US Navy Minelaying in the Second World War

USS Terror (CM-5) website, terror.ringleib.com · November 2026

This essay covers the mines, the ships, submarines and aircraft that laid them, and the main American campaigns of 1942–45. The Army Air Forces' 1945 campaign against Japan is included because Navy officers designed and assembled the mines and helped plan the drops.

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The mines

By 1941 the Navy still relied on a weapon designed for the North Sea barrage of 1918: the Mark 6, a spherical moored antenna mine about 34 inches across, weighing some 1,400 pounds with a 300-pound TNT charge, plantable in water as deep as 3,000 feet. A copper antenna rose from the case toward the surface. When a steel hull brushed it, seawater completed a simple battery (the "K-pistol"), a relay closed, and the mine fired. That gave one mine a much taller danger space than a contact mine moored at a single depth.

Two later surface-ship types appear in *Terror*'s allowances. The Mark 16 was a larger antenna mine, meant to replace the Mark 6, with a heavier Torpex charge. The Mark 18 was a sensitive magnetic bottom mine for shallow water. Authorized track capacity on *Terror*, late in the war, was about 850 Mark 6 mines, or slightly fewer Marks 16 or 18, or about a thousand of the compact Mark 23.

Submarines fired mines from ordinary 21-inch torpedo tubes. The Mark 10 was a moored horned mine; the Mark 12 was a cylindrical aluminum-case magnetic mine that could also be dropped by aircraft. *Argonaut*, the only American submarine designed as a minelayer, was built to plant the larger Mark 11 from a special tube, but she was converted to a transport early in the war and never laid a service field. By 1943 fleet boats could trade three torpedoes for eleven mines and often sailed with mixed loads.

The mines that mattered most in 1945 were aircraft-laid bottom influence weapons, retarded by parachute and left on the harbor floor. The Mark 13 was an earlier aircraft magnetic mine. The Mark 25 was a large (about 2,000-pound) influence mine; the Marks 26 and 36 were 1,000-pound weapons of the same family. A B-29 could carry seven Mark 25s or twelve of the smaller mines. Fuzes were magnetic, acoustic, or pressure, sometimes combined, with variable sensitivity, random arming delays, and ship counters that let a set number of vessels pass before the mine fired. Pressure fuzes, which felt the hump in the water as a hull went over, were treated as unsweepable with the gear of 1945 and were held back until late in the war for fear the enemy would copy them. The Germans had a similar device and likewise withheld it until Normandy.

Almost all service mines had sterilizers, in the spirit of the Hague rules, so a mine that broke its mooring or outlived its field would eventually go safe. Anti-sweep mines, with only a tiny charge, could be mixed into a moored field to cut a sweeper's wire.

Layers: ships, submarines, aircraft

American thinking after 1918 divided minelayers into two families. Converted coastal cargo ships, lightly armed, would plant defensive fields around home ports. Offensive layers had to work in reach of the enemy: either sturdy Fleet Train ships for advance bases, or fast combatants that could dash in, sow a field overnight, and be gone by daylight. In the 1920 type system those ideas became the Mine Layer (CM), the Light Minelayer (DM), and the Coastal Mine Layer (CMc). Auxiliary minelayers (ACM) were added in wartime; almost all of them were former Army mine planters.

The Navy entered the war short of large layers. *Oglala* (CM-4), a converted coastal liner, was the only CM still in commission in 1936. That fact drove the General Board to write characteristics for a new fleet minelayer, funded in Fiscal Year 1939. The result was *Terror* (CM-5), built at the Philadelphia Navy Yard and commissioned 15 July 1942: 454 feet 10 inches long, about 5,875 tons standard, 20 knots, 5-inch and antiaircraft guns, and a mine deck designed around roughly 900 Mark 6 mines. She was the only purpose-built American fleet minelayer of the war. Two sisters, *Catskill* and *Ozark*, were begun as minelayers but completed as landing ships. Converted merchantmen such as *Miantonomah* and *Monadnock* did much of the defensive work and went with *Terror* to North Africa.

The fast work belonged to the destroyer-minelayers. Fourteen flush-deck Wickes-class destroyers had been converted in 1920 (DM-1 through DM-14) by landing their torpedo tubes and fitting mine rails from amidships to the stern. When those ships wore out, eight more (DM-15 through DM-22) took their place and served through the war; all eight still active were at Pearl Harbor on 7 December 1941. In 1944 twelve new *Allen M. Sumner*-class destroyers were completed as DM-23 through DM-34. Their Pacific careers mixed mining with escort, transport, and antisubmarine work.

Submarines and aircraft did the deep offensive work. Fleet submarines planted 658 Mark 10 and Mark 12 mines in 36 fields. Navy aircraft—carrier Avengers and land-based patrol planes—laid several hundred more, notably at Palau in March 1944. Army aircraft, including B-24s in the outer zone and, in 1945, B-29s of the 313th Bomb Wing on Tinian, laid the great majority of American offensive mines. A

Navy depot on Tinian prepared the weapons and helped train the crews. Under U.S. command, American and Allied forces planted on the order of 50,000 mines in the war: nearly 19,000 of them Navy defensive contact mines, about 12,000 of them Army Air Forces mines in Japanese home waters.

How a large minelayer sowed a field

Terror's mine deck is the best-documented American example. Six tracks ran aft to six stern doors, odd numbers to starboard and even to port, lower numbers inboard. Each track on the mine deck held about 89 mines. More were stowed on platforms below and brought up on two elevators, two mines at a lift. An electrically powered locomotive, or "bogey," on each track moved the line aft; a rider stayed on the machine in case remote control failed. At the after end, hydraulic pushers advanced the mines a set interval and sent them over the stern. Interlock switches kept a track motor from running until the door was open, so a mine could not jam against a closed door. Lights in the control pit, one per track, went out when a track was ready. A timed bell told a hand-launch operator, if the pushers failed, when to let the next mine go. As a mine crossed the stern it tripped a counting wheel in the pit. The usual method was to start on tracks 1 and 2, restock them from a center storage track, then refill the deck from below. Officers judged that the gear could lay at about 18 knots with a three-second interval; faster than that was hard on the equipment.

Smaller layers were simpler: two or four rails and a crew shoving mines aft by hand or with modest machinery.

Degaussing and other countermeasures

Influence mines, especially magnetic bottom mines, forced a new kind of self-defense. A steel hull distorts the earth's magnetic field; a fuze on the bottom can feel that change. Degaussing coils, wired around a ship and calibrated, set up a canceling field. Ships were also "depermed" at intervals and run over magnetic ranges—open-water cable arrays that measured the remaining signature. *Terror* herself ran the range in San Francisco Bay on 9 August 1945, at the end of her post-repair trials. Against moored contact mines the older answer was still used: paravanes streamed from the bow to cut moorings and tow mines clear. Acoustic mines were answered, imperfectly, with noisemakers on sweepers. Pressure mines had no good sweep in 1945. The Japanese sometimes tried to explode them with small craft; the Americans later used lightly manned "guinea-pig" ships to steam suspected channels.

The Atlantic and defensive fields

Harbor defense had long been shared with the Army, whose mine planters maintained controlled fields—mines fired from shore—at home ports. The Navy's own defensive planting in 1941–42 covered approaches and bases on both coasts and in the Caribbean, using moored contact mines. Light minelayers also sowed early Pacific defensive fields, including one near French Frigate Shoals in March 1942.

Terror's first operation was the invasion of French North Africa. She crossed with a reinforcement convoy for Operation Torch, left it at dawn on 14 November 1942, and entered the wreck-strewn harbor at Casablanca. There she fueled *Miantonomah* and issued mines to her. On 16 November, working with the

converted minelayers *Miantonomah* and *Monadnock*, she helped plant a protective field off the port. The Dictionary of American Naval Fighting Ships describes *Terror* laying, with two minesweepers, a barrier that stretched some seven miles out from El Hank Light and gave Allied shipping a protected channel. She spent the next night discharging depth charges and ammunition, and sailed on the 17th. It was almost the only time in the war she was used purely as the large layer she had been designed to be. After months of training out of Yorktown, she went to the Pacific in October 1943.

The Pacific: Solomons, submarines, and the advance west

In the Solomons the old destroyer-minelayers did the dangerous night work. On 1 February 1943, *Tracy*, *Montgomery*, and *Preble* sowed some 250 to 300 mines between Doma Reef and Cape Esperance, to interfere with the Japanese evacuation of Guadalcanal, and cleared the area with enemy ships only a few miles away. That night the destroyer *Makigumo* struck a mine and was scuttled. On the night of 6–7 May, *Gamble*, *Preble*, and *Breese*, led in by *Radford*, laid more than 250 mines in about 17 minutes across Blackett Strait, a favored "Tokyo Express" route. The next night four Japanese destroyers ran into the field. *Kuroshio* sank; *Kagero* and *Oyashio* were crippled and, the following day, finished off by aircraft. Navy and Marine Avengers also began aerial mining in March 1943, dropping Mark 12 mines off Kahili and around Bougainville.

As the Central Pacific drive moved west, *Terror* was more often a depot, survey headquarters, and issue ship than a layer. She supported mining of the passes at Funafuti in November 1943, and defensive fields at Makin in January 1944, at Kwajalein in March and April (where *Montgomery*, *Preble*, and a "track boat" *Terror* had fitted planted mines along the reefs), and at Ulithi in October. She also ferried thousands of mines, ammunition, and mine-detail men, and transferred mines to carriers for air delivery.

Fleet submarines had already taken the war to Japan's doorstep. Boats from Pearl Harbor laid their first fields on 25 October 1942 and by year's end had planted 91 mines in four fields in Japanese home waters, interfering with traffic down the east coast of Honshu and toward the Inland Sea. Later fields were sown off Indochina, Malaya, Borneo, and in Makassar Strait. Of the 658 submarine mines planted in 36 fields, 421 mines in 21 of those fields were later credited with sinking 27 ships (about 63,000 tons) and damaging 27 more (about 120,000 tons). The numbers are modest beside the torpedo campaign, but the fields also delayed and diverted traffic that never appeared in a sinking report.

Carrier aircraft showed what a few mines could do in a confined waterway. On 30–31 March 1944, Avengers planted 78 mines in the entrances at Palau, trapping 32 Japanese ships inside. Follow-up bombing and torpedo strikes sank them. Several more ships were lost trying to enter, and the Japanese closed the harbor for weeks. Navy patrol planes mined Truk the next month and closed that anchorage as well.

Operation Starvation

The largest American mining campaign of the war was flown, not steamed. At Admiral Nimitz's urging, and with a much greater effort than the Army Air Forces had first been willing to give, Major General Curtis LeMay assigned the 313th Bomb Wing—about 160 B-29s on Tinian—to mine Japan's home wa-

ters. The Navy's Tinian depot prepared the weapons. Operation Starvation opened on the night of 27 March 1945, when more than a hundred B-29s mined Shimonoseki Strait, the bottleneck between Honshu and Kyushu. By mid-April some 2,000 mines were in the strait. No large Japanese warship used it after 27 March; when *Yamato* sortied for Okinawa in April she had to go out by Bungo Strait, a route that led to her detection and loss.

Later phases mined the approaches to Tokyo, Nagoya, Kobe, and Osaka, then the west coast of Japan and Korean ports, reseeding the earlier fields through July and August. Between 27 March and the end of the war the 313th flew 46 missions and about 1,529 sorties, laying 12,135 mines in 26 fields. Fifteen B-29s and just over a hundred aircrew were lost. The mines were a mix of magnetic, acoustic (including low-frequency), and pressure-magnetic types. About 670 Japanese ships were sunk or badly damaged, totaling more than 1.25 million tons; a little under 500 of those ships were sunk. In the last months of the war, mines sank more Japanese ships than any other cause. The campaign used well under six percent of XXI Bomber Command's sorties. Postwar analysts argued that cutting off raw materials and food did more to throttle Japanese war production than many factory raids, and that an earlier start might have shortened the war.

Flagship and tender

From late 1944 *Terror* was flagship of Commander Minecraft, Pacific Fleet, after a Pearl Harbor conversion to take a staff. She went to Iwo Jima in that role in February 1945, issuing water and spares to the minesweepers and firing on shore batteries to cover them. At Kerama Retto and off Okinawa she was both flagship and tender: hull and engine repairs, issue of food, water, and spares, berthing for boat crews, even a hospital overflow. That secondary life—not the mine rails—was how most of her Pacific war was spent, and how she was caught at anchor when she was hit in the early morning of 1 May 1945. Casualties were serious; the mine deck was damaged, but the machinery and hull remained sound enough for her to reach the West Coast under her own power.

After the surrender

The fields did not go safe on V-J Day. Pressure mines in particular remained a hazard, and ships were still being lost that autumn. Occupation forces first swept the approaches they themselves needed. Japanese minesweeping, reorganized in September 1945, was placed under American supervision (Task Group 52.10, later the minesweeping officer on the staff of Commander Naval Forces Japan). Navy estimates right after the war ran to a couple of years of work in the Pacific alone; Japanese sweepers, many of them former Navy crews, were still at it well into the occupation, and in some waters much longer.

The other layers and their wars

Terror was unique as a purpose-built fleet minelayer, but she was never the whole force. The night plants in the Solomons, the radar-picket fights off Okinawa, the defensive fields off North Africa and Sicily, and the first American mines in Japanese home waters were the work of other ships, boats, and squadrons.

The flush-deck destroyer-minelayers

Eight converted four-stack destroyers carried the light-minelayer designation through the war: *Gamble* (DM-15), *Ramsay* (DM-16), *Montgomery* (DM-17), *Breese* (DM-18), *Tracy* (DM-19), *Preble* (DM-20), *Sicard* (DM-21), and *Pruitt* (DM-22). All eight were at Pearl Harbor on 7 December 1941. Together they earned 44 battle stars; two did not survive the war.

Gamble drew first blood east of Guadalcanal, and not with mines. On the morning of 29 August 1942 her lookouts sighted a large Japanese submarine, which dived. *Gamble* made repeated depth-charge runs—eleven charges, then ten more after she regained contact in a spreading oil slick—and watched deck planking, debris, and a large air bubble come up. The boat was later identified as *I-123*. That afternoon she rescued four ditched aviators from *Saratoga*; a few days later she helped free the grounded transport *William Ward Burrows*. In May 1943, with *Preble* and *Breese* and led in by *Radford*, she took part in the Blackett Strait plant already described above. Her end came off Iwo Jima. On 17 February 1945 she provided fire support and, according to her war diarist, hit an ammunition dump at the foot of Mount Suribachi. The next evening, after covering *Terror* during fueling and then joining the screen of the battleship *Nevada*, a twin-engine aircraft came in on the starboard beam at about fifteen feet, too low for radar. It released two 250-pound bombs that struck amidships just above the waterline. All of *Gamble*'s boilers exploded, both firerooms flooded, and she went dead in the water. *Dorsey* (DMS-1) took her in tow. Five of her crew were killed, eight were wounded, and one man was missing and later presumed dead. Towed to Saipan, she was decommissioned on 1 June 1945 and, on 16 July, towed out of Apra Harbor, Guam, and scuttled. She received seven battle stars.

Tracy, *Montgomery*, and *Preble* laid the Cape Esperance–Doma Reef field on 1 February 1943 that sank *Makigumo*. *Tracy* had already helped plant a defensive field near French Frigate Shoals in March 1942 and had been off the Guadalcanal beaches on 7 August. After the surrender she swept Japanese home waters and, the flush-deck history records, became the first Allied ship to enter Nagasaki Harbor. *Montgomery* spent sixteen months on escort and minelaying from Fiji, Espiritu Santo, and Nouméa, with a side trip north in the autumn of 1942 to lay mines in the Aleutians for the recapture of Attu and Kiska. On the night of 24–25 August 1943, while laying a field off Guadalcanal, she collided with *Preble* and lost twenty feet of her bow; both ships were repaired. In 1944 she planted defensive mines at Kwajalein, taking mines from *Terror*, and in September she worked off Peleliu and Angaur destroying Japanese mines as they were swept. She received the Navy Unit Commendation for her Palau service, 12–15 September 1944. Her luck ran out at Ngulu on 17 October. Anchored with her engines secured, she sighted a drifting mine close aboard to port; the wind laid her onto it before she could get underway. The explosion flooded both engine rooms and one fireroom, ruptured fuel tanks, and killed four of her crew. She was kept afloat, towed to Ulithi, steamed home under her own power, and was decommissioned at San Francisco on 23 April 1945.

Breese was the third ship of the Blackett Strait group. *Ramsay*, *Sicard*, and *Pruitt*, joined for a time by *Montgomery*, were sent to the Aleutians. There, on 10 May 1943, *Sicard* rammed the destroyer *Macdonough* and then towed her into Adak. *Preble* and *Montgomery* later worked with *Terror* at Kwajalein, plotting and planting along the reefs. After the surrender, most of the surviving flush-deckers were reclassified as auxiliaries and sold for scrap by the end of 1946.

The Robert H. Smith class at Okinawa

Twelve new *Allen M. Sumner*-class destroyers, converted while building, commissioned in August–October 1944 as the *Robert H. Smith* class, DM-23 through DM-34. They formed Mine Squadron 3, in three divisions: *Robert H. Smith*, *Thomas E. Fraser*, *Shannon*, and *Harry F. Bauer*; *Adams*, *Tolman*, *Henry A. Wiley*, and *Shea*; and *J. William Ditter*, *Lindsey*, *Gwin* (flagship), and *Aaron Ward*. Off Okinawa they screened the wooden minesweepers, then spent weeks on radar picket stations. Eight of the twelve earned a Presidential Unit Citation or a Navy Unit Commendation. *Aaron Ward* and *J. William Ditter* were damaged beyond economical repair; both steamed home under their own power, were decommissioned on 28 September 1945, and were scrapped the next year.

Aaron Ward (DM-34) arrived off Okinawa in late March 1945, supported the Kerama Retto and Okinawa sweeps, and later helped fight the fire on the evacuation transport *Pinkney* after a kamikaze hit, taking off twelve survivors. On 30 April she took radar picket station number 10. On the afternoon of 3 May, after the weather cleared, she was attacked repeatedly. She splashed the first two aircraft; a third, though hit many times, released a bomb that burst in the after engine room and then crashed the superstructure. Steering control was lost, the rudder jammed hard left, and she turned in a tight circle. In the evening attacks that followed—the same raid that sank *Little* (DD-803) and LSM(R)-195—more planes hit her. A Bureau of Ships war-damage report recorded six kamikaze crashes and three large bombs. Spaces between the midship bulkheads flooded almost to the waterline, about 1,650 tons of water came aboard, and she arrived at Kerama Retto with no freeboard aft. Power forward was kept on the emergency diesel. After emergency repairs she went to Pearl Harbor on her starboard shaft. She was never rebuilt. She received the Presidential Unit Citation for 3 May. (A later Navy Memorial summary gives 42 killed that day; the Dictionary of American Naval Fighting Ships speaks of heavy casualties without a total, so that figure is not used here as a settled count.)

Lindsey (DM-32) had already supported minesweepers and knocked out shore guns off Iwo Jima. Off Okinawa on the afternoon of 12 April, in a mass kamikaze attack, her gunners hit seven diving aircraft, but two damaged “Vals” still crashed her. Fifty-seven of her sailors were killed and 57 were wounded. The second crash tore some 60 feet off her bow. Only the “all back full” ordered from the bridge kept the pressure of inrushing water from collapsing the fireroom bulkhead and sinking the ship. Towed to Kerama Retto, given a temporary bow at Guam, she reached Norfolk under her own power in August.

Shea (DM-30), besides screening sweepers, stood picket duty all around Okinawa. On 16 April she splashed six aircraft in about ten minutes. On the morning of 4 May, on picket station northeast of Zampa Misaki, a Japanese *baka* (Ohka) suicide bomb closed at more than 450 knots, struck the starboard side of the bridge, passed through the sonar room and chart house, and exploded beyond the port side. Fires broke out in the mess hall, combat information center, and handling rooms. She lost internal communications; two 5-inch mounts and the forward director were knocked out. One officer and 26 men were killed, and 91 others were wounded. She received the Navy Unit Commendation.

J. William Ditter (DM-31) dodged a torpedo from a submarine on 26 March, sank a suicide boat two days later, and shot down two bombers on the night of 2 April. Assigned to picket duty from mid-April, she was attacked on 6 June, while patrolling with *Harry F. Bauer* and *Ellyson*, by a large group of kami-

kazes. Her guns downed five; a sixth glanced off the number 2 stack and another crashed the port side near the main deck. She lost all power. Damage-control parties kept her afloat until the tug *Ute* could tow her to Kerama Retto. She was repaired enough to steam home, and then scrapped.

Harry F. Bauer (DM-26) had already been a picket and bombardment ship at Iwo Jima. Off Okinawa a torpedo crashed through a ballast tank on 6 April and failed to explode. On 6 June, in the same raid that wrecked *Ditter*, a plane crashed close aboard and flooded two compartments; even so, she escorted the crippled *Ditter* in. During later repairs an unexploded bomb was found in one of the flooded spaces. She received the Presidential Unit Citation.

Henry A. Wiley (DM-29), nicknamed "Hammering Hank," fired some 3,600 rounds in fire support off Iwo Jima, often close under Suribachi. At Okinawa she screened sweepers, then spent 34 days on radar picket duty. On 28–29 March and on landing day she destroyed kamikazes at close range. On the morning of 4 May she splashed a bomber, then went to the aid of the sinking *Luce* (DD-522). In less than a quarter of an hour she shot down three kamikazes and two *baka* bombs, one of which, already hit, bounced over her fantail and exploded off the port quarter. She then picked up *Luce* survivors. Her Okinawa score, as recorded in her history, was 15 Japanese aircraft. She received the Presidential Unit Citation.

Gwin (DM-33), flagship of Mine Squadron 3, had taken part in the preliminary bombardment of Iwo Jima. Off Okinawa she was credited with some 16 enemy aircraft, nine of them on 16 April and 4 May. At dusk on 4 May, with reports of aircraft to port, a second group came out of the setting sun to starboard. She splashed five; a sixth crashed the after 40-millimeter platform. Two of her men were killed, two were missing, and 11 were injured. After repairs at Kerama Retto she went on to sweep the approaches to Tokyo Bay, destroying some 41 mines in two days, and was in the bay at the end of August. She received the Navy Unit Commendation.

Adams (DM-27) took her first casualties on 23 March, before she even reached the Okinawa sweep area, when a projectile from her after 5-inch mount exploded prematurely, killing two sailors and injuring 13. In the days that followed she supported the wooden minesweepers under frequent air attack and was credited with several aircraft destroyed. On 1 April a damaged Japanese plane splashed close under her stern; two bombs exploded under the fantail, jammed the rudders at hard right, and left her steaming in circles while two more suicide aircraft came in. She destroyed one; *Mullany* (DD-528) got the other. Towed into Kerama Retto, she was sent home for permanent repairs and missed the rest of the campaign. She received the Navy Unit Commendation.

The name ship *Robert H. Smith* (DM-23) served as a picket north of Iwo Jima and later off Okinawa, where she was twice attacked by kamikazes before the landings and, on a later six-week picket tour, was credited with five aircraft; she received the Navy Unit Commendation. *Shannon* (DM-25) gave fire support at Iwo, then covered sweepers and pickets at Okinawa and, after the surrender, in the Yellow Sea and off Japan. *Thomas E. Fraser* (DM-24) also fought at Iwo and Okinawa, escorted the kamikaze-damaged hospital ship *Comfort* to Guam in early May, and on 6 June relieved the battered *Ditter* on picket station; she was in Tokyo Bay on 2 September. *Tolman* (DM-28) served with the same squadron through the Okinawa operation.

Converted minelayers: CM, CMc, and ACM

The Navy's first large minelayers were rebuilt cruisers. *Baltimore* (later CM-1) and *San Francisco* (later CM-2) were converted before the First World War and did their most important mining in 1918, helping to plant the North Sea barrage—*San Francisco* as flagship of Mine Squadron 1. *San Francisco* was decommissioned in 1921, stricken in 1937, and sold in 1939. *Baltimore* left active service in 1922 and lay at Pearl Harbor as a receiving-ship hulk; she was still there, already stricken, during the attack of 7 December 1941. Sold for scrap in 1942, the hulk was finally towed out and scuttled off Oahu in September 1944.

Shawmut, a converted coastal liner, also worked the North Sea barrage. Renamed *Oglala* (CM-4), she was flagship of the Pacific Fleet Mine Force on the morning of 7 December 1941, moored outboard of the light cruiser *Helena* at 1010 Dock. A torpedo aimed at *Helena* ran under *Oglala* and exploded against the cruiser; the blast stove in the minelayer's port bilge. A bomb that burst nearby added to the damage. With power gone and no pumps, she was hauled astern of *Helena* so she would not pin the cruiser to the pier, and about two hours after the first hit she rolled over and sank alongside the dock. The salvage became a legend: she was righted in April 1942, sank again more than once during pumping, and was finally dry-docked in July. Refitted on the West Coast, she returned to service later in the war as an engine-repair ship (ARG-1).

Of the Second World War coastal conversions, *Wassuc* (CMc-3) spent almost the entire war in the Chesapeake and along the East Coast on experimental and training duty for the Bureau of Ordnance, though she did lay a small defensive field off Cape Hatteras on 22 May 1942. By 1944 she was the Navy's last coastal minelayer still so rated. She was decommissioned in November 1945.

Miantonomah (CMc-5, later CM-10) and her near-sister *Monadnock* (CMc-4, later CM-9), both converted from fast coastal cargo ships, sowed early defensive fields off the Virginia Capes, Cape Hatteras, Key West, and Trinidad. In November 1942 *Miantonomah* laid a defensive field off Fedala during the Morocco landings—narrowly missed by torpedoes in two U-boat attacks that sank other ships in the anchorage—then joined *Terror* and *Monadnock* on 16 November to extend the field to Casablanca. In 1944 she went to Europe in support of the invasion, running port-clearance stores between English and liberated French harbors. On 25 September, leaving Le Havre, her captain ordered the highest state of watertight integrity and all men not on watch below to be on deck in lifejackets. About 2,000 yards beyond the block ships, at 1415, an underwater explosion under the engine room—possibly two—broke her back. She sank in about 20 minutes, with the loss of some 58 officers and men.

Monadnock, after Torch and East Coast training, went to the Pacific in late 1943 and, in May 1945, as a unit of Task Force 52, laid fields at Kerama Retto and off the Hagushi anchorage at Okinawa. Redesignated ACM-10 that July, she later lifted occupation troops to the Western Pacific. She received three battle stars.

Keokuk (CM-8), a larger converted merchantman, laid mines off the Atlantic coast and at Casablanca, then, in July 1943, planted antisubmarine fields off Gela, Sicily, under air attack on 11 July. Reclassified as a net-cargo ship (AKN-4), she spent the rest of the war laying and hauling nets in the Pacific—at Tarawa, in the Marshalls, and off Saipan during the June 1944 landings, and later at Peleliu. *Salem*

(CM-11), another cargo conversion, laid antitorpedo nets at Kerama Retto at the end of March 1945 and helped shoot down an aircraft attacking *Lunga Point* (CVE-94) on 2 April. In August 1945 she was renamed *Shawmut* to free the name *Salem* for a new cruiser. *Weehawken* (CM-12), a converted car ferry, laid defensive fields at Casablanca in late December 1942 and, in July 1943, off the Gela beaches, coming through heavy Luftwaffe raids with only fragments from a near miss. She later went to the Pacific and earned two battle stars. In October 1945 a typhoon drove her hard aground; her hull broke, and she was decommissioned as a total loss in December.

Almost all of the auxiliary minelayers (ACM) were former Army mine planters, taken into the Navy to help maintain defensive fields and, later, to support amphibious operations. *Monadnock* was a notable exception, joining the ACM list only after her Okinawa minelaying was done.

Submarine minelayers

Argonaut, the only American submarine designed as a minelayer, never planted a wartime field. The work was done by fleet boats firing Marks 10 and 12 through ordinary torpedo tubes. Thirty-two submarines laid 658 mines in 36 fields. No submarine was lost on a minelaying mission.

The first field went down off the approaches to Bangkok on 16 October 1942, when *Thresher* planted 32 Mark 12 mines; *Gar* laid another 32 in the same area four days later. From Pearl Harbor, *Whale* slipped into Kii Suido on 25 October and planted 24 moored Mark 10 mines, intended to push coastal traffic into deeper water where torpedoes could reach it. *Sunfish* mined the approaches south of Nagoya in mid-December; *Drum* planted 24 mines in Bungo Suido, the western gate of the Inland Sea, on 17 December. *Trigger*'s field off Inubo Saki, already mentioned above, gave her crew the rare sight of a ship breaking her back in a field just laid. Later plants along Indochina, Malaya, Borneo, and Makassar Strait were often mixed loads of eleven mines and a full torpedo stowage. Postwar accounting could score only 21 of the 36 fields, but those 421 mines were credited with 27 ships sunk and 27 damaged.

Navy aircraft units

Navy and Marine carrier and patrol aircraft began offensive mining well before the B-29 campaign. After dusk on 20 March 1943, 42 Navy and Marine TBF Avengers, each carrying one Mark 12 magnetic mine, mined Kahili harbor in the northern Solomons without loss, supported by a diversionary heavy-bomber raid, and repeated the operation the next night. Further air plants followed around Bougainville that month. On 30–31 March 1944, Avengers from the fast carriers of Task Force 58 planted 78 mines in the entrances at Palau, with the results already noted. In April, aircraft of Fleet Air Wing One—PB4Y-1 Liberators and PB2Y-3 Coronados flying from Eniwetok—mined Truk and closed that anchorage for about a month. Navy aircraft laid several hundred mines in all, a small number beside the Army Air Forces' inner-zone campaign, but in confined waters a few dozen mines could close a fleet base. The 313th Bomb Wing's Operation Starvation, flown with Navy-designed and Navy-assembled mines, remains the largest American mining effort of the war; it is described above.

Fuzes, degaussing, and sterilization

This section is about how the mines actually went off, how a ship tried not to set them off, and how a field was supposed, in time, to go safe. The wartime language is used here: a fuze or "firing mechanism" is the device that decides to fire; a sterilizer is what later makes that decision impossible. Where a detail comes from a postwar teaching text rather than a 1945 pamphlet, that is noted.

Contact horns and the antenna mine

The oldest reliable way to fire a moored mine was to wait until a ship hit it. Ordnance Pamphlet 898, the Navy's mine-identification manual in its August 1945 revision, describes several contact devices then in service. The one most people picture is the chemical, or Hertz, horn: a soft lead cylinder with a glass vial of acid inside, mounted over a small battery cup that already held a carbon electrode and a zinc electrode, wired to an electric detonator. So long as the vial was intact, there was no electrolyte and no cell. When a hull crushed the horn, the vial broke, acid ran into the cup, the cell came to life, and the current fired the detonator. Snag lines could be tied to a horn so that a ship might break the vial without striking the horn itself.

A switch horn was simpler and purely mechanical. A spike sat between contacts, held off them by a spring—OP 898 gives the spring loading as a range, not a single figure. If the spike was forced over, it closed a battery-detonator circuit. A rigid "curtain-rod" antenna could take the place of the spike. Other contact devices, used less often by the United States, included hydrostatic horns, LeClanché-cell horns (seawater wetting a dry electrolyte), and pendulum or bridle mechanisms that fired if the case was tilted or a hoop was rotated. OP 898 notes that more than one contact device could be fitted on a single mine: a chemical horn with a switch horn, or either type with a galvanic antenna.

The galvanic, or "sea battery," fuze is the one that mattered most on *Terror*'s tracks. A copper antenna or copper spike stood in the water as one electrode. Seawater is a weak electrolyte. When a steel hull—a dissimilar metal—touched the copper, a small current flowed into the mine's internal circuit and completed a battery-detonator path. On the Mark 6, the standard American moored mine of both world wars and the type *Terror* was built to plant in quantity, that circuit was the "K-pistol." A copper antenna rose from the spherical case toward the surface and was connected, through a relay, to a copper plate on the outside of the mine. The current down the antenna operated the relay and the mine fired. One mine thus threatened a much taller column of water than a horned mine moored at a single depth, which is why the same field could be planted more thinly. Some Marks 6 also carried a lower antenna in the mooring and, NavWeaps records, a few Hertz horns as a backup. The type was not meant to be dangerous on the deck: a time delay, a hydrostatic switch that stayed open until the mine had sunk several feet, and a further lock on the explosive train kept it unarmed until it was well under. Authorized late-war track capacity on *Terror* was about 850 of these mines (or slightly fewer Marks 16 or 18). The Mark 10, fired from a submarine's torpedo tube, was a horned moored mine; the Mark 16 was the heavier Torpex antenna mine meant, in time, to succeed the Mark 6.

Magnetic, acoustic, and pressure fuzes

Influence fuzes did not need to be touched. They waited on the bottom, or in a moored case, for a sign that a ship was near: a change in the earth's magnetic field, a particular underwater sound, or a brief drop in water pressure.

The first magnetic mines the Allies had to understand, and the type the Navy's 1945 merchant-ship history used to explain the danger, were dip-needle weapons. A magnetized needle, hung horizontal between two contacts, was free to move in a vertical plane. A steel ship distorts the vertical component of the earth's field; if the distortion was strong enough, the needle overcame a light hairspring, touched a contact, and closed the detonator circuit. Dip-needle mines had to be built in nonmagnetic cases, usually aluminum, and they answered to the *amount* of field change, which made them relatively simple—and, once understood, easier to neutralize by reducing a ship's field.

Induction fuzes were a different instrument. OP 898 describes a coil of wire on a magnetically permeable core, connected to a circuit that closed a switch in the detonator line. A moving magnetic field—a ship underway—induced a small current in the coil. A 1957 Naval Academy text, *Naval Ordnance and Gunnery* (NavPers 10797-A), adds useful detail, consistent with wartime practice, though it is not itself a 1945 pamphlet: a search coil might have many thousands of turns of fine wire on a permalloy core, and was used with a steel case, which added to the effective core. Induction mechanisms could look not only at the size of the change but at its rate, and some were built to require two or more pulses, or "looks," of opposite polarity before they would fire. American aircraft and submarine mines of the Mark 12 and Mark 13 families, and the later Mark 25, 26, and 36 bottom mines, belonged to this influence world. NavWeaps describes the Mark 25, the large (about a ton) aircraft mine, as magnetic in its basic form, with later mods using an A-5 acoustic trigger or an A-6 pressure trigger; the thousand-pound Marks 26 and 36 were of the same family, with magnetic, acoustic (including low-frequency), pressure, and combination fittings. Those "Mod" designations were how a single case could be issued with a different instrument rack.

Acoustic fuzes used a microphone—typically, in later American practice, a rugged crystal type—and a circuit that closed the detonator switch only if the sound had the right frequency, intensity, and duration. Ships are noisy in the water: propellers, machinery, hull vibration. The noise varies with speed, loading, depth, and the bottom, so the fuze could not simply fire at the loudest bang. The usual design, as the 1957 text explains it, was to fire when intensity reached a set value after building up at a prescribed rate. A sound that rose too fast (a countermine) tripped an anticountermining circuit and made the mine passive for a short time; a sound that rose too slowly was ignored. Low-frequency acoustic mechanisms, used against Japan in 1945, were especially troublesome for sweepers, because ordinary noisemakers did not always speak in the band the microphone was listening to. American acoustic assemblies were interchangeable fittings for several cases, often combined with a magnetic unit.

Pressure fuzes felt the hollow that travels with a moving hull. Water is pushed aside at the bow and closes in aft; under the ship the pressure on the bottom drops slightly for several seconds. OP 898 describes a set of small air volumes, in one of which a diaphragm-controlled switch was mounted, arranged so that this negative-pressure "hump" compressed the diaphragm and closed the switch. Wave action also changes pressure, but much faster, and the fuze was designed to ignore rapid fluctuations. The Ger-

man “oyster,” withheld until the eve of Normandy, worked on the same principle. The Japanese recovered American magnetic-pressure mines in 1945 and had only limited success against them. American pressure fittings on late-war Mark 25 and related mines were issued late, and usually in combination with a magnetic or acoustic unit, because a pressure fuze alone was both hard to sweep and hard to keep from being confused by weather. There was no satisfactory pressure sweep in 1945.

Combination fuzes required two influences at once, or in a set order: magnetic and acoustic, or pressure and magnetic, and in some assemblies all three. A sweeper towing only a magnetic tail, or only a noisemaker, would not satisfy the circuit. That is why mixed fields had to be worked one influence at a time, and why a “sterilized” pressure-magnetic mine remained a special problem after the surrender.

Arming delays, counters, and other fittings

A mine that armed on the rail, or in the air, was a danger to its own side. Several independent safeties were used together.

Hydrostatic arming was the basic one. An extender, driven by water pressure, moved the detonator into the booster only after the mine had reached a set depth; until then the detonator sat clear, so that a knock on deck would not set off the main charge. A clock starter, also hydrostatic, started—or, in some designs, could stop—the arming clock. Surface-laid fittings often had a soluble washer around a spindle, so that even after the mine was in the water the hydrostat could not travel until seawater had dissolved the washer. Aircraft mines used an arming wire pulled free as the mine left the aircraft. Submarine mines had a safety bar that fell away as the mine left the tube, and often a lock-ball that kept the hydrostat from moving until the mine was deep enough. Safety nuts, removed just before planting, kept extenders and clock starters locked for handling and stowage; if they were left on, the mine would not arm at all.

Clock-delay (CD) mechanisms postponed arming for a set time after planting, so that the layer could be well clear, or so that a field would not come alive until a chosen moment. They were spring-driven cams operating switches. A 15 July 1945 mine-warfare note describes an electrolytic “arming cell Mark 2” that could replace a soluble washer on certain clock starters: seawater formed a small cell between a zinc disk and a silver-chloride cup, the zinc wasted away, and after a nominal few days—the time could move with temperature, pressure, and salinity—the starter was free to arm. The same note records that mines laid in Manila Bay in December 1944 were fitted with sterilizers so they would not become “boomerangs” when American forces entered a few weeks later, and that U.S. sweepers later found no live mine in the area.

A ship counter (an “SE” device, originally “ship eliminator”) did not delay arming so much as delay firing. It let a chosen number of complete actuations pass—sweepers, perhaps, or the first ships through a channel—and fired only on a later one. Sensitivity could be set, and some delays were randomized, so that the enemy could not be sure which ship in a line would be taken.

Two other fittings belong with these, though they were not fuzes. An anticountermining device temporarily deadened the mine's circuits after a nearby shock, so that one explosion would not sympathetic-detonate the field. Anti-sweep mines, with only a tiny charge, could be mixed into a moored field; they had little buoyancy, and when a sweeper's wire rode up the mooring they slid down onto the wire and cut it, ending that pass. None of these devices made a mine safe to pick up.

Degaussing in more detail

A steel ship is a magnet, in two different ways. Permanent magnetism is built in during construction and is slowly changed by the earth's field, by vibration, and by heading and latitude; induced magnetism appears whenever the hull sits in the earth's field and changes as the ship heels, pitches, or steams onto a new heading. A dip-needle or induction fuze on the bottom feels the vertical disturbance most of all. No practical degaussing system erased the field of a ship of any size. The aim was to bring the remaining signature below the fuze's setting, especially the vertical component.

The foundation of an installed system was the M, or main, coil: one or more horizontal loops running from bow to stern, often near the waterline or around the upper deck, carrying a current that opposed the ship's vertical magnetization. Many ships also had F (forecastle) and Q (quarterdeck) coils—shorter horizontal loops in the forward and after thirds of the ship, preferably at a different height from the M coil—to deal with the uneven, longitudinal component of the field. Those F and Q coils could be split, in more elaborate installations, into pairs for permanent and induced magnetism (FP–QP, FI–QI), sometimes with reverse polarity in one stretch. An A, or athwartship, coil, in vertical loops in fore-and-aft planes, compensated the beam-wise component. A 1942 Navy costing list treated four basic outfits as standard: Mark I (M only), Mark II (M and A), Mark III (M, F, and Q), and Mark IV (M, F, Q, and A). Merchant ships were usually simpler: from May 1942, A coils were not fitted on them; ships under 62 feet in beam got only an M coil, and wider ships M, F, and Q. Later Navy training also describes an L, or longitudinal, coil—loops in vertical planes parallel to the frames—used when compensation for pitch, and for remaining fore-and-aft magnetization, was needed. It is a real coil in the American system; this essay does not assign it ship by ship beyond the 1942 list.

Coils were only half the work. Ships were also depermed, flashed, or wiped, procedures the Bureau of Ordnance supplied equipment and instructions for, and that naval-district commandants were responsible for carrying out. Deperming used heavy temporary windings and large currents to reduce permanent magnetism. Flashing sent a series of high-current pulses through a temporary loop (on submarines, often a "Z-loop" at the waterline) and was, for boats, repeated on a schedule measured in months. Wiping ran a live cable along the hull for a similar, sometimes shorter-lived, effect. After treatment, and after coil currents had been set, the ship was run over a magnetic survey range: cables on the bottom that measured the remaining field as the ship steamed over them, so that the coil currents could be adjusted. Ranges were used in daylight and, when the load required it, at night. *Terror* herself ran the range in San Francisco Bay on 9 August 1945, at the end of her post-repair trials.

Degaussing fought with the compass. The same coils that quieted the hull could pull a magnetic compass off, and compensating coils were part of the standard outfit. On some Alaskan merchant runs the disturbance, together with armament and splinter protection, was enough for the Bureau of Ships to look at gyro compasses as a defense item. Coil currents also had to be reversed or reset with latitude and heading; an M-coil setting that cancelled the field in one hemisphere would not automatically do so in the other.

Degaussing was a defense against magnetic fuzes, and a poor one in very shallow water. It did nothing for acoustic or pressure mines. Those were answered, imperfectly, by the sweeper's noisemakers and, for pressure, by the lack of any good sweep—hence the later use of guinea-pig ships to check a channel the hard way.

Sterilization and making a mine safe

Convention (VIII) relative to the Laying of Automatic Submarine Contact Mines, signed at The Hague on 18 October 1907, forbade unanchored automatic contact mines unless they became harmless within one hour after they left the layer's control, and forbade anchored automatic contact mines that did not become harmless as soon as they broke loose from their moorings. Belligerents were also to do their utmost to render anchored contact mines harmless within a limited time, and, after the war, to remove what they had laid. The convention is written for *contact* mines; influence mines did not yet exist as a service weapon and are not named. American practice in 1941–45, in the spirit of those rules, was to fit almost all service mines with sterilizers, and Fleet Admiral King authorized the more nearly unsweepable combination and low-frequency mines for the Japan campaign only with timed sterilizers.

A sterilizer (an "SD," or self-destructive, mechanism in later Navy language) ended the armed life of a mine after a set period. The usual method was to short out the battery; sometimes the detonator circuit was simply opened. On a moored mine the same idea could be carried further: a sinking detonator blew out a plug and flooded the case, so that the mine sank or lost the buoyancy that held it in the danger zone. Sterilizing switches could be built into a clock-delay mechanism. A more positive type, described in the 1957 teaching text, was an electrolytic cell: current slowly ate away an anode until a spring-loaded plunger ruptured the cell and closed switches that shorted the battery. When a field had to be sure of going safe by a given date—so that friendly ships could enter—two or more sterilizers could be wired in parallel. Battery life itself was a crude sterilizer: once the dry cells were dead, the fuze could not fire. That was not something a planner treated as a substitute for a designed SD.

None of this made a sterilized mine a harmless object. Shorting a battery or flooding a case is not the same as removing several hundred pounds of TNT or Torpex. A floater whose fuze has gone open-circuit is still a disposal problem, as is a bottom mine whose sterilizer has run but whose charge is intact. After Operation Starvation, sterilizers sometimes did exactly what they were supposed to do—and sometimes did not, or had not yet—and a "safe" field still had to be swept and then dealt with by specialists. Rendering-safe was explosive-ordnance-disposal work: identify the type, isolate or remove the detonator and booster so the firing circuit could not reach the main charge, and then destroy or recover the charge. The Mark 6 mines on *Terror*'s tracks, with their hydrostatic safeties and, in service, sterilizing features in the spirit of the 1907 rules, were designed not to fire on the rail or as floaters; they were not designed to be manhandled as empty iron.

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