impact fuse made its appearance as a mutual development by a number of electrotechnical firms. In this fuse the igniting energey was created by a small coil being forced out of the magnetic field ~~xxximxxxx~~ by the impact of a steel core; this induced electric tension in the coil, and this current was conducted to the igniting element.

33 The structure of this interesting fuse is shown in the attached photos; in those photos the individual parts are as follows:

1, is a plastic wind propeller which, after removal of a protecting cap from the fuse head, was driven by the slipwind and released the fuse mechanism.

2, is a centrifugally functioning coupling and unintentional arming of the fuse was excluded by the fact that only at wind velocities above 30 ~~xxxxxxx~~ meters per second it connected with

3, the spindle by means of grooves in the coupling ~~xpixdlx~~ shaft locking into the gear cuttings on the spindle. The spindle thereupon wound itself out of

4, the socket far enough to release

6, the contact spring from

5, the extension pin of the spindle.

At safety position this spring short-circuited

7, the magnetic coil; in fuse-armed position, 33 however, it connected the igniting medium with the magnetic coil. In this position fuse No. (66) was armed, and at impact the wind propeller with its spindle, the length of which was extended by screwing out of the socket, was forced inward, forcing

le, the core, out of the magnetic field. The current induced in the coil was conducted by

9, the plug prong, to the igniting medium, which was thereby ignited.

To prevent the core from falling out of the magnet, the central part of the fuse, which was of pressed artificial resin, had a small overlapping edge, which was ripped off by the core at impact of the fuse. This required little force and therefore caused no retardation.

The lower part of fuse No. (66), also of XXXIXXIX synthetic resin, was readily removable in order to be able

34 to mount the fuse in the base of a bomb; in this case the two parts of the fuse had to be connected by a cable.

The photos of the No. (66) fuse (p.453) show the fuse adapted for use as a nose fuse in SD-9, SD-10A, and SD-15 fragmentation bombs.

The casing, 4, has a spherical base so that the spindle with the wind propeller at impact can stand at a slope, since even at such flat angles as 20° on the sloped facings of a tank it was possible to achieve penetration with the

Photo

Electrical Nose Fuse No. (60)

At safety Armed

Photo

Ignited at a sloping impact

of a tank it was possible to achieve penetration of the armor plating with the SD-4- 1 hollow-charge antitank bomb.

When a large number of small bombs are ejected from a bomb container, they are liable naturally to knock hard against each other. To protect the wind propeller against these knocks it was provided with a steel basket, which served simultaneously to screw the in the entire fuse by a 25-mm thread.

For the outside suspension of large-caliber bombs armed with the No. (66) fuse, the fuse had a protecting cap. This was attached to the steel casing and removed by a wire at bomb release.

Later, the No. (66) fuse was also used in the Army Panzerfaust[1] antitank missiles, replacing the former fuses which had caused numerous accidents. It was also to be used in the air-to-air R-4-M rocket.

"Nuisance fuses" (Stoerzuender) was the heading under which the German Air Force included all fuses used for the purposes of extending the effects of an air attack beyond the time of the actual bombing, by means of bombs set to explode at varying intervals after impact, or which would be detonated by exterior causes such as jolting or other movement.

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[1] Antitank rocket type missile used by infantrymen.

The most [illegible] fuse No. (50), the firing system of which is shown in the attached sketch (p. 456). It was usually built into the second fuse cavity of an SC-250 or SC500 bomb, which normally had a clockwork long-delay fuse No. (17a).

Fuse No. (50) was constructed as an ordinary single-circuit electrical fuse, the only difference being that the the transmission of current from the accumulator to the ignition condenser was not completed within seconds but only after XXX a lapse of about ten minutes, and thus long after impact of the bomb. The hose springscontacts built into the fuse were extremely sensitive (according to British sources any movement of the fuse by 0.15 inXXZXX millimeters was enough to activate them within 0.025 se[illegible]) so that there was no possibility to dig out and remove any such bombs which appeared to have failed to explode.

The same fuse was also used in nose-spike bombs. These were 110- and 550-pound mine-type bombs with a spike, 40 inches in length, welded onto the nose. Dropped onto a railroad permanent way they remained sticking and the vibrations of a train passing over them activated the fuse, in a way similar to the functioning of the acoustic remote detonation fuses used in marine ground mines.

Any effort by enemy personnel to discharge the conden-

[illegible] fuse No. [illegible], the springing stop of which is shown in the attached sketch (p. 45[illegible]). It was usually built into the second fuse cavity of an 250-kg or 500-kg bomb, which normally had a clockwork long-delay fuse No. (17A).

Fuse No. (5[illegible]) was constructed as an ordinary single-circuit electrical fuse, the only difference being that the the transmission of current from the accumulator to the ignition condenser was not completed within seconds but only after xXx a lapse of about ten minutes, and thus long after impact of the bomb. The nose springcontacts built into the fuse were extremely sensitive (according to British sources any movement of the fuse by 0.15 XXXXXXX millimeters was enough to activate them within 0.025 seconds) so that there was no possibility to dig out and remove any such bomb which appeared to have failed to explode.

The same fuse was also used in nose-spike bombs. These were 110- and 550-pound mine-type bombs with a spike, 40 inches in length, welded onto the nose. Dropped onto a railroad permanent way they remained sticking and the vibrations of a train passing over them activated the fuse, in a way similar to the functioning of the acoustic remote detonation fuses used in marine ground mines.

Any effort by enemy personnel to discharge the conden-

35a [illegible].

Diagram

Legend:

Schaltung des sogenannten Stoer-Zuenders (50) = Electric circuit of the so-called nuisance fuse No. (50)

35b Diagram

Legend:

SC-250-Stabo = SC-250 (550-pound) nose-spike bomb

Buchse fuer Stoerzuender (50) = XXXXXXXXXX Cavity for No. (50) nuisance fuse

Buchse fuer Langzeitzuender (17) o. (57) = Cavity for long-delay fuse No. (17) or (57)

Druckstueck = Pressure section

Stachelspitze = Nose spike

35 condenser by the insertion of a plug closed the circuit and the bomb exploded.

That the No. (17) long-delay fuse initially was not intended as a nuisance fuse but rather bxxsix for use by air forces serving as the extended heavy artillery supporting the ground forces is evident from its very construction. It was a clockwork operated fuse, of which there were two versions : No (17A) and No. (17B). No. (17A) was set, prior to suspension of the bombs under the aircraft, by means of a special setting key, to initiate detonation of the bomb after a delay of between 2 and 72 hours; No. (17B) was set in the same way to detonate after a delay of between 5 and 120 minutes. With reference to the longest duration of delay, the only means to insure such small margins of error as 30 minutes or one minute was by a clockwork mechanism, and this degree of time precision was essential to enable the infantry to occupy previously bombed terrain without danger from over-delayed detonations.

Up to the moment of impact the striking pin and clockwork mechanism of the No. (17) fuse were held in a state of inertia, since otherwise the balance wheel of the clockwork would have been damaged. It was only after penetration into the target that the clockwork mechanism was set in motion through the delayed-action circuit in the electrical upper

36 part of the fuse mechanism by means of a powder train which melted an obstruction of synthetic resin.

In order to make it impossible for enemy bomb disposal personnel to remove the long-delay fuses from bombs, the No. (17A) fuse in later bombings was combined with the No. (40) disarming obstruction fuse, which became armed at impact and could only be rendered XXXXXX innocuous by boring the entire fuse casing and cavity out of the bomb.

The British Government soon realized the threat which these so-called nuisance bombs constituted for the armament industries, means of transportation, and the population, and formed commissions which included notable scientists who developed all manner of methods to dispose of unexploded bombs. On the German side, in turn, every effort was made to frustrate these efforts of the British so that this form of indirect

37 warfare gradually assumed proportions reminiscent of mine warfare at sea and which tied down considerable manpower in bomb disposal operations.

When it became known that the British were able to arrest the No. (17) long-delay fuse by placing a large electro-magnet over it and to discharge the No. (50) vibration fuse by means of steam or a fluid with low condictivity, the time had arrived for the German side to use other nuisance fuses. The No. (60) fuse contained two 1.5-Volt dry cell batteries as

37 its source of power; these batteries were switched in via the aircraft fuse control circuit at bomb release and therefore had a considerably longer life-span than the No. (50). Besides its highly sensitive tube-springs, its ignition contacts consisted of three mercury-filled tubes, which were also arranged in the various surfaces and closed the circuit to the ignition at the slightest change of position.

Chemically functioning long-delay fuses were used by both opposing sides, first by the Royal Air Force in the bombing of the Stavanger airfield in Norway in April 1940. Although this fuse also had a mechanical xxxx disarming obstruction, the first unexploded bomb of this type showed on inspection that an important part of the fuse had broken, so that the details of its construction became known.

The long-delay system here consisted of a glas ampule containing aceton, which shattered at impact, releasing the aceton to dissolve a celluloid disc within a few hours, thereby releasing the fuse striking pin and initiating the detonation of the bomb.

Because of the fact that the trajectory of bombs in soil usually curves upward and the point of unexploded bombs usually has an upward slope, the XXXXXXXXXXXXXXX celluloid disc frequently did not come into contact with the aceton itself but only with its fumes. This extended the time of

37 delay, a circumstance which the Royal Air Force considered as a disadvantage, whereas the number of days spent in uncertainty as to when the bomb would detonate caused the German bomb disposal services serious difficulties.

To improve the functioning of their long-delay fuses, the British commands gave orders that the arming propeller was to be screwed in further so that the aceton container would be fractured already while the bomb was still falling. In this way the aceton flowed onto the sealing celluloid disc and the space above the fuse striking pin was sealed by a rubber washer. On the German side it was now possible to rely on the majority of all British long-delay action bombs detonating between four and eight hours after impact and to take action accordingly. The bombs which did not explode within this space of time were usually genuine duds, which could be dug out with relatively small risk after a certain time allowed for safety.

The German chemical long-delay fuse No. (57) also functioned by the dissolving action of aceton on xxxxxxx a celluloid disc and had **a disarming obstruction**; an innovation here was an acceleration ignition device, which initiated the bomb detonation if the bomb struck a target with a resistance coefficient greater than the penetrating capability of the bomb casing. Only mine-type bombs with one-piece drawn and pressed

38 springs of quality category I were to be [illegible] [illegible]

[illegible].

The No. (57) fuse was delivered to the troops with three separate timing periods. The fuse running times, from 1-100 hours were stamped into the side of the fuse casing and were regulated by different concentrations of the dissolving fluid.

39 The minimum bomb release altitude was 1,000 feet to insure arming of the disarming obstacle fuse even if the bomb impacted on soft soil. On release of the bomb from the plane, the aceton was released onto the celluloid disc after a short travel through the air.

The acceleration ignition was set at 5,000 (g), experience having shown that this factor was suitable for bombs of the SC-250 and SC-500 classes.

The method used by the British Civil Air Defense to cope with this chemical fuse was to remove a [illegible] from the fuse head, pump the air out of the fuse casing and then force in a quickly solidifying synthetic rubber solution. This solution hardened within a few minutes, and the fuse socket could then be drilled out. Dry ice or liquid air could be used to freeze the fuse head and thereby arrest the dissolving process of the aceton on the celluloid, and the entire bomb could then be removed.

Since measures of this kind developed with astonishing

39 [illegible] the enemy side to cope with German delayed-action bombs, it was possible to think out contrary devices insuring that the very method used to disarm a bomb would initiate the detonation, such as electric coils built into the clockwork fuses which were activated by the magnet used to arrest the clockwork mechanism, or bimetal springs which closed the ignition circuit when the fuse was subcooled or when it warmed up through evaporation. The use of various types of nuisance fuses and of misleading identification symbols stamped onto the fuse casings also served to confuse bomb disposal personnel.

The previously mentioned No. (50) vibration fuse was originally intended for use by the German army in the west in the attack against the Maginot Line, which also applied to 40 the No. (17) clockwork time fuse. However, neither of the two were used for this purpose.

The following is the background to development of the No. (50) electrical fuse:

At the time the primary mission of the German Air Force was one of Army support. Lacking heavy artillery, the Army High Command had planned that the Air Force was to drop large caliber mine-type bombs at various specified points intended for an attack to break through the French frontier defenses; these bombs were to be detonated simultaneously

40 with the German attack on the ground, fortifications engineers calculated that the concentrated effect of 50 to 100 SC-250 and SC-500 bombs, carrying roughly 15 tons of explosives, dropped within a radius of 20-30 meters of a concrete strongpoint definitely could put that strongpoint out of action.

Army radio experts suggested that each bomb should have a trailing antenna for remote detonation purposes.

However, the bomb fuse experts of the Air Force produced a far simpler solution with the No. (50) electrical fuse, which could be made available immediately. In dress rehearsals for the assault on the Maginot Line a He-111-H-3 bomber squadron laid a field of roughly 100 SC-250 bombs armed with the No. (50) fuse, the individual planes approaching from various directions to carry out a mass release of bombs. Within three minutes all bombs were placed on target without a single one detonating and a few hours later a single dive-bomber dropped an Sc-500 bomb with a 14-second fuse delay into the target area. (At the front a single round of gunfire would have served the same purpose).

As it was, however, the earth shock caused by the bomb impact alone was sufficient to activate the vibration contacts of the No. (50) fuse and detonate all bombs in the ground simultaneously.

However, no frontal attack was launched against the

40 [illegible] and the No. (50) fuses were not used for the originally intended purpose.

Later, the No. (50) fuse served exclusively as a nuisance fuse until the No. (60) made its appearance. A few hundred were dropped with the marking (25) in order to confuse the enemy, who adapted their bomb disposal methods to the markings found on the fuses.

The No. (60) battery fuse was also marked (25), but with the letter "y" stamped after the name of the manufacturers, which the enemy were quick to discover. This was also a case of the enemy gaining possession of the very first bomb so marked because one of the batteries had no contact. Sub-cooling the battery to a temperature of -30° Centigrade so increased its internal resistance that it became ineffective.

Although the enemy did succeed in devising a method to deal with each fuse used, the original purpose of the nuisance fuses was achieved, that of tying down enemy expert personnel in large numbers completely out of proportion to the effort expended in development of the fuses.

If the use of nuisance fuses had been controlled by a special "Nuisance Bomb Inspector", similar to the system in naval warfare, air warfare could have been made far more effective.

The No. (41) combined impact-time fuse for the SD-2-t

41 bomb designed for use by ground-attack aircraft unexpectedly also served as a nuisance fuse when a bomb released with a timed setting impacted prematurely, for example on trees or buildings. Usually, this impact halted the clockwork mechanism, which could be set in motion again by negligible causes and cause the bomb to detonate later.

Experience showed that a small fragmentation bomb lying unexploded on the surface of the ground could at times have a greater nuisance effect than a large bomb in the ground. This led to development of the special SD-2 nuisance fuse which served to "mine" airfields and the coastal auto road in Northern Africa. The more usual method was to drop these small bombs in bomb-containers from high altitudes rather than from low altitudes. To cope with these "Butterfly Bombs,"as the British called them, two light tanks had to travel over the ground XXXX each carrying one end of a "drag line" so that here again a parallel could be drawn with the use of minesweepers in naval mine warfare.

The No. (70) nuisance fuse was developed from the normal No. (41) fuse; the rotation of the brake vanes on the SD-2 bomb served to arm the fuse, as was the case with the normal No. (41) fuse; however, the fuse did not detonate the bomb but xxxx remained stationary at a very sensitive setting, which detonated the bomb in response to the slightest vibra-

42 vibration of the ground, such as that caused by a motor vehicle or by a plane taking off.

The No. (79) nuisance fuse was a clockwork fire fuse which could be set with a delay of 10, 20, or 30 minutes and was released my the force of impact.

Small nuisance bombs were dropped in masses and to make them less easy to find, the brake vanes disconnected during

43 the fall from the bomb proper. It was not advisable to drop bombs of this kind over territory intended for later occupation by friendly troops.

The SD-2 bomb and the three fuses just described were copied precisely by the USAAF already during the war, which indicates that the USAAF expected these to produce great results in certain circumstances.

Mention must now still be made of the fuses, all of which functioned mechanically, used in other small caliber bombs.

The No. (13) fuse used in the 2.2-pound electron incendiary bomb had only one safety device in the form of a plug which secured the ~~xxxxxfiringxpin~~ spiral-spring-driven fuse firing pin for safe transportation. This plug or pin was withdrawn when the bombs were placed in their containers. In the containers the bombs were placed fuse end ~~dxxx~~ backwards, so that even in the event of a crash landing by the carrying plane

43 aircraft the shock could not affect the [illegible] firing pin which could result in the pin striking the percussion cap.

On the other hand, fuse No. (15) was so robust in structure that it required a considerable impact force to set it in function. The bomb itself being only poorly stabilized the minimum prescribed release altitude was several hundred meters.

In the newly developed 5.3-pound electron incendiary bomb and in the Brand-10 fire bomb with its flammable fluid filling, both of which had half-shell stabilizers, use was made of fuse No. (23A), in which a securing bolt insured greater safety during flight, similarly to the British INC 4-lb incendiary bomb.

One should have no qualms about taking over constructions of the enemy which have proved good. Thus, the No (45) membrane fuse for the small-caliber SD-1 and SD-5 fragmentation bombs (adapted 50-mm and 80-mm mortar shells) evolved from a French version. These fuses had a highly sensitized reaction when soft material in the target area (sand, but also water) entered the fuse head, where the front membrane was pierced and the fuse striking pin attached to the second membrane was forced into the duplex cap. The casing with its membranes is of soft steel, so that at impact on a hard surface (paving or concrete) the fuse head was so deformed that the striking pin impinged on the percussion cap.

44 when packed in the bomb containers, the fuse of the one bomb rested in the open tube of the stabilizing vane section of the bomb in front, which was of the same caliber. This insured adequate safety in the transport of filled containers over short distances of a few miles, as is the case between the ammunition dump at which the containers are packed and receiving airfield, as well as during flight.

However, bomb containers thus packed could not be jettisoned without doing damage.

The old No. (5) mechanical fuse for the 22-pound fragmentation bomb was a dual-construction stemming from the times of the Army Ordnance Office and had caused numerous accidents which made ~~IXXXXpopular.~~ the bomb as such unpopular. It was also unsuitable for packing in bomb containers and in the SD-10A 22-pound bomb was replaced by the No. (66) electromagnetic fuse.

LIST OF GERMAN FUSES FOUND [illegible] WITH GERMAN BOMBS

Fuse No.	Uses in Bomb Types	Type of Fuse	Remarks
(6[illegible])	SD-4-HL Hollow-charge, SB-9/10A/15	Induction	see Sketch AS-7 (AS-3)
(59)	SD-50	Proximity	not introduced
(50)	SC-250 & 500	Nuisance	Remained effective approx. 1 week
(60)	SC-250 & 500	"	Remained effective approx. 1 year
(17)A	SC-250 & 500	Long delay	72 hour clockwork
(40)	SC-250 & 500	Disarming obstruction	Mechanical supplement to No.(17) w/ disarming obstruction
(57)	SC-250 & 500	Long delay	chemical process
(15)	B-1, 3 E	mechanical impact (no safety device)	
(23)A	B-1,3E, & Brand-10	as above	Armed by tumble disc
(73)	SD-1, SD-3	mechanical membrane	No special safety device, set before loading
(5)	SD-10	Mechanical impact	1) High sensitivity for high altitude bombing 2) 5 second delay-action for low-altitude bombing
(41)	SD-2-t	Mechanical impact & time fuse	Setting selected before loading
(70)	SD-2-t	Nuisance	
(67)	SD-2-t	Long delay	Clockwork setting 10 - 20 - 30 minutes
(24)	SB-1000/2300	Acceleration	Functioned by deformation of bomb nose

Remarks: The final digit in the fuse designation denotes:

...0 : Nuisance fuse
...1 : Dual function (Impact + time) fuse
...3 Mechanical fuse
...4 Acceleration fuse
...5 For use against shore targets
...6 : High sensitivity impact fuse
...7 : Long-delay fuse
...8 : For use [illegible] ships
...9 : Time fuse

(89)	Be-C-50 (Bomb container)	Time fuse	Settings between 4 & 60 seconds

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LIST OF MOST FREQUENTLY USED GERMAN ELECTRICAL IMPACT AND TIME FUSES

Fuse Type	Used in Bomb Types	Fuse Arming Altitude in High-Altitude Bombing (in meters)			Remarks
		Instant	Retarded	Delay	
(15)	SC/SD-50/250/500	270-670	0.05 sec 340-800	14 sec 14-45	Former version see (25)
(25)	SC/SD-50/250/500	480-1140	0.08 sec 480-1100	14 sec 4-10	Replaced by (25)A
(25)A	SC/SD-50/250/500	44-240	0.08 sec 480-1100	14 sec 4-10	Replaced by (25)B
(25)B	SC/SD-50/250/500	44-240	0.08 sec 150-500	14 sec 4-12	Replaced by (25)C
(25)C	SC/SD-50/250/500	40-230	0.08 sec 150-930	14 sec 4-12	Replaced by (25)D
(26)	KC-250, Flam Fire bomb	45-126			Replaced by (55)A
(28)A	SC-250/500 Kopfring (w/nose ring)	14-40	0.15 sec 0 - 52	________	Replaced by (38)
(28)B	SC-1000/1800	--	0.12 sec 18-52		w/supplementary acceleration ignition
(35)	PC-1000/1400	w/0.1 sec delay 14-45	0.1 sec 14-45		In semi-AP bombs
(38)	SC-250/500 Kopfring (w/ nose ring)	w/0.2 sec delay 170-320	0.5 sec 240-940	5 sec 8-20	for bombing of ships
(48)	PD-1000	w/0.45 sec delay 270-670	0.75 sec 340-800		In AP bombs
(55)	SBe-50/SB-50/250	44-240	--	14 sec 8-14	As (55)A
(9)	LC, AC, and AB	with supplementary time switch-box for 5 & 40 sec delay			
(49)	PC-1000/1800RS (Rocket accelerated)	Propellent rocket ignited after 2.7 seconds	0.45 sec. retarded bomb detonation		In rocket acc. AP bombs
(59)A	LC and AB	Burn. duration 13 seconds	Burn. duration 36 seconds		Powder train fuse f/bombing from 2000 &3500 meters altitude
(69)	AB (bomb container)	Burn. time 2 seconds	Burn. time 7 seconds	--	For low-level & dive bombing
(79)	AB (bomb con-	Burn. time 5 seconds	Burn time 30 seconds	--	From 500 & 5000 meters altitude

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Remarks:

Retarded = Impact detonation with very short delay

Delay = Detonation ... seconds after impact

For definition of bombdesignations see Report A-1 (Bericht A 1)

Last cipher in bomb designation denotes:

...1 - 4 Mechanical type fuses

...5 Electrical fuses for bombing of shore targets

...6 Highly sensitive fuse

...7 Long delay fuse

...8 Electrical fuse for bombing of ships

...9 Electrical time and proximity fuse

...0 Nuisance fuse.

APPENDIX TO [illegible] H-- [illegible]

NOMOGRAM OF BOMB PENETRATION DEPTH AND DIRECTION

Legend:

Abwurfhoehe = h	=	Bomb release altitude = h
Auftreffwinkel	=	Impact angle
Bombenart	=	Type of bomb
42 cm Sprgr.	=	420-mm explosive shell
200,250 etc m/s	=	200, 250 etc. meters per second
2, 3, 4 etc Km	=	2000, 3000, 4000, etc. meters
Druckfestigkeit	=	Pressure resistence coefficient
Panzerstahl	=	Armor steel
Granit	=	Granite
Beton	=	Concrete
harter Kalk	=	Hard limestone formation
weicher Kalk	=	Soft limestone formation
Sand	=	Sand
Lehm	=	Loam
Eindringvermoegen $Z = q \cdot 4$	=	Penetration capability $Z = q \cdot v$
Eindringweg in versch. XXXXXXX Zielmaterial	=	Penetration depth and direction in various target materials