*UNITED STATES ARMY IN WORLD WAR II*

The Technical Services

# THE CHEMICAL WARFARE SERVICE: FROM LABORATORY TO FIELD

*by*

*Leo P. Brophy, Wyndham D. Miles*

*and*

*Rexmond C. Cochrane*

*OFFICE OF THE CHIEF OF MILITARY HISTORY*

*DEPARTMENT OF THE ARMY*

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carbon monoxide in the air was sufficient to maintain this lethal blood level, and it was present in bunkers for seven to ten minutes after flame attack. They also learned that for intervals up to fifteen seconds there was almost complete absence of oxygen in a bunker under attack, and that unconsciousness would likely be almost instantaneous in such an event. Any one of these factors or any combination of them, therefore, meant certain death, quite aside from the effects of direct contact with the flame.[58]

Work on flame defense led to the construction of a hood-type mask built to withstand 1,000° F. for one minute, to the development of a steel sliding door for pillbox apertures, to experimental fireproof clothing and water fog, and to spray extinguishers, all of which proved unsatisfactory. The CWS finally concluded that no positive defense could be devised against flame attack.[59]

Flame throwers were not major weapons in the same sense as cannon, rifles, and bombs. Rather they were weapons that proved valuable in certain tactical situations. The men in the Pacific, the locale of most of these situations, did much to bring about the improvement of flame throwers. Americans started work on them later than Europeans and Japanese, but while enemy armies did not push the development of the weapon, Americans, particularly in the Pacific, called for it more and more frequently as the war progressed. Despite the fact that the American achievement in flame thrower development and production does not look impressive, it surpassed that of the enemy during the same period.

[58] "Toxicology of Flame Attack in Enclosed Spaces" and "Toxicology of Carbon Monoxide and Anoxia," in Symposium on the Toxicological Aspects of the Flame Thrower, Dumbarton Oaks, 29 Jan 45. ETF 235-45.

[59] (1) MIT MR 136, Protection Against Flame Throwers, 12 May 45. (2) CWS R & D Program Monthly Report, FY 1945, Jun 45, p. 63.

## CHAPTER VIII

# Incendiaries

In 1917-18 the Chemical Warfare Service branched out from its research on toxic agents into other fields, one of which was incendiary mixtures. Chemists experimented with incendiary fillings for shells, grenades, and bombs, but did not have time to perfect any of the munitions.[1] In this field CWS overlapped the Ordnance Department's work on incendiaries. In 1920 the War Department set up a line of demarcation between the two services, with the Ordnance Department henceforth to design the munitions and the CWS to provide the filling.[2]

During the 1920's and early 1930's the CWS practically ignored incendiaries. In the first place, they had not been very effective in World War I, and there was no indication that they would be in the future. Secondly, there was a widespread feeling that high explosives were better. An Ordnance Department study, written in 1934, stated that "everything that can be accomplished by an incendiary bomb can in most cases, at least, be accomplished as well or better by either a smoke bomb loaded with WP [white phosphorus] or demolition bomb loaded with a high explosive."[3] Along the same line, Maj. Gen. Amos A. Fries had said in the Report of the CWS, 1922, "Purely incendiary materials are generally of much less importance [than smoke]." Thirdly, lack of funds forced the CWS to leave out of its research programs all but the most vital projects—and, as noted, incendiaries did not seem important at the time. Finally, the division of

[1] (1) Fries and West, *Chemical Warfare,* pp. 336-44. (2) Ray, Incendiaries.

[2] WD GO 54, Sec IIIc, 28 Aug 20.

[3] From a study on the relative effectiveness of incendiary and demolition bombs by Maj H. H. Zornig, OD, 17 Jan 34, quoted in A. L. Kibler, Brief Review of Work Done to Date on Incendiaries. ETF 180-2, 10 Apr 34.

responsibility between the CWS and Ordnance was unfortunate in one respect—neither service felt as enthusiastic about the development of incendiaries as it would have if given sole authority.[4]

The unrest abroad in the mid-thirties revived interest in incendiary bombs. In 1935 a reporter on the New York *Herald Tribune* covering the Italian invasion of Ethiopia found a partially burned bomb that had been dropped by an Italian plane. He shipped it back to his newspaper, which gave it to Professor Joachim E. Zanetti of Columbia University, a CWS reserve officer. Zanetti passed it on to the CWS, which then analyzed it.[5] In the summer of 1936 Maj. Gen. Claude E. Brigham sent an officer to Europe to gather information on incendiary bombs. In December of that year, the CWS added an incendiary project to its program, and chemists began experiments. These experiments provided them with the experience and data that were to prove extremely useful when the service began to produce incendiaries a few years later.

## *Incendiary Bombs*

### *One-Hundred-Pound Bombs*

The earliest American incendiary bomb of World War II was the 100-pound missile, M47. It began in a roundabout way in 1937 when the GHQ Air Force asked the Ordnance Department for a chemical bomb.[6] Ordnance completed the munition in 1940. At this time the armed forces had no incendiary bomb, and as an emergency measure the Ordnance Department recommended that the new chemical bomb be pressed into use as an incendiary, by loading it with gasoline and cotton waste.[7] While the idea seemed good, tests conducted by the CWS showed that ordinary gasoline was almost useless as a filling. When bombs exploded the gasoline atomized and burned out so quickly that it scarcely had time to transfer heat and fire to the target. A material was needed to thicken the gasoline so as to make it burn slowly.

[4] Green, Thomson, and Roots, *Planning Munitions for War*, pp. 259, 452.

[5] L. Wilson Greene, "Prewar Incendiary Bomb Development," *Armed Forces Chemical Journal*, II (October 1947), 25–30.

[6] Ltr, CG GHQ Air Force to TAG, 2 Jul 37, sub: 100-lb Chemical Bomb. Cited in Ordnance Technical Committee Minutes (hereafter cited as OCM) 16808.

[7] (1) Green, Thomson, and Roots, *Planning Munitions for War*, pp. 455–56. (2) Bomb, Chemical, 100-lb, M47, Classified as Standard, 3 Oct 40. OCM 16142. (3) Bomb, Chemical, 100-lb, M47, Incendiary Filler, Approval of, 20 Nov 40. OCM 16274.



Overseas the British were adding rubber to the gasoline in bombs, making a filling resembling sticky rubber cement. Following the lead of the British the CWS adopted smoked rubber, crepe rubber, and latex as thickeners, designating the respective fillings as incendiary oil SR, incendiary oil CR, and incendiary oil LA.[8]

With the advance of Japanese armies in Southeast Asia cutting the flow of natural rubber to the United States, the CWS and NDRC made a wide search for substitute thickeners. Two lines of research led to success. Chemists at Du Pont found that isobutyl methacrylate polymer, (IM), converted gasoline into a tough, rubbery jelly. Unfortunately a large amount of IM—from 15 to 20 percent—was necessary to thicken gasoline to the required point, and IM was in short supply. Plastic firms were using it to make transparent bomber noses and other war items. The CWS had to find materials that could replace part of the IM without impairing the desirable properties of the filling.[9]

While experiments were going on with IM, NDRC chemists at Arthur D. Little, Inc., and Harvard University had taken a different tack and were investigating soaps as thickeners. Such an investigation had been carried out by CWS chemists in World War I but without much success. Their gasoline-soap mixtures had been hard and friable, lacking the adhesiveness and cohesiveness demanded in a gasoline incendiary filling.[10] The new generation of chemists was more fortunate, coming up with an aluminum soap of naphthenic and palmitic acids that converted gasoline into a thick jelly suitable as an incendiary. The men named it napalm from *na*phthenic and *palm*itic. Gobs of napalm thickened gasoline, scattered by the explosion of a bomb, clung to many surfaces and burned fiercely for several minutes. The mixture was as effective as rubber thickened gasoline. Furthermore napalm could be used to thicken gasoline for flame throwers, greatly increasing the range.[11]

[8] (1) CWTC Item 425, Incendiary Fillings for M47 100-lb Chemical Bomb, 16 Dec 41. (2) CWTC Item 457, same title, 10 Feb 42.

[9] (1) Gaul and Finkelstein, Incendiaries, pp. 145–62. (2) Report of Activities of the Technical Division, pp. 39–43.

[10] (1) Arthur B. Ray, "Incendiaries in Modern Warfare," *Industrial and Engineering Chemistry*, 13 (1921), 645–46. (2) Ray, Incendiaries, pp. 33–57.

[11] (1) Louis F. Fieser, George C. Harris, E. B. Hershberg, Morley Morgana, Frederick C. Novello, and Stearns T. Putnam, "Napalm," *Industrial and Engineering Chemistry*, 38 (1946) 768–73. (2) Louis F. Fieser, U.S. Patent 2,606,107, Incendiary Gels. (3) E. W. Hollingsworth, "The Use of Thickened Gasoline in Warfare," *Armed Forces Chemical Journal*, IV (January 1951), 26–32. (4) R. W. Hufferd "Spectacular Developments Made in Incendiaries," *Chemical Engineering*, 53 (1946), 110–13. (5) Summary Tech Rpt Division 11, NDRC, pp. 192–226. (6) Noyes, *Chemistry*, pp. 410–19.

Now the CWS possessed two thickeners, IM and napalm. It had to decide how much of each material to purchase. Firms which had begun to manufacture napalm were having difficulty producing satisfactory, uniform batches. The thickener IM, on the other hand, was hard to obtain in competition with aircraft manufacturers and other war industries. The Army settled the question by allotting most of the IM elsewhere, leaving the CWS and its contractors to overcome the problems holding up the manufacture of napalm. By January 1943 only one manufacturer was in full-scale production, but at the end of the year nine other companies had joined in. From 500,000 pounds in 1943, production jumped to 8,000,000 in 1944 and 12,000,000 in 1945.[12]

Finding a thickening agent for the gasoline filling was not the only difficulty in developing the M47 100-pound bomb. The casing had to be modified in several ways before the war was over. Originally the specifications called for walls one thirty-second of an inch thick. After a number of bombs had been made the CWS and the Ordnance Department discovered that the metal was too thin to withstand rough handling. New specifications doubled the wall thickness, the missile being redesignated as M47A1.[13] When bombs were filled with mustard, moreover, the agent for which they had originally been designed, pressure from gaseous decomposition products sometimes split the welds. Since the CWS had to keep a supply of mustard filled bombs on hand for retaliation in case of enemy chemical attack, the seams had to be strengthened. About the same time a problem arose with incendiary fillings. Bomb interiors were coated with acid-proof paint to protect them from corrosion by mustard. Evidence accumulated that this paint was affecting thickened gasoline. Bombs with thicker welds and without the acid-proof paint, designated as M47A2, were then turned out and saw action until the end of the war.[14]

During the conflict the CWS procured three and a half million M47-type bombs. Although referred to as 100-pounders, their total weight, including forty pounds of incendiary filling, was only seventy pounds. Japan and Germany each felt the flaming burst of more than one-half million missiles. In one attack on the Focke-Wulf aircraft plant at Marienburg,

[12] (1) See below, pp. 350–52. (2) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[13] OCM 18706, 27 Aug 42, cited in CWTC Item 1275, Standardization of Bomb, Incendiary, 100-lb, AN–M47A3, 22 Mar 45.

[14] Bomb, Chemical, 100-lb, M47A1, Modification of, to Bomb, Chemical, 100-lb, M47A2, 23 Oct 42. OCM 19111. (2) CWTC Item 803, Classification of 100-lb Incendiary Bombs, 3 Sep 43.



Burning Phosphorus From a 100-Pound Incendiary Bomb *on an enemy airfield, Rabaul, New Britain. Aircraft are Japanese Betty-type bombers.*

East Prussia, in October 1943, Flying Fortresses dropped more than thirteen thousand 100-pound incendiaries mixed with high explosives, almost completely destroying the works. That same month the ball-bearing plants at Schweinfurt suffered critical damage from M47 incendiaries and HE. Later in the war and on the other side of the world the XXI Bomber Command frequently employed mixtures of M47's and 6-pound M69 incendiaries in fire raids on Japan. The U.S. Strategic Bombing Survey estimated that an M47 100-pounder was twelve times as effective as a 500-pound general purpose bomb against targets classified as readily inflammable, and one and one half times as effective against targets classified as fire resistant. The M47 napalm filled bomb, uneven as its development had been, proved to be one of the most valuable American bombs of the war.[15]

Germany and Japan had no incendiaries comparable to the American

[15] Crawford, Cook, and Whiting, Statistics, "Procurement." p. 21. (2) *The Chemical Warfare Service in World War II,* pp. 71, 74. (3) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. II, *Europe: Torch to Pointblank* (Chicago: University of Chicago Press, 1949), pp. 697, 703–704. (4) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. V, *The Pacific: Matterhorn to Nagasaki* (Chicago: University of Chicago Press, 1953), pp. 614–44. (5) Green, Thomson, and Roots, *Planning Munitions for War,* p. 472.

M47. The closest in weight were 50-kilogram bombs, but these carried explosives in addition to the incendiary filling. In the German bomb the incendiary effect came from thirty pounds of benzene thickened with rubber, with bits of phosphorus scattered through the mixture for ignition. The nose held twenty pounds of TNT, enough to cause a respectable explosion. The German Air Force did not employ this bomb to any great extent, generally relying on other types and sizes.[16] The Japanese missile contained thirty-five pounds of a solution of phosphorus and carbon disulfide, in which were suspended phosphorus-impregnated rubber cylinders an inch long and an inch in diameter. A charge of picric acid in the nose of the bomb caused casualties and could also be set for air bursts which scattered rubber incendiary pellets up to 150 feet. The 50-kg. bomb was generally employed by the Japanese.[17]

*Four-Pound Magnesium Bombs*

Surprising as it may seem, the first great incendiary raids of World War II were not carried out with large bombs, but with small missiles weighing only a few pounds. In September 1940 the Germans showered London with 1-kg. magnesium alloy bombs, starting innumerable fires, damaging considerable property, and injuring many people. Any doubt concerning the effectiveness of small incendiaries was gone forever. A few months later the Joint Aircraft Committee, established to allocate American materiel between the United States and Great Britain, recommended that the Ordnance Department produce a 4-pound magnesium bomb suitable for the Army, the Navy, and the British. Ordnance thereupon modified the British Mark II/A 4-pound incendiary and standardized it as the American AN–M50 (A standing for Army, N for Navy).[18]

During the preliminary work it became apparent that the old demarcation between the CWS and Ordnance Department which gave the former responsibility for the filling and the latter jurisidiction over the casing would not be an efficient way of manufacturing magnesium bombs. One

[16] German Chemical Warfare Materiel, p. II–D–5.

[17] (1) Japanese Chemical Warfare. (2) Col. George J. B. Fisher, *Incendiary Warfare* (New York: McGraw-Hill, 1946), p. 49.

[18] (1) Memo for the Secretary, Ordnance Technical Committee, 1 Apr 41, sub: Bombs, Standardization by Army, Navy, British Purchasing Committee. Cited as ref a, CWTC Item 1220, Obsoletion of 40-lb Steel Case Type Incendiary Bombs and Clusters for Same, 11 Jan 45. (2) Bomb, Incendiary, 4-lb, and Bomb, Incendiary, 40-lb, Classified as Standard and Designated Bomb, Incendiary, 4-lb, AN–M50, and Bomb, Incendiary, 40-lb, AN–M51, 19 May 41. OCM 16816. (3) Bombs, Incendiary, 4-lb, AN–M50–X, 4-lb, AN–M50, and 40-lb, AN–M51, Clearance for Procurement and Classification as Standard, 22 Jul 41. OCM 17028.



organization should have charge of the entire operation, planners agreed. Ordnance, busy with other munitions and not enthusiastic about incendiaries, dropped out, leaving the CWS in full charge of the AN–M50 and related bombs.[19]

Initial investigations at Edgewood improved the fuze, found substitutes for critical materials (such as a metal plug for a cork plug in the vent), and modified the filling. The completed bomb, AN–M50A1 (A1 signifying the first alteration in the standard munition), was approximately twenty-two inches long, hexagonal in cross section, and about three inches thick. The cast magnesium body held a thermite-type mixture known as therm-8, or thermate. The filling would burn for 1 to 2 minutes, the case for 6 to 7 minutes longer.[20]

Factories began to turn out magnesium bombs in the spring of 1942, slowly at first but soon in tremendous quantities. Most of the bombs went to Great Britain on lend-lease and were dropped in air raids over Europe. The early 4-pound bomb had flaws, as might be expected in a new munition. Fuzes sometimes broke when the bombs struck, first fire mixtures failed to heat fillings to the ignition point, and metal plugs stuck in vents, causing heated air to build up pressure and blow the bombs apart. Furthermore, the British dropped the bombs from higher altitude than the CWS had designed them for, and many of the bombs broke on impact.[21]

Engineers at CWS strengthened the fuze to withstand harder impacts, replaced metal vent plugs with cork, and developed a better first fire mixture. The improved bomb, AN–M50A2, slightly lighter and thinner than its predecessor, functioned well. As fast as the new munitions came from plants they were shipped to Europe and used. The earlier model remained in reserve until 1944 when it was discarded.[22]

[19] (1) Green, Thomson, and Roots, *Planning Munitions for War*, pp. 259, 452. (2) Ltr, C Ord to C CWS, 10 Jul 41, sub: Procurement of Incendiary Bombs, with inds. CWS 471.6/241–280. (3) Notes of conference in office of General Moore at 11 p.m. on 15 July, 1941, by Lt Col J. T. Lewis, Asst SGS, sub: Incendiary Bombs. CWS 471.6/241–280. (4) Brophy and Fisher, *Organizing for War*, ch. II. (5) WD GO 10, Sep 41. (6) WD GO 13, 24 Nov 41.

[20] (1) Therm-8 was a mixture of 80 percent thermite and 20 percent of the Ordnance Department's M8 flare mixture. (2) L. Wilson Greene, "Prewar Incendiary Bomb Development," pp. 25–30. (3) TM 9–1980, 3 Jun 42. (4) TM 3–330, 23 Mar 42.

[21] (1) Ltr, CG SOS ETO to Chm CWTC, 13 Apr 43, sub: 4-lb Incendiary Bomb, AN–M50A1. CWS 471.6/68. (2) Report of Activities of the Technical Division, p. 89.

[22] (1) Capt J. E. Gilbert, Development of 4-lb Incendiary Bomb, AN–M50A2. TDMR 1224, 4 Mar 46. (2) Baum, History of Research and Development of the CWS in WW II, pp. 37–46. (3) S. J. Magram, A Survey of Starters for Burning-Type Munitions. TDMR 655, 24 May 43. (4) Lt J. E. Gilbert, Fillings for Magnesium Incendiary Bombs, AN–M52. TDMR 437, Sep 42. (5) CWTC Item 807, Standardization of Bomb, Incendiary, 4-lb, M50A2, 3 Sep 43. (6) CWTC Item 1017, Obsoletion of Bomb, Incendiary, 4-lb, AN–M50A1, 5 May 44.

Aircraft dropped more 4-pound magnesium bombs than all other incendiary bombs put together. Almost thirty million fell on Europe, and almost ten million on Japan, causing damage that ran into astronomical figures.

*Four-Pound Steel-Cased Bombs*

The chief obstacle blocking American production of magnesium bombs in 1941 was the scarcity of magnesium. Since the metal had little commercial use before World War II, America did not have a large magnesium industry. During the emergency period firms sent most of the metal to aircraft plants, leaving little available for other purposes. Despite the fact that industry expanded its facilities as rapidly as possible, for a time there was simply not enough of the metal for the armed forces.

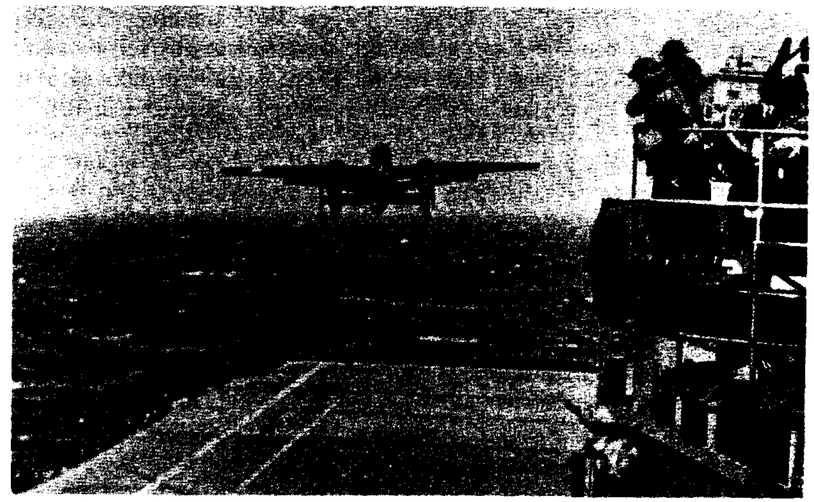
The Ordnance Department was aware of these facts when it began development of 4-pound magnesium bombs. It planned a substitute bomb having the same dimensions and incendiary filling as the M50, but with a steel case in place of magnesium. It sent the plans and models of the substitute bomb, called the M54, to the CWS when that service took over responsibility for incendiaries, and the bomb was completed by the technical staff at Edgewood.[23]

The CWS let out contracts, through its procurement districts, for enough metal parts and thermate filling to fabricate twenty million M54 bombs. Contracts were signed in November 1941, and so effectively did industry co-operate that the first missiles were ready for testing at Aberdeen Proving Ground in December, several months before the magnesium bombs came from production lines. Each month millions of bombs were fabricated, filled, and stored in CWS depots to await the call of the Air Forces.

Not all of the bombs, however, remained in storage. On 24 February 1942, the Eastern Chemical Warfare Depot at Edgewood Arsenal received orders to ship forty-eight 500-pound clusters of AN–M54 bombs to Benicia Arsenal, California, for reissue to Lt. Col. James H. Doolittle. The men who filled the order and handled the clusters had no idea of their ultimate destination. Shortly after noon on April 18 a B-25 bomber commanded by Doolittle roared over Tokyo and unloaded some of these clusters on the city. Plane after plane followed, bombing factory areas and military installations, while other aircraft struck at Kobe, Yokohama, and Nagoya.[24]

[23] (1) Bomb, Incendiary, 4-lb, T1 Classified as Substitute Standard for Bomb, Incendiary, 4-lb, AN–M50, Designated Bomb, Incendiary, 4-lb, AN–M54, 28 Jul 41. OCM 17052. (2) CWTC Item 412, Approval of Development Project for Small (1 to 2 lb) Incendiary Bomb, and Military Characteristics, 14 Oct 41.





B-25 Bomber Loaded With 500-Pound Clusters of M54 Bombs *leaving the flight deck of USS* Hornet *for the first American airstrike against the Japanese homeland, April 1942.*

Doolittle's raid, the first American airstrike against the Japanese homeland, was one of the few times during the war when M54 bombs were used. After increasing supplies of magnesium enabled the CWS to procure large quantities of M50 bombs, the service finally halted production of the substitute bomb altogether. Thirteen million M54 bombs lay in warehouses while millions of M50's passed by on their way to air bases. In 1945 when there was no possible chance of M54 bombs being pressed into service again, the CWS declared the model obsolete.[25]

The fact that the Air Forces almost never employed M54's during the war made the production of steel-cased bombs, in one sense, a loss. On

[24] (1) George W. Scaggs, History of the Eastern Chemical Warfare Depot (formerly Edgewood Depot), p. 99. (2) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. I, *Plans and Early Operations* (Chicago: University of Chicago Press, 1948), pp. 438–44.

[25] (1) CWTC Item 1220, Obsoletion of 4-lb Steel Case Type Incendiary Bombs and Clusters for Same, 11 Jan 45. (2) CWTC Item 1288, same title, 22 Mar 45.

the other hand, these bombs were a reserve for a possible emergency. The contractors had the tools, men, and experience, moreover, to switch to the production of magnesium bombs when magnesium became available. Under the circumstances the loss was more apparent than real.

### *Clusters for Four-Pound Bombs*

Four-pound magnesium bombs and other small incendiaries were not dropped individually, but in clusters which were held together by devices called adapters.

The Ordnance Department began development of the first American adapter. The CWS inherited the item when it accepted responsibility for incendiary bombs.[26] The device was made up of two end plates, two longitudinal bars, and four steel straps, and it held together thirty-four bombs. The adapter was designated as Model M5, the entire cluster of bombs as the AN-M6.[27] A larger adapter, holding 128 bombs, was developed shortly afterward. This adapter was standardized as the M6, the cluster as the AN-M7.[28]

These clusters, known as the quick-opening type, endangered aircraft. Occasionally they opened so quickly that parts glanced off the tail of the bomber. Parts of the adapter also "drifted" through the air and sometimes struck planes coming along below. To keep the cluster intact until it fell a safe distance the CWS devised delay mechanisms. One device blew open the straps twelve seconds (equivalent to a 2,000 foot drop) after the cluster left the plane. Another device was a metal flap, hinged to the end of the adapter. The air jerked up the flap, pulling wires which opened the cluster twenty-five to fifty feet below the plane. The delay mechanisms worked well, but the CWS did not standardize them because aimable clusters were superseding the quick-opening type.[29]

Aimable clusters were developed to improve the accuracy of high altitude bombing. Quick-opening clusters had been suitable for low or medium

[26] (1) Ltr, C CWS to CG EA, 22 Sep 41, sub: Design of Cluster Adapters for 4-lb Incendiary Bombs. CWS 680.429/390. (2) The Ordnance model, T2, is described in TM 3-330, 23 Mar 42.

[27] (1) CWTC Item 898, Standardization of Incendiary Bombs, 21 Jan 44. (2) TM 9-1980, 3 Jun 42. (3) Seth Q. Kline, Robert E. Patchel, and Charles T. Mitchell, Development of Quick-Opening Cluster Adapters, M4, M5, M6, M7, and M8 for Incendiary Bombs. TDMR 1015, 16 Apr 45.

[28] (1) CWTC Item 898, cited above. (2) TM 9-1980, Nov 44.

[29] (1) Capt Theodore R. Paulson and Charles T. Mitchell, Development of Delay Buckle Release on Cluster Adapters for Small Bombs. TDMR 795, 20 Jan 44. (2) Aaron S. Berlin, Development of 100-lb Cluster Adapter E20 for Low Altitude Bombing. TDMR 889, 13 Sep 44.



altitude bombing raids because the bombs landed within a small area. As the war progressed and planes flew at higher altitudes, bombs from quick-opening clusters scattered widely as they fell, many landing completely outside the target area. Aimable clusters prevented this fault by holding bombs together until they were some distance down, then opening by means of a time fuze and allowing the bombs to fall free.

Aimable cluster M17 consisted of an adapter, M10, and 110 4-pound bombs. The total weight was 490 pounds. The adapter was similar to the quick-opening type, but was streamlined by being enclosed in a cylindrical case, and by attachment of a tail fin and round nose. A time fuze adjustable from six to ninety-three seconds regulated the distance that the cluster fell before opening. The fuze detonated a strand of primacord, enclosed in a long tube running the length of the cluster, and the exploding primacord burst the steel straps binding the cluster. Later, on recommendation of the Joint Aircraft Committee, the CWS modified the adapter so that the cluster could be used on British and Navy aircraft. The modified cluster, designated as Model AN-M17A1, was used throughout the remainder of the war.[30]

### *Explosive Four-Pound Bombs*

In any raid a number of bombs would turn out to be duds, others would land on open ground, and still others would burn out in buildings without setting them afire. Therefore only a fraction of the bombs would start a fire and if firemen were alert they had an excellent chance of extinguishing the bombs or limiting the blaze. While airmen could not avoid wasting bombs they could give those that hit the target an opportunity to start conflagrations if they could keep firemen away.

The British solved this problem by producing magnesium bombs containing a small amount of black powder, and mixing these explosive incendiary bombs with the regular type. When bombs landed, fire fighters were unable to distinguish between explosive and nonexplosive bombs and kept their distance. Explosive bombs themselves had a disadvantage since the blast scattered the incendiary mixture and lessened the chance of

[30] (1) CWTC Item 924, Standardization of Adapter, Aimable Cluster, M10 (500-lb size), 21 Jan 44. (2) Seth Q. Kline, Development of Aimable Cluster E4, 500-lb, for Incendiary Bombs AN-M50. TDMR 724 1 Sep 43. (3) CWTC Item 1019, Standardization of Cluster, Aimable, Incendiary Bomb, AN-M17A1, 5 May 44. (4) TB CW 11, Aimable Cluster, AN-M17A1, 27 Jun 44.

a fire; therefore only a small proportion of explosive bombs were mixed with the regular missiles.

When the Ordnance Department began the development of magnesium incendiaries for the American Army early in the war it adopted the British explosive bomb, changed its designation to AN-M50X (the X for "explosive"), and then passed it on to the CWS along with other bombs. Service engineers changed the design slightly, redesignating it as the AN-M50X-A1. The powder charge was held in a plastic cup in the nose of the bomb, and detonated when heat from the filling reached it.[31]

In 1942 the Germans went a step further and substituted lethal TNT for the relatively harmless but terrifying black powder. Raiders flying over Birmingham, England, in July released explosive incendiary bombs that caused more than five hundred casualties. In retaliation the AAF asked that American 4-pounders be loaded with HE.[32] The CWS designed a bomb identical in size, shape, and weight with the standard magnesium bomb, except that it had a hollow steel nose filled with tetryl, detonated by a delay fuze. This fuze gave the incendiary an opportunity to start a fire before exploding. Then tetryl shattered the steel nose and the lower section of the magnesium case into hundreds of fragments, capable of injuring or killing people within a radius of fifty feet. Two types of explosive bombs were produced, one exploding between 1 and 10 minutes after it struck (type A), the other exploding after a delay of 60 to 70 seconds (type B). The bombs were used in the ratio of 4 of type A to one of type B, since this brought about the most uniform distribution of explosions.[33]

The explosive bomb was based on the current 4-pound magnesium bomb, M50A1, and therefore had flaws that appeared in the standard bomb. When the CWS redesigned the latter in 1943 it incorporated similar changes in the explosive bomb, redesignating it as M50X-A3 and employing it throughout the remainder of the war.[34]

[31] (1) Bomb, Incendiary, 4-lb, and Bomb, Incendiary, 40-lb Classified as Standard and Designated Bomb Incendiary, 4-lb, AN-M50, and Bomb, Incendiary, 40-lb, AN-M51, 19 May 41. OCM 16816. (2) Bombs, Incendiary, 4-lb, AN-M50-X, 4-lb, AN-M50, and 40-lb, AN-M51, Clearance for Procurement and Classification as Standard, 22 Jul 41. OCM 17028. (3) CWTC Item 411, Incendiary Bombs, 14 Oct 41.

[32] Ltr, C CWS to CG CWS EA, 17 Aug 42, sub: Incendiary Bomb with Explosive Charge. AGO 471.6/510.

[33] (1) CWTC Item 670, Standardization of Bomb, Incendiary, 4-lb, M50X-A2. (2) CWTC Item 714, same title, 23 Apr 43. (3) L. M. Prince, Jr., Variable Delay Explosive Incendiary Bomb, AN-M50X-A2. TDMR 585, 27 Mar 43.

[34] Louis G. Willke, Development of Bombs, AN-M50X-A3, Type A, Type B, and Type B Alternate. TDMR 1041, 16 May 45. (2) CWTC Item 838, Standardization of Bomb, Incendiary, 4-lb M50X-A3, 15 Oct 43.



In incendiary clusters for the Air Forces, the CWS packed approximately 20 percent explosive incendiary bombs. Model AN-M6 quick-opening cluster contained 34 bombs, of which 6 were explosive. Quick-opening cluster AN-M7 held 128 4-pounders, including 26 of the explosive type. Aimable cluster M17A1 carried 88 incendiary and 22 explosive.[35]

It is not known how many casualties explosive bombs caused, in all probability a relatively small number. But certainly the presence of explosives kept fire wardens from approaching burning missiles and putting them out, with consequent great property damage.

### *Large Incendiary Bombs*

In the spring of 1942 the CWS received reports that German aircraft were dropping large incendiary bombs filled with crankcase oil. The British, too, were employing large missiles filled with rubber thickened gasoline in their raids over Germany. As a result the CWS decided to develop incendiary bombs much larger than any of the standard American models.[36]

A large bomb could not be obtained by simply filling a casing with thickened gasoline. The missile had to be ballistically stable for accurate bombing, it had to burst at the proper moment, and it had to have a device for setting the filling on fire. Beginning with a design similar to the Ordnance Department's 250-pound general purpose bomb, the CWS constructed a missile holding 95 pounds of thickened fuel and weighing 160 pounds filled. Although the bomb was too large and the black powder-magnesium burster igniter failed to set off the filling, the design served as a steppingstone to a better bomb. This munition, smaller and lighter (135 pounds), with less filling (70 pounds), and a HE-white phosphorus burster igniter, seemed likely to be satisfactory. The project came to an end in April 1943, however, when the Army Air Forces asked instead for a 500-pound munition suitable for precision bombing against large industrial targets.[37]

While the 500-pound bomb was being developed the CWS had been experimenting with a new incendiary filling called pyrotechnic or PT-1

[35] Nellie Anson, Clusters and Adapters for Chemical and Incendiary Bombs. ETF 420-21, 1 Dec 47.

[36] (1) Ltr, C Tech Svc OC CWS to CG Edgewood Arsenal, 4 Jun 42, sub: Chemical Bombs. (2) Ltr, C Tech Svc OC CWS to CG Edgewood Arsenal, 6 July 42, sub: Chemical Bombs. Both in CWS 471/51.

[37] (1) Capt Roman L. Ortynsky, The E-1 and the E-2 250-lb Incendiary Bombs. TDMR 1032, 26 Apr 45. (2) Ltr, CG AAF to C CWS, 3 Apr 43, sub: Large Incendiary Bombs. AAF 471.6. (3) CWTC Item 694, Military Characteristics for 500-lb Scatter Type Incendiary Bomb, 23 Apr 43.

fuel. This was a complex material, having as its main ingredient "goop," a mixture of magnesium particles and asphalt used as an intermediate in the Hansgirg magnesium process. To goop was added gasoline thickened with IM, oxidizing agents, and magnesium scraps from magnesium bomb plants. The PT-1 fuel provided a use for magnesium that otherwise would have been wasted. It also gave the service a filling which, because of its hot, metallic ash, was a better fire starter than ordinary thickened gasoline, particularly against targets that did not ignite easily.[38]

As in the case of gasoline thickening agents, HC smoke mixtures, and other materials, the CWS had to look forward to the possibility that a shortage might develop in PT-1. The supply of goop and IM were both critical. Chemists found that IM might be replaced by synthetic rubber, and goop by a magnesium-aluminum alloy. These substitute mixtures, PT-2 and PT-3, were not employed since sufficient ingredients kept coming to produce ample amounts of ordinary PT-1 fuel.[39]

Four types of 500-pound bombs looked suitable on paper, and to determine which was best the technical staff, with co-operation from the Ordnance Department, set to work on all of them. One had a thick steel casing filled with napalm and carrying a HE-white phosphorus burster igniter. Two others were identical with the above except for the casing, one being of thin steel, the other of magnesium. The fourth bomb was filled with a number of small incendiary units that scattered when the bomb exploded.[40]

The thin steel-cased bomb was eliminated midway in development because of production difficulties, but the other three went through the testing process. The final choice, based on ease of production and bombing results against industrial-type test buildings, was the thick steel-cased missile, designated as AN-M76.[41]

The AN-M76, essentially a modified 500-pound general purpose bomb,

[38] Capt W. A. Franta, Capt Harvie Barnard, and James S. Carson, Development of PT1 Incendiary Gel (pyrogel). TDMR 1283, 2 Mar 48.

[39] (1) Capt E. J. Schantz, Lt Bradley Dewey, Jr., and James S. Carson, PT-2 Incendiary Gels Thickened with Synthetic Rubber. TDMR 962, 22 Jan 45. (2) Capt Bradley Dewey, Jr., and James S. Carson, PT-3 Incendiary Gels Thickened with Synthetic Rubber. TDMR 1180, 21 Feb 46.

[40] (1) Capt Roman L. Ortynsky, The 500-lb Incendiary Bomb, E1. TDMR 1043, 1 May 45. (2) Capt William H. Daiger, Test of the 500-lb. Magnesium Incendiary Bomb, E12. TDMR 1049, 12 May 45. (3) Capt Julius Kovitz, Development of 500-lb Tail Ejection Incendiary Bomb, E16. TDMR 1016, 30 Mar 45.

[41] (1) Capt Roman L. Ortynsky, The AN-M76 (T2-E1) 500-lb Incendiary Bomb. TDMR 1028, 25 Apr 45. (2) CWTC Item 928, Standardization of Bomb, Incendiary, 500-lb, M76, 21 Jan 44.



held either 115 pounds of IM filling or 180 pounds of PT-1 filling, for a total weight of 425 or 490 pounds. In comparison with the 100-pound M47, the 500-pounder had greater penetrating power, was more accurate and, containing three to four times more filling, created a more intense fire. It was therefore the choice against strongly constructed industrial and military structures that might withstand the impact of a 100-pound bomb, or against targets that had to be bombed accurately from high altitudes. On the other hand, it was wasteful to drop 500-pounders on light structures since a plane could carry more 100-pound bombs and start a larger number of fires.[42]

The Army Air Forces did not drop nearly as many 500-pound bombs as it did smaller missiles, since the large munitions were intended for use only against heavily roofed structures that could stand up under the impact of light bombs. Still, the number dropped by aircraft was by no means insignificant, more than 39,000 falling on Germany and almost 38,000 on Japan.[43]

The five-hundred pound bomb was the heaviest incendiary standardized by the CWS, but several larger missiles went part way through the development stage. The idea of a 1000-pound incendiary had its origin in the fire bomb, prepared in the field by filling droppable airplane gas tanks with thickened gasoline. Since the Navy already had a 1000-pound practice bomb, Mk 66, the CWS decided that modification of the Navy missile would be the quickest means of producing an incendiary bomb of this size. Engineers loaded the Mk 66, using a range of napalm fillings and a variety of burster igniters, but V-J Day arrived before the work was completed.[44] The Navy's 2000-pound bomb, Mk 67, served in the same manner as a model for a 2000-pound incendiary, and the end of the war also brought an end to this project.[45]

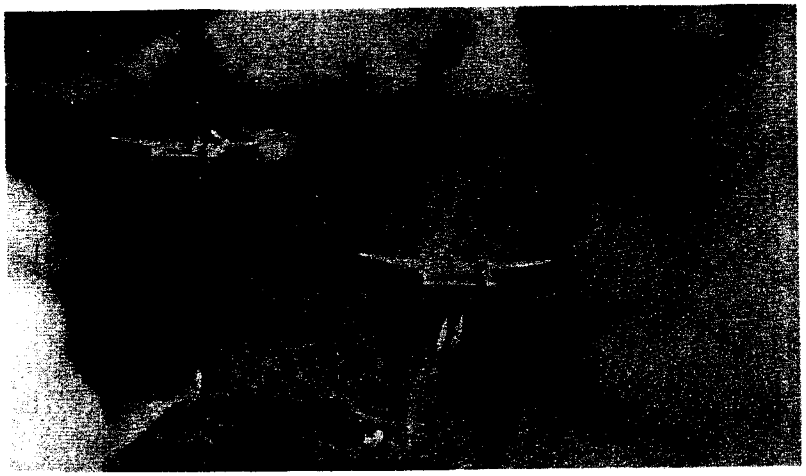
The large bombs of the German Air Force weighed approximately 250 and 550 pounds. They were thin shelled missiles filled with crude oil and were not particularly efficient. Thickened fillings, which probably would have increased the effectiveness of the bombs, were just coming into use when Germany surrendered. Japan's largest incendiary bomb, weighing about 550 pounds, was radically different in design from American or German bombs. It contained more than 700 open-end iron cylinders filled

[42] TB CW 4, Bomb, Incendiary 500-pound M76 (T2-E1), 4 Apr 44.

[43] *Chemical Warfare Service in World War II,* p. 74.

[44] Gaul and Finkelstein, Incendiaries, pp. 585-91.

[45] *Ibid.,* pp. 591-92.



LOCKHEED P-38'S DROPPING FIRE BOMBS *near Ipo Dam, Luzon.*

with thermite. Fuzed to burst 150 to 200 feet above the ground, the bomb scattered the cylinders, which continued to burn for about one minute, over a radius of 500 feet.[46]

*Fire Bombs*

Somewhere early in the war a pilot dropped his spare gasoline tank on an enemy position, circled back and ignited the gasoline with tracer bullets. Who the first pilot was to employ his fuel tank as a bomb and where the action took place are not matters of record, but the event marked the birth of the fire bomb, as this type of incendiary was called. Jettisonable wing and belly tanks were convenient because they were on hand at almost all airfields and could be employed as bombs without affecting their primary purpose as gasoline containers. The Army Air Forces tried to find a device that would fire the gasoline when the tank smashed into the target, and thus save the pilot from making a dangerous, low altitude pass over the area to ignite the gasoline with tracers. They tried attaching incendiary grenades and small incendiary bombs to tanks, but tests

[46] (1) Japanese Chemical Warfare. (2) German Chemical Warfare Materiel, p. 160. (3) Fisher, *Incendiary Warfare,* p. 49.



showed that these makeshift igniters were not reliable. The AAF then asked the CWS to design an igniter that would function at least 90 percent of the time, and would be so small that it would not change the streamlined shape of the tank.[47]

After considerable work, including the standardization of an igniter that later proved unsatisfactory, engineers devised two fairly reliable devices. One was inserted into the tank through the gasoline cap, the other was fastened to the tail. To make doubly certain that the fire bomb would burn, both types could be attached. Spontaneouly ignitable white phosphorus was the filling for use on land, sodium for targets on water.[48]

Fire bombs were employed on a variety of missions in the theaters from mid-1943 onward. At Tinian, low-flying P-47's dropped wing and belly tanks, generally filled with an oil-gasoline mixture since napalm was still scarce, on beaches as a preliminary to marine landings, and on overgrown areas to burn away foliage concealing enemy installations.[49] On Luzon, fire bombs proved to be "one of the most effective implements of aerial-delivered destruction," in burning off wide areas of vegetation, and in setting fire to enemy held villages.[50] A 165-gallon fire bomb holding approximately 960 pounds of thickened gasoline could burn off vegetation in an oval-shaped area 300 feet long and 100 feet wide. In Europe the XIX Tactical Air Command used fire bombs effectively in attacks on deep shelters because of their effect on ventilating systems, and in strikes against gun positions where intense heat impaired or destroyed enemy artillery.[51]

Fire bombs were made in many sizes, from small tanks holding 30 gallons up to tanks of 300-gallon capacity. In Europe the most popular sizes were 100, 108, and 110 gallons; in the Pacific 150 and 165 gallons. All together, the AAF dropped more than 12,000 fire bombs over Europe, while Army, Navy, and Marine planes in the Pacific employed twice that number against the Japanese.[52]

[47] Gaul and Finkelstein, Incendiaries, pp. 550–83.

[48] (1) Tests of the AN-M52A1 and AN-M52XA1 Bombs, Modified as Igniters (E1 and E1R1) for Droppable Fuel Tanks. TDMR 1172, 9 Nov 45. (2) Development of Fuze Adapters and Bursters for the Igniter, Incendiary Gasoline Tank. TDMR 1089, 13 Aug 45. (3) CWTC Item 1174, Standardization of Igniters, M15 & M16, 11 Jan 45.

[49] Hoffman, *The Seizure of Tinian,* pp. 34–35, 37.

[50] Maj Charles W. Boggs, Jr., "Marine Corps Monographs," *Marine Aviation in the Philippines* (Washington, 1951), p. 92.

[51] *After Action Rpt, Third U.S. Army, 1 Aug 44–9 May 45.* vol. 1, an. 3, p. 2.

[52] *Chemical Warfare Service in World War II,* p. 75.

*The Six-Pound Oil Bombs*

The incendiary bomb most widely used against Japan was a 6-pounder. The NDRC conceived the idea for the bomb in 1941 after European air raids had proven the effectiveness of small incendiaries. Since magnesium was scarce, the NDRC contracted with the Standard Oil Development Company for a steel-cased bomb filled with thickened gasoline.[53]

The new bomb differed in principle from standard and experimental CWS munitions. Instead of burning where it landed, like the 4-pound magnesium bomb, or bursting and scattering its contents over a wide area, like the 100-pound bomb, the missile acted like a small mortar, ejecting a single blob of filling a distance of several yards. To achieve this, engineers devised a radical design. Inside the bomb at the forward end they put the fuze, followed by a small powder charge to eject and ignite the filling, then the filling of jellied gasoline contained in a cheesecloth sack, and finally, at the base, tail streamers. When the missile came to rest in the attic of a building, for example, the powder blew the filling out of the bomb. The filling hit the underside of the roof, stuck there, and burned.

An innovation in this bomb was the design of the stabilizers. Instead of metal fins the tail consisted of cloth ribbons. These saved weight and space (the ribbons were folded in the base of the bomb and were unfolded by the airstream). Also, because of air resistance, they kept the bomb from dropping too fast and penetrating too deeply. The ideal velocity would be just enough for the bomb to break its way through a roof and come to rest on the rafters.

Designers started off by modeling bombs of different sizes, but after tests, including "raids" against abandoned buildings at Jefferson Proving Ground, demonstrated the superiority of the 6-pound bomb, they concentrated on it. The completed bomb was approximately a foot and a half long, hexagonal in cross section, and about three inches thick. The service standardized it as the M69 in 1942, less than a year after the project began, and started production in November.[54]

Several flaws showed up in proofing carried out with samples from the production line. Cloth tail ribbons could not stand the sudden pull as they snapped outward in mid-air, and they tore loose from bombs.

[53] (1) Noyes, *Chemistry,* pp. 389–96. (2) *Fire Warfare,* pp. 7–31.

[54] (1) CWTC Item 529, Standardization of 6-lb Oil Incendiary Bomb and 500-Pound Cluster Adapter, 4 Aug 42. (2) CWTC Item 570, same title, 29 Sep 42. (3) CWTC Item 621, Redesignation of Bomb, Incendiary, Oil, 6-lb, M56, 24 Nov 42. (4) TM 9–1980, Nov 44.



Fuzes did not always function, and fillings did not always ignite. After these weak points were corrected, more than 90 percent of the bombs caught fire when they landed.[55]

Originally, M69's were dropped in quick-opening clusters, similar to the clusters used for small magnesium bombs. All went well until aimable clusters appeared in 1943. These, since they were streamlined and released from high altitudes, attained considerable velocity by the time they opened. Tail ribbons on the bombs unfolded with a terrific jerk, tearing the cloth or snapping ribbons completely off the missiles. Apparently all that had to be done was to find sturdier cloth and a stronger method of attachment. Actually engineers had considerable difficulty finding cloth strong enough to stand the strain, yet light enough not to unbalance falling bombs. Then, after finding suitable cloth, the CWS was not able to procure all it needed. The problem continued throughout the war, forcing the CWS to make several modifications in the ribbon retaining mechanism and in the ribbons themselves.

Supplies of M69 bombs became available in 1943, at a time when the AAF was giving thought to the strategic bombing of Japan. Many believed that incendiaries would be highly effective against the wooden structures in Japanese cities. The Air Forces already knew something of what British and American incendiaries could do in Europe. Could that experience be measured and tested for use against Japan? New incendiary munitions had been under development. What was the best incendiary for the new mission?

These questions were answered in bombing "raids" against industrial-type buildings at Edgewood, against a simulated Japanese village constructed by the AAF at Eglin Field, and in the successive razing and rebuilding of a composite German-Japanese village at Dugway. Among the points that had to be determined was the degree of penetration of bombs, and the time-temperature factor for igniting the typical Japanese target.

These large-scale, costly field tests demonstrated the merits and defects of different bombs, and indicated that the M69 would be effective. The missile wobbled and therefore was not always accurate, but its inaccuracy turned out to be of little moment in the low altitude, large area bombing later carried out over Japan.

The great air campaign against the Japanese islands began in November

[55] (1) Report of Activities of the Technical Division, p. 98. (2) Gaul and Finkelstein, Incendiaries, pp. 402–06. (3) Capt Roman L. Ortynsky, Tests of M69 Bombs at Huntsville Arsenal, February 4–9, 1943. TDMR 576, 17 Feb 43.

1944, taking the form of high altitude precision bombing with HE bombs. At first incendiaries were dropped only in inconsequential numbers. Then on 25 Februrary 1945 the XXI Bomber Command changed its bombs and hit Tokyo with more than 400 tons of M69's. Photos from reconnaissance flights showed that approximately a square mile of the urban area had been destroyed or damaged. This marked the turning point in bombing tactics. Maj. Gen. Curtis LeMay adopted the policy of low level area bombing with incendiaries. On the evening of March 9, more than 300 superforts swarmed over Tokyo, dropping about two thousand tons of incendiaries, mostly clusters of M69's. Photographs indicated that almost 16 square miles of the city had been burned out. Tokyo police records, examined after the war, showed that more than one-quarter of a million buildings were destroyed—about one-fourth of the total in Tokyo. It was the most devastating fire raid of the war up to that time. Before representatives of Japan appeared on board the USS *Missouri,* AAF bombers had dropped more than one hundred thousand tons of incendiaries on Japan, most of them M69's. The tremendous destruction wrought in the Orient showed how accurate had been the foresight of those who planned this bomb four years earlier.[56]

### *Incendiary Oddities*

The incendiary bombs just discussed include those important in operations; yet they represent only a minor proportion of the aerial incendiaries that the CWS worked on during the war. By itself or in co-operation with the NDRC, under its own initiative or upon request from other branches of the armed forces, the CWS undertook the development of many other incendiary bombs. Some went part way through the development cycle, others proceeded all the way to standardization.

An example of a munition that was standardized but never employed is the incendiary leaf, developed in 1941–42 by the CWS and the Celanese Corporation of America. It was intended for dry grain fields, forests, thatched roofs, and other targets that would burn easily. As with the 4-pound magnesium bomb, the idea came from the British. Leaves were made in the form of disks, eight inches in diameter, one-fourth of an inch thick, and composed of pyroxylin. One type had pellets of white phosphorus attached to it, embedded in a putty-like material. When containers

[56] (1) Craven and Cate, *The Pacific: Matterhorn to Nagasaki,* chs. 18, 20, 21, 23. (2) *Chemical Warfare Service in World War II,* p. 74.



of leaves were dropped, they opened in mid-air and the leaves spun to the ground. The sun dried and cracked the covering material, permitting air to ignite the phosphorus and this, in turn, the leaf. Another type was coated with a friction sensitive chemical. These were stored and dropped in containers filled with a desensitizing fluid. The containers opened, the leaves whirled away, and the liquid evaporated. On striking an object of any kind, the leaf burst into flame. The CWS standardized these incendiaries, but when intelligence reports indicated that leaves dropped by the British on Germany had caused little, if any, damage, the service abandoned the munition.[57]

One example of an incendiary that seemed useful in the planning stage, but proved unnecessary after it was developed and tested, was a device to ignite oil slicks on water. In September 1942 the Navy Bureau of Ordnance asked the CWS to devise such a munition. The service modified existing incendiary bombs for the job, and also tried containers filled with calcium carbide (carbide reacts with water, producing acetylene which catches fire from the heat of reaction).

The NDRC took a different approach and designed the city slicker. This was a container filled with small cardboard cartons, each carton holding an incendiary mixture, chiefly magnesium dust and a bag of calcium carbide. Dropped from a bomber, the container opened and spilled the cartons into the air. When they landed water entered through holes, was heated by reaction of the carbide, and then acted on the incendiary mixture.

Tests finally showed that the standard, 100-pound incendiary bomb filled with thickened gasoline and fitted with a sodium burster ignited oil slicks with fair regularity. An additional advantage of using this bomb was that industry would not have to produce oil slick igniters and the armed forces would have one less munition to clutter up supply channels. Engineers therefore stopped work on oil slick igniters and turned to other projects.[58]

While the incendiary leaf and city slicker were unusual, they were no match in this respect for the bat incendiary. This bomb was conceived on the day the Japanese bombed Pearl Harbor. Lytle S. Adams, a dental surgeon from Pennsylvania, was returning from a visit to Carlsbad

[57] (1) James S. Carson, WP Incendiary Bomb M2 (Leaf). TDMR 482, 17 Dec 42. (2) Red Phosphorus Incendiary Bomb M1 (Leaf). TDMR 484, 23 Dec 42. (3) CWTC Item 354, Bomb, Incendiary, Leaf, 22 Jul 41. (4) CWTC Item 598, Withdrawal of Military Requirement for Incendiary Leaves, 24 Nov 42.

[58] Capt Roman L. Ortynsky, Ignition of Oil Slicks on Water. TDMR 814, 4 Mar 44.

Caverns when news of the attack came over his car radio. The thought flashed through his mind that the millions of bats in American caves might be fitted with incendiary bombs and dropped on Japan. He drove back to Carlsbad, captured some bats for tests, ransacked libraries for data on the subject, and in January sent his proposal to the White House. President Roosevelt OK'd it, and the project was on.

Adams and his search teams drove hundreds of thousands of miles, traveling day and night, to explore bat caves. In their yearlong survey they found America's largest colony, estimated at between 20 and 30 million bats, in Ney Cave, Texas. In 1943 the CWS and NDRC began to design an incendiary weighing less than an ounce for attachment to bats. The finished product was an oblong, nitrocellulose case filled with thickened kerosene and carrying a delayed-action igniter. Two sizes were made, the larger capable of burning for six minutes, the smaller for four. A bomb was attached to the loose skin on the bat's chest by a surgical clip and a piece of string. When released from a container that opened automatically in mid-air, bats were supposed to fly into hiding in dwelling and other structures, gnaw through the string, and leave the bombs behind.

All sorts of complications arose to slow the project. Bats were cooled to force them to hibernate. They could then be handled and transported and not have to be fed (a bat can eat many times its own weight of insects each day). But artificial cooling was tricky business, and in early attempts the bats did not wake up. After this problem was solved and bats were taken aloft for test flights, many failed to co-operate and either flew away or else dropped to earth like stones. Some bats got loose from a careless handler and set fire to a hangar and to a general's automobile.

The Army gave up the project to the Navy, which passed it along to the Marine Corps. All this experimentation took time, and in 1944 when the Chief of Naval Operations found that bats would not be ready for combat until mid-1945 he canceled the project. So ended the most extraordinary incendiary bomb of the war, leaving those who were acquainted with it to wonder what would have happened if bomber bats had been released over Japan.[59]

Less weird than the bat incendiary was the butane bomb. It was well known that mixtures of hydrocarbon vapors and air would explode under certain conditions if touched by a flame. A number of serious industrial accidents had been traced to the presence of such explosive mixtures. At New London, Tex., 18 March 1937, almost 300 children were killed in a school when natural gas leaked into the air and exploded.

After war broke out the CWS considered the possibility of using butane and similar hydrocarbons as incendiary agents or explosives. Theoretically, bombs filled with butane would burst and the gas would escape into the air, forming an explosive mixture. Finally a board of officers studied the technical difficulties in the way of using butane in bombs. After it concluded that butane offered "no advantage over current standard explosive and incendiary agents," the matter seemed to be settled. Nevertheless in July 1944 Lt. Gen. Brehon B. Somervell ordered the CWS to investigate the usefulness of explosive hydrocarbon mixtures as fillings for bombs and other munitions. A few months later the AAF added its voice to Somervell's. Although the CWS was aware that butane munitions were impractical, it had no choice but to assign men to the project. Engineers detonated butane "bombs" statically at Edgewood, and then dropped actual bombs on Japanese-type fortifications at Dugway. These tests convinced the Army and AAF that while mixtures of butane and air would explode quite handily under laboratory conditions, it was impossible to get a vigorous explosion in the field because of such uncontrollable factors as wind velocity, air temperature, ignition time, point of impact of the bomb, and type of target. The CWS dropped the project without any further objecttion from the Army or AAF.[60]

An incendiary of an entirely different kind from those that have been mentioned was the Weary Willie. By the end of 1944 the AAF had a number of worn-out aircraft that could no longer be used safely in combat. Someone came up with the idea that these planes might be loaded with explosives or incendiaries and flown by remote control over important targets in enemy territory. The Army handed the CWS the problem of determining the most effective incendiary cargo for these Weary Willies or remote controlled bombs.

At Edgewood, engineers tried to figure out the best payload by stacking different kinds and sizes of incendiary bombs as they would be piled inside the planes, and igniting them. This method of testing did not work out very well because engineers could not duplicate the conditions under which bombs would be used. The service laid plans for simulated

[59] (1) Robert Sherrod, *History of Marine Corps Aviation in World War II* (Washington: Combat Forces Press, 1952), p. 129. (2) Charles E. Mohr, "Texas Bat Caves Served in Three Wars," *National Speleological Society Bulletin* no. 10 (April 1948), pp. 89–93. (3) Capt Wiley W. Carr, Live Carriers for Small Incendiaries. ETF 180–27, 8 Jun 43.

[60] Capt R. E. Bolgiano, Development of an Inflammable Gas Bomb. TDMR 1136, 24 Sep 45.



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bombing raids, but before they could be carried out the AAF dropped the idea of employing Weary Willies.[61]

In addition to the aerial incendiaries discussed above, the CWS worked on 3-pound, 6-pound, 25-pound, 30-pound, and 40-pound bombs; a 2-pound bomb with a plastic case; the 2-pound magnesium bomb, AN-M52, abandoned because of poor ballistic properties; and the 10-pound M74, produced too late in the war for wide use. The reason that so many models were designed and then discarded somewhere along the development line is that incendiary bombs, as a means of mass destruction, were new in World War II and the necessary characteristics were not well defined. The CWS, Ordnance Department, and AAF learned what physical and incendiary properties were required in a satisfactory bomb only as large-scale, expensive tests were completed at proving grounds, and as surveys of American bombing raids became available. Even when items were unsatisfactory the effort that went into them was not entirely wasted. From failures engineers and chemists got information that could be applied to the development of successful munitions.

### *Incendiary Grenades*

Second only to incendiary bombs in terms of wartime production were incendiary grenades. The CWS between 1942 and 1944 procured more than eight million which were employed wherever American troops saw action.[62]

The standard grenade, AN-M14, consisted of a round tin can, of the same type used for smoke grenades, loaded with a thermite mixture. It was born in late 1940 when the Infantry and Engineers asked for a munition that could destroy enemy matériel or American equipment on the verge of capture. Ordnance engineers designed the grenade body while CWS chemists developed the filling.[63]

What the users wanted was a munition that could burn through crankcases, cylinder heads, and transmission cases; fuse breech mechanisms beyond repair; ruin the rifling of large cannon; weaken bridge girders and steel rails; and burn through armor plate on tanks. But it was not possible to design a grenade-size incendiary capable of doing all of these things because the small quantity of filling could not provide sufficient heat. What the Army got was a grenade containing about one and one-half pounds of a thermite-type mixture, able to fuse the breech of a 37-mm. gun, ruin the bore of 75-mm. guns and larger, and burn through quarter-inch steel plate.

[61] (1) CWTC Item 1270, Military Requirement and Military Characteristics for Incendiary for Remote Controlled Bombs, 22 Mar 45. (2) CWTC Item 1439, Cancellation of Projects in CWS Project Program for 1945, 2 Aug 45.

[62] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[63] Capt J. W. Gilbert, Development of Grenade, Incendiary, AN-M14. TDMR 1114, 22 Aug 45.



Production began in 1942. By 1943 there were so many AN-M14's on hand, and troops were using them so slowly, that the CWS stopped production and made no more for the remainder of the war.

In the field, rangers carried these grenades on raids into enemy territory. Infantrymen used them on trip wires to catch prowling Japanese at night, to destroy disabled American tanks, to ignite gasoline poured into enemy caves and fortified positions, and to signal after dark. While the AN-M14 was one of the grenades least employed, it served a useful purpose in special situations.[64]

The CWS investigated two other kinds of incendiary grenades, a bursting type and a frangible type. The bursting type, containing a small explosive charge to scatter the burning incendiary mixture, did not go beyond the experimental stage. The frangible type, however, got more attention. These grenades, made from glass bottles filled with gasoline and carrying cloth wicks in the necks, came out of the Spanish Civil War. In action the soldier poured a bit of gasoline on the wick, touched it with a match, and threw the bottle. Upon impact the bottle burst and the gasoline went up in flames.

Despite their crudeness, Molotov Cocktails, as they were called, could put tanks and mechanized vehicles out of action. In addition they could be produced quickly and easily. These factors led the CWS to investigate frangible grenades in 1941.

Technicians first tried to improve the old Molotov Cocktail by making it self-igniting. To do this they added alcohol to the gasoline, and attached a tube of chromic anhydride to the bottle. When the bottle broke the gasoline was ignited by the reaction between the alcohol and anhydride. While this munition, standardized as frangible grenade (GA) M1, worked satisfactorily, it was dangerous to produce, store, and ship. A bottle broken accidentally could start a fire that might destroy a plant,

[64] (1) "American Forces in Action Series," *Small Unit Actions* (Washington, 1946), pp. 31-34. (2) H. M. Cole, *The Lorraine Campaign*, UNITED STATES ARMY IN WORLD WAR II (Washington, 1950), p. 386. (3) Maj John N. Rentz, "Marine Corps Monographs," *Marines in the Central Solomons* (Washington, 1952), p. 87. (4) "Klieg Lights in the Jungle," *Chemical Warfare Bulletin* 30 (Jun-Jul 44), p. 32.

warehouse, or ship. No grenades of this type were ever stored or issued to troops and in 1943 the service discarded them.[65]

Next, engineers tried using ordinary railroad fusees as igniters, taping them to the grenades. In operation the soldier pulled a wire leading from the fusee to start it burning and then tossed the bottle. Although this type of igniter seemed safe, it would not flare up when wet and therefore had to be discarded. Finally engineers came up with a small igniter that fired a .38 caliber blank cartridge into the gasoline at the instant the bottle broke. This device remained standard on all frangible grenades.[66]

For grenade fillings the CWS had a range of flammable materials. An early mixture, copied from the British, contained carbon disulfide, white phosphorus, and rubber. This filling was spontaneously flammable and therefore hazardous in filling plants and storage depots. Within a few months the service discarded it and adopted gasoline thickened with napalm (NP) and isobutyl methacrylate (IM).[67]

The CWS turned out more than a half million frangible grenades mostly with IM fillings. They were hardly worth the trouble involved. When it came to dealing with enemy armored forces, American troops preferred antitank guns, bazookas, cannon, and other weapons.

The Japanese had a "potato masher" or stick-type grenade consisting of a cylindrical body attached to a wooden handle. The filling was composed of white phosphorus, carbon disulfide, and pellets of rubber. Germany had two incendiary grenades. The frangible glass type contained gasoline. Two matches fastened to the bottle served as igniters. The metallic grenade, used to destroy equipment that might be captured, was a 1-kilogram incendiary bomb with the tail removed, and the bomb fuze replaced by a pull-igniter. The Germans and Japanese both found incendiary grenades useful items of special equipment.[68]

### *Incendiary Shells*

The CWS did its initial work on incendiary shells for the Navy, which wanted munitions that submarines, surface raiders, and regular naval ves-

[65] (1) CWTC Item 562, Standardization of Incendiary Filled Frangible Grenades, 29 Sep 42. (2) CWTC Item 609, same title, 24 Nov 42. (3) CWTC Item 746, Obsoletion of Grenade, Frangible, M1, 11 Jun 43.

[66] (1) CWTC Item 692, Obsoletion of Grenade, Frangible, M1, 23 Apr 43. (2) CWTC Item 746. (3) CWTC Item 737, Standardization of Igniter, Frangible Grenade, M3, 11 Jun 43.

[67] (1) CWTC Item 692. (2) CWTC Item 746. (3) CWTC Item 902, Reclassification of Incendiary Fillings for Grenade, Frangible, M1, 21 Jan 44.

[68] (1) Japanese Chemical Warfare. (2) German Chemical Warfare Materiel, pp. I–J–7, I–J–9.



sels could use to burn junks, sampans, warehouses, barracks, and supply dumps. In early experiments CWS engineers tested base ejection shells filled with thickened gasoline and white phosphorus, but these missiles generally atomized the filling instead of ejecting it whole, and the men discarded the idea.

They then turned to exploding-type shells filled with small incendiary canisters. Steel and magnesium canisters of different sizes containing a number of incendiary mixtures were tried. The experiments had to take into account the shell velocity, type of fuze, and construction. The large number of variables that had to be investigated slowed the work and it was many months before the service narrowed its choice to a 5-inch shell containing four cylindrical canisters, each filled with a special thermite mixture. The end of hostilities terminated this project.[69]

The AAF presented the service with a similar problem in 1944 when it asked for incendiary shells that 75-mm. aircraft cannon could fire at cargo vessels and fuel dumps. The CWS munitions experts started with base ejection shells containing small magnesium canisters. It was no easy matter to find an incendiary filling suitable for the canisters. Nor was it easy to design canisters that could be blown from a 75-mm. shell, ignite, and set fire to the target. To complicate matters still more the capacity of 75-mm. shells was so small that the shells were not effective unless they landed in a highly flammable area and then functioned perfectly. All these obstacles blocked progress during 1944. Finally in 1945 it became evident that the project was impractical, and it was canceled.[70]

Like the Navy and AAF, the CWS itself had thought of using incendiary shells. White phosphorus mortar shells, normally employed for laying down smoke or causing casualties, could start fires under favorable conditions. For example, dry hay or leaves might be ignited. But WP would not ordinarily set fire to wooden structures.

In 1943 the service set out to develop base-ejection incendiary shells, then canceled the project in 1944 when a survey of the theaters of operation showed that only the CBI had use for such a munition. Later that year the ETO changed its mind, and in January 1945 the service resumed the project. By V–J Day development had reached the point where the

[69] (1) Gaul and Finkelstein, Incendiaries, pp. 647–65. (2) Capt J. H. Hayes and Capt E. R. Marshall, 5-Inch Navy Shell. TDMR 1112, 26 Sep 45.

[70] (1) Capt Julius Kovitz, Development of 75-mm. Base Ejection Incendiary Shell, T–34. TDMR 1190, 13 Dec 45. (2) CWTC Item 1439, Cancellation of Projects in CWS Project Program for 1945, 2 Aug 45.

Army authorized limited procurement of 4.2-inch mortar incendiary shells for field tests.[71]

American forces did not press for incendiary shells because they were useful only in special situations. This occasional usefulness had to be weighed against the inconvenience of another item in supply channels. Furthermore, white phosphorus ammunition served the purpose of incendiary ammunition where the target was easy to ignite.

If we can judge by the variety of incendiary shells in the German and Japanese armies, both these nations placed a higher value on them. The Japanese army had incendiary 75-mm. artillery and 90-mm. mortar shells filled with white phosphorus, carbon disulfide, and rubber pellets. This mixture was the same as the one used in Japanese incendiary bombs. The Navy employed a 12-cm. antiaircraft shell loaded with steel pellets filled with white phosphorus. When this shell exploded the pellets streaked through the air and caught fire.[72]

Among German incendiary munitions were 50-mm., 100-mm., and 105-mm. shells containing high explosive and thermite. They were felt to be particularly effective against tanks. An 88-mm. antiaircraft shell was reminiscent of the Japanese AA shell in containing a number of small incendiary slugs. It was more spectacular as a fireworks display than as a munition for shooting down planes.[73]

### *Incendiary Rockets*

In addition to incendiary bombs, grenades, and shells, the CWS worked with incendiary rockets. Rocket research, to determine if the munitions would be suitable for toxic fillings, was first undertaken for the service by the NDRC in 1941. Incendiary fillings became the subject of CWS experimentation two years later, with the Ordnance Department and Navy co-operating in the design of rocket bodies and mortars.

In 1943 the CWS began to develop a 2.36-inch incendiary rocket for the bazooka. Chemists filled shells with various thermite and PT mixtures and tested them. The missiles were not stable ballistically, and the fuel would not always ignite upon impact. While these problems might eventually have been solved, there was another obstacle that proved insurmountable. The rocket cavity held so little filling that it was practically

[71] (1) Gaul and Finkelstein, Incendiaries, pp. 665–75. (2) Lt Oren E. Ross, 4.2-Inch Chemical Mortar Shell, Incendiary, E66R3. TDMR 1218, 5 Mar 46.

[72] (1) Tactical and Technical Trends, no. 22, 8 Apr 43, p. 17. (2) Japanese Chemical Warfare.

[73] German Chemical Warfare Materiel, p. I–H.



useless in starting fires. The CWS gave up, and thereafter worked with larger missiles.[74]

A much more suitable rocket, from the viewpoint of quantity of filling, was an 8-inch missile that the service devised by adding a rocket motor to the tail of the Ordnance AN–M30 30-pound bomb. Loaded with PT fuel, this rocket could range up to 600 yards. When it landed a burster igniter broke open the casing and scattered burning fuel over a radius of sixty yards.[75]

In similar fashion the CWS and Ordnance Department Rocket Research Division evolved an incendiary rocket from the AN–M57 250-pound general purpose bomb. With three rocket motors attached to the base, the bomb would fly almost half a mile. Containing eighty pounds of PT fuel, this was the largest experimental rocket worked on by the service.[76]

The development of incendiary rockets for the Army proceeded slowly until the autumn of 1944, because none of the theaters or branches of the armed services set up a military requirement for the munition. Then a joint Army-Navy testing and experimental board asked for one hundred 7.2-inch incendiary rockets for trial. This became a joint project of the Ordnance Department and CWS, with the latter filling the rocket with incendiary fuel and fitting it for bursting and ignition. The rocket head held about twenty pounds of PT fuel, a quantity shown by test to be adequate for starting fires. This rocket was never standardized, but the CWS would have considered it satisfactory for use as a standard munition if the need for such a rocket had arisen.[77]

The Navy was more interested than the Army in incendiary rockets. In 1943 it considered the possibility of firing 3.5-inch incendiary rockets from LCT's during amphibious operations. Engineers at CWS carried out experiments that indicated rockets of this size, like the 2.36-inch bazooka rocket, could not hold sufficient incendiary filling. The Navy turned to the 4.5-inch rocket, with the thought that it might be used to burn light structures, such as nipa shacks, in the Pacific. Rockets of this size filled with PT fuel and fitted with an HE burster and WP igniter satisfied the requirements set up by the Navy. The end of the war cut off the development of 4.5-inch rockets at the service test stage.[78]

[74] J. J. Jungbauer, Development of the 2.36-inch Chemical Rockets. TDMR 850, 24 Jun 44.

[75] R. E. Bolgiano, Development of 8-in. Incendiary Rocket E2. TDMR 893, 25 Sep 44.

[76] R. L. Ortynsky, Development of 11-in. Incendiary Rocket, E33. TDMR 1101, 21 Aug 45.

[77] R. E. Bolgiano, Development of 7.2-in. Incendiary Rocket Head E27. TDMR 1146, 16 Oct 45.

[78] (1) R. E. Bolgiano, Tests of the 3.5-inch Incendiary Rocket Mk 11. TDMR 1184, 28 Nov. 45. (2) R. E. Bolgiano, Test of the 4.5-inch Incendiary Rocket Mk 9. TDMR 1161, 2 Nov 45.

The development of incendiary rockets proceeded slowly because the Army did not ask for them and the Navy was only mildly interested. Without a definite military requirement, the CWS was not justified in diverting men and funds from crucial projects. The work done was exploratory in nature, and served to give engineers experience that would have been useful if theaters of operations had suddenly requested incendiary rockets to place beside HE rockets.

In World War II the Chemical Warfare Service's greatest stride was in the field of incendiaries. During the period from 1941 to 1945, all its standard bombs and grenades, experimental shells and rockets, sprang forth. The service procured more incendiary bombs than any other single item, and it spent more money and employed more manpower on incendiaries than on an any other item of supply.

# CHAPTER IX

# Smoke

At Algiers, Bizerte, Naples, and other Mediterranean cities during World War II German bombers flew over harbors intent on blowing Allied shipping out of the water. In all but a relatively few instances they found nothing but an impenetrable haze covering the targets. On New Guinea and Luzon American paratroopers dropped safely to earth protected from bullets of Japanese riflemen by screens of white smoke. At beachheads, highways, and river crossings in Italy, France, and Germany, troops and trucks went about their work under a shield of artificial fog. Never before had armies been able to protect their troops and hide their movements as successfully as Allied forces did in World War II.

Military history records the tactical use of smoke in early times, but reliable smoke munitions are of fairly recent origin. Not until World War I did armies develop standard munitions and give them a wide trial. The British Army produced grenades and shells containing white phosphorus that emitted white smoke, and carbonaceous mixtures that gave off black smoke. The German Army, lacking phosphorus, depended on oleum, chlorosulfonic acid, and sulphur trioxide, all of which reacted with moisture in the air to form white fog. The French contributed Berger mixture, which threw off a gray smoke when heated. The American Army designed grenades, shells, candles, pots, and other munitions based on European originals, but did not get them to the battle zone in time for use. From the smoke munitions of World War I evolved most of the efficient screening devices used by friend and foe in World War II.

### *White Phosphorus*

White phosphorus (CWS symbol, WP) is a soft waxy substance that reacts spontaneously with oxygen. When phosphorus is scattered from a bursting munition the heat of the explosion causes the phosphorus to