Raoul E. Drapeau

Operation Outward

Britain's World War II offensive balloons

MOST STUDENTS OF WORLD War II are aware of the thousands of barrage balloons that Britain employed throughout the war to help protect cities, ports, and other important targets from low-flying Luftwaffe dive bombers and fighters. These large gas balloons measured about 64 ft (19.5 m) long by 34 ft (10.4 m) in diameter and were tethered to the ground by steel cables attached to winches and rose to heights of up to 5,000 ft (1,524 m).

In addition to making the German aircraft fly higher than planned, those that did fly low had to maneuver to avoid the barrage balloons and their cables, thereby cutting their accuracy. Those aircraft that did impact the cables or balloons were often destroyed or heavily damaged. During what was termed the "Blitz," which was the period from September 1940 to May 1941 when Luftwaffe attacks centered on London and other large or important cities, 102 aircraft struck barrage balloon cables and either crashed or had to make a forced landing.

That history, including the iconic photographs of barrage balloons deployed near Tower Bridge, the Houses of Parliament, and other strategic structures and installations is well known (see Figure 1). What is less well known is what happened next.

Errant Balloons

On the night of 17 September 1940, during the Battle of Britain when the Luftwaffe was incessantly attacking England by air, a raging storm with gale-force winds ripped many of the barrage balloons away from their moorings. The balloons were carried by the winds over the North Sea toward mainland Europe, dragging their severed cables behind them.

Within hours, reports of electrical outages in Denmark, Sweden, and Finland began to come in. The balloons' heavy tethering cables had struck high-voltage overhead electric transmission and distribution lines, and the resulting short circuits caused power outages affecting electrified railroads and even whole cities. One balloon strike resulted in the toppling of the broadcast tower of the Swedish international radio service.

One such report said "On Wednesday evening the Swedish west coast witnessed a great 'invasion' by foreign barrage balloons. Over the coast of the province of Halland, the barrage balloons came over in such numbers that at times the sky was lit up with sparks when the balloon cables touched electric wires."

Genesis

It occurred to Britain's leaders that if wayward balloons could accidentally cause damage to overhead electric power transmission lines, perhaps a purpose-designed and deployed balloon system could do even better.

In early 1940, the Air Vice Marshal of the Balloon Command, the organization responsible for the barrage balloons,

figure 1. Barrage balloons over Buckingham Palace, London, during World War II (from *Air Publication 3003–A Brief History of the Royal Air Force*, 2004).

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Since the launch of *IEEE Power & Energy Magazine* in January 2003, the "History" column has offered articles on the development, expansion, and improvement of the electric power system and the utilization of electric power to do productive work. We have featured inventors, engineers, and entrepreneurs who created what has become known as the "Electrical Age" and have showcased many outstanding electrical innovations and achievements.

This issue's "History" column represents a change of pace in that it is a fascinating account, authored by Raoul E. Drapeau, of a beleaguered Great Britain using its ingenuity and limited resources during World War II to devise and implement a program specifically intended to disrupt the supply of electric power and damage or destroy electrical infrastructure.

Operation Outward was a British Admiralty program that, between March 1942 and September 1944, manufactured and launched almost 46,000 inexpensive hydrogen-filled meteorological balloons trailing a length of wire intended to contact and short circuit overhead high-voltage and lower-voltage transmission and distribution lines in Germany and in occupied Europe. By all accounts, this campaign succeeded in randomly disrupting target electrical systems, was conducted with relative safety to Women's Royal Naval Service (WRNS) personnel involved, and was extremely cost effective. In addition to the actual damage caused and the loss of electric power, Operation Outlook had significant harassment value by imposing extra demands on German air defenses and aviation fuel supplies.

Raoul Drapeau is a businessman, lecturer, author, inventor, and former naval officer. He holds a B.S.E.E. degree from Cornell University and an M.S.E.E. degree from Rensselaer Polytechnic Institute. He also holds 13 U.S. and foreign patents and is an active inventor. He has taught adult education courses in the history of engineering and invention for many years.

He has authored numerous articles on business and the history of technology, including a recent article in *WW II History Magazine* on the famous but controversial formerly top-secret Norden bombsight. He recently authored *Your Invention*, an educational book for inventors on the development, protection, and marketing of inventions, and has also recently published *The Fat Man's Disk*, a fictional mystery thriller set in the Middle East.

We are pleased and honored to welcome Raoul Drapeau to these pages as our guest history author for this issue of *IEEE Power & Energy Magazine*.

—Carl Sulzberger
Associate Editor, History

wrote "Since the outbreak of war, I have had constant complaints from the electricity distributors regarding the damage done in this country by [barrage] balloons that have broken away from their moorings." He went on to suggest that "…advantage might be taken of this to impede and inconvenience the enemy."

On 19 September 1940, Winston Churchill, ever the out-of-the-box thinker, captured the sentiment when he wrote a comment on a memo to the War Cabinet "We may make a virtue of our misfortune."

The British military rightly assumed that balloon attacks would be very hard and expensive for the Germans to defend against.

And so was born Operation Outward, an offensive weapon scheme that the British hoped would carry the battle to Germany and the occupied countries less expensively and more safely than British night bomber attacks.

The British military rightly assumed that balloon attacks would be very hard and expensive for the Germans to defend against. The balloon cruising altitude was high enough that even if spotted in the daytime, it would exact a significant cost in fuel and wear and tear on their fighter aircraft that were diverted to the task of intercepting and destroying the balloons.

Trials

Captain C.G. Banister, director of Boom Defence (an Admiralty group responsible for laying antiship and antitorpedo booms to protect harbors), a proponent of using balloons as an offensive weapon, continued to press the point. He suggested holding trials to determine what size balloon could be used, the particulars of the wire (length, diameter, material), the meteorological considerations, and most important, whether safety devices (e.g., circuit breakers) on the high-voltage lines would work well enough to make the scheme ineffective.

To help prove its case, the Admiralty ran trials using surplus spherical latex meteorological balloons about 8 ft (2.4 m) in diameter when inflated. Calculations based on the trials predicted that there would be between 10% and 75% chance of a balloon's wire coming into contact with a high-voltage overhead line during a 30 mi (48 km) transit along the ground.

Surprisingly, the trials showed that even a thin steel wire (much thinner than that used to tether the static barrage balloons), when drawn in sliding contact across two or more phases, could cause an arc as long as 15 ft (4.6 m) that would be maintained until the circuit breaker opened. In some cases, the arc's heat melted the aluminum outer layers and then the reinforcing steel center strands of the conductors. Further, even if not severed, the conductors would be so weakened by the arc that they would be susceptible to breaking due to increased load demands or even normal weather events such as wind, snow and ice. Then, even if the trailing wire was severed by the arc, the balloon with the remaining portion of the wire could be carried along with the wind to engage yet another electric line (see Figure 2).

A balloon's trailing wire could cause the same kind of phase-to-ground short that would occur from normal peacetime causes, such as conductors breaking. These resulted in tripping of circuit breakers and an inconvenient, but usually short-term, resultant loss of power. However, if the trailing wire caused a phase-to-phase event, it could be much more serious.

The British knew that the German high-voltage electric transmission system was protected by Petersen coils, which could not cope with phase-to-phase shorts of the type that would likely be caused by the balloons' trailing wire. Further, they knew that the German systems of that time used slower-acting circuit breakers, also not designed to handle phase-to-phase shorts. The British concluded that this design could lead to the destruction of the circuit breakers and transformers and cause even more catastrophic faults, such as wrecking an entire power generating station, which actually happened in 1942.

Even though the British electrical system had a more developed grid than that of Germany, which could make it more vulnerable, it also had faster-acting circuit breakers, and had proven itself more capable of tolerating (but not be completely protected from) hits from errant barrage balloon cables.

figure 2. Artist's conception of what a fleet of balloons might have looked like as it encountered an overhead power line (image courtesy of Raoul E. Drapeau).

This made the British less worried about the effects of possible retaliation and more encouraged about the potential of trailing wires as a weapon.

Further supporting the argument that trailing wires could be an effective weapon was the idea that since the balloons would be released in large numbers, they would be likely to cause numerous faults in the same area, thereby complicating the task of repair and further diverting valuable resources. Also, even a single balloon could cause multiple disruption events as its long wire dragged along the ground.

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Considering the shortages of materials for repair of electric power systems in England and especially in Germany, it was clear that the consequential damage of a balloon strike could be much greater than that caused by a single bomb dropped from an aircraft.

Operation Outward

The initial approval to begin Operation Outward, as it was to be called, was given by the Prime Minister and the Chiefs of Staff on 4 March 1942. Operations began on 20 March from Landguard Fort in Felixstowe in Suffolk on the southeast coast of England. Balloons were to be released between the hours of 10 a.m. and 4 p.m., subject to suitable meteorological conditions.

Eventually, there were three launching sites for Operation Outward, lined up 50 mi (80.5 km) apart on a north-south line along the southeast coast of England. The original was at Felixstowe, and expansion sites were added at Oldstairs Bay in Kent near Dover and Waxham in Norwich, north of Great Yarmouth. These particular locations were chosen due to their nearness to the coast and to make sure that there would be suitable additional locations to take best advantage of wind conditions.

Since the Royal Air Force (RAF) had been placed in charge of the static barrage balloons through its Balloon Command, it would have been logical to also give the RAF the responsibility for Operation Outward. But because the Admiralty had made the proposal, owned the balloons, designed the apparatus, used their own sites and provided the personnel, they were placed in charge of the launching operation.

The RAF remained concerned about collisions between balloons and their aircraft in spite of the facts that the balloons were small and the wires very thin, and that the trials had shown potential collisions to not be a problem. As a result, the RAF was given control to both permit the release of balloons and to order operations shut down if flight operations so required. This condition was to prove troublesome for Operation Outward and led to much sniping between the RAF and the Admiralty.

Design Matters

Modern military organizations are used to having the best materials that money can buy, including ultrastrong molded engineering plastics and finely turned metal parts. In 1940s England though, designers had to make do. The Operation Outward payload consisted mainly of two small concentric tin canisters, the inner one filled with mineral oil and the outer one holding a spool of string and piano wire. There was a time-delay fuse attached to the outer wall.

Inside the 8-ft (2.4-m) diameter hydrogen-filled balloon was a loose cord, one end of which led to a spring-loaded valve. The other end exited the balloon and was secured at a length corresponding to the desired cruising altitude, usually 25,000 ft (7,620 m). When the balloon reached its planned cruising altitude, it had enlarged enough from the reduced atmospheric pressure to tighten the internal cord and release some hydrogen from the valve, thereby cutting the lift a little and halting the rise in altitude.

As the balloon was launched, the fuse was lit at a point corresponding to the number of hours of flight desired. After several hours, when the balloon had already started to descend at a leisurely rate of 200 ft/min (61 m/min) because of insufficient lift from leakage of hydrogen, the fuse would burn through a cord holding the trailing wire and cord in place and they would unwind, dropping down beneath the balloon.

The trailing cable consisted of 700 ft (213 m) of 0.125-in (3.2-mm) diameter, 40-lb (18.1-kg) test hemp cord secured to the balloon, and 300 ft (91.4 m) of 0.072-in (1.8-mm) diameter (15 gauge) steel piano wire with a breaking strength of about 1,000 lb (454 kg) attached to the end of the cord. The hemp cord was used to keep the unit weight and cost as low as possible.

As the balloon was launched, the fuse was lit at a point corresponding to the number of hours of flight desired.

At the same time that the wire was released, the stopper on the canister holding the ballast oil was pulled out, allowing the oil to slowly drip out. This slow reduction in weight, plus the reduction in load due to the wire being partially supported by the ground, would keep the balloon at a more-or-less constant operating altitude of 1,000 ft (305 m) for the 30-mi (48-km) run the Admiralty hoped to achieve.

Meteorology

Since they were at the mercy of the winds, the balloons were an indiscriminate, unguided weapon. For the weapon to be effective, the winds had to be in the right direction to carry the balloons eastward and occur often

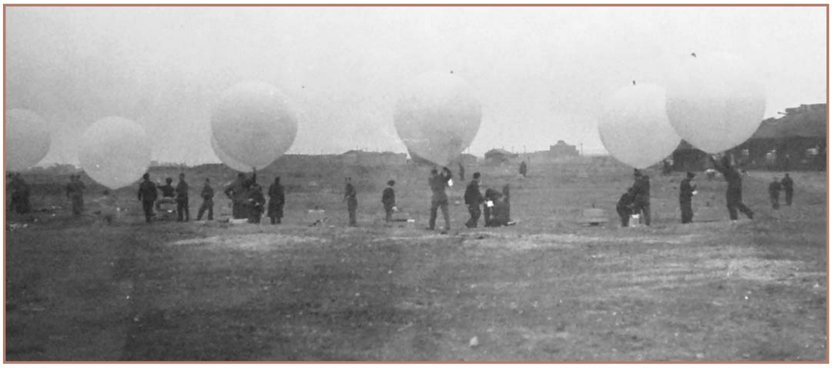

figure 3. Actual Operation Outward balloon launch from the Felixstowe, Suffolk, site (from The National Archives of the United Kingdom, folder #ADM 199–848).

enough to make it worth the effort. Although there was much discussion and disagreement on this point within the British military, evidence showed that winter winds would be most favorable for the British. Winter would also be the best time of year for operations since the electrical loads were the greatest, and repair operations would be the most difficult.

There was ample opportunity for the Germans to retaliate when the winds were blowing westward as they often did, particularly since occupied Europe from which they could launch balloons was so close to England. However, the Germans never did retaliate, perhaps because they did not have access to the needed latex raw material and, by that time, they were preoccupied with Operation Barbarossa, their invasion of Russia that had begun in June 1941.

Flight Operations

Initially, the balloons were to be launched shortly before blackout, giving them most of the night over enemy territory before Luftwaffe planes could detect and shoot them down. But even though the cruising altitude of the balloons would be controlled and high enough to avoid encounters except possibly during ascent or descent, the RAF prevailed, and almost immediately the hours were changed to between 10 a.m. (after the night bombers had returned) and one hour before sunset. That policy avoided encounters between bombers and balloons but exposed the balloons to ground and air fire, particularly as they neared the ground. The most puzzling objection to their use as an offensive weapon was that "attacks of this nature should not be originated from a cricketing country," suggesting that Operation Outward somehow constituted poor sportsmanship.

Assuming that the RAF gave permission to launch, the conditions suitable for launch were mostly weather related. Favorable wind speed and direction at cruising altitude were needed so that the balloons would arrive at the target area up to eight hours after launch. Additional requirements were no icing, minimum winds at ground level for launching operations, and speeds above 10 mi/h (16.1 km/h) in the target area so that the balloons would drag their wires.

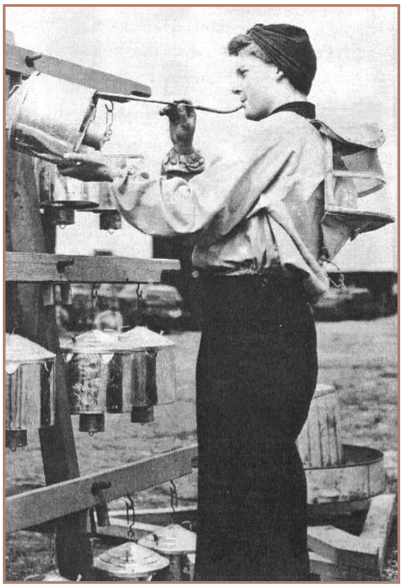

figure 4. Royal Navy WREN Cecilia Banister, daughter of Captain C.G. Banister, director of Boom Defence for the Admiralty, lighting the fuse on a payload during a balloon launch operation (from E.G. Finley, *RCN Beach Commando W*, 1944, p. 71).

At each of the three launching locations, there were several places where balloons would be inflated, payloads attached, and the balloons then released. Workers built three-sided shelters out of canvas and wood that provided some protection from the wind. Each crew, of which there were several at each location, could launch ten balloons per hour (see Figure 3).

By early August 1942, the launch rate was 1,000 balloons per day from Felixstowe. As the balloons rose in the air, some citizens in the area thought they were parachutes, triggering a panic that an invasion was under way until the local police calmed them.

Because of ongoing pressures on obtaining male military personnel for combat duty, Outward balloon launching operations were conducted mainly by the WRNS personnel, commonly called WRENS, under the supervision of Royal Marines and noncommissioned officers. Even though it was a surprise to the chauvinistic British military establishment, the WRENS conducted themselves well, often working in foul weather conditions and even under enemy attack. The entire program employed 140 WRENS in this work (see Figure 4).

The launching operations were quite dangerous to the launch crews because of the ever-present chance of explosion or fire from the inflammable hydrogen used to fill the balloons. There were many instances of friction between the balloon and canvas shelter that led to unexpected bursting of the balloons and fire. One of the precautions was to wear a flash-proof jacket, a metal mesh hood, special gloves, and protective hand cream. In spite of the danger, Captain Banister reported that as of the end of the war, there had been no fatalities in crews, although many were burned or got what was termed an "instant suntan."

The WRENS, many of whom were holding jobs for the first time in their lives, developed things to amuse themselves, such as adopting songs of the day as their own, including "I don't want to set the world on fire." That seems oddly appropriate considering that about half of the nearly 100,000 Outward balloons that were launched contained incendiary weapons intended to start fires in the coniferous forests of Germany. They also wrote daring (for the time) messages on the balloons themselves, such as "Take this you bastards" and "Balls to Hitler, Goering, and Goebbels."

Interservice Relations

During the entire program, there was constant sniping between the Admiralty, which ran Operation Outward, and the Air Ministry, which was responsible for fighter, bomber, and barrage balloon operations. It is not unusual to have interservice rivalries, but in this case it was carried to extremes, with each side pointing out the perceived foolishness of the other.

It is curious for an American used to simple salutations and closes in business letters to read the flowery wording used in these British military communications. Many messages began with "I have the honour to refer to your letter…," and then conclude with "I have the honour to be, Sir, Your obedient Servant." However, in the body of the message, the writer would criticize the recipient in the harshest terms.

Since they were at the mercy of the winds, the balloons were an indiscriminate, unguided weapon.

For example, the director of plans was puzzled by the Air Ministry's intransigence in bringing up reasons not to pursue the project. In late 1941, he wrote "The obstructive tactics of the Air Ministry in this matter are only too obvious, though why they should wish to obstruct an operation which should reinforce their own bombing effort is difficult to understand."

In a 1941 memo to the Vice Chief of Naval Staff, commenting on Air Ministry criticism of Admiralty plans, Captain Banister wrote "Referring to the attached memo, the disadvantages are only such as might have been expected to emanate from the Air Ministry and the statement in Paragraph 2(vi) is a typical example of their misrepresentation of facts."

Censorship

Unlike in the United States where freedom of the press is a basic right, in wartime Britain the government could issue stop orders, as it did in April 1942 when it demanded that all references about small drifting balloons be stopped. The military wanted to keep it under wraps in case they might need a similar weapon in the future. British newspapers were thenceforward restricted to simply reprinting reports published in European newspapers, all of which reported on incidents on the mainland, and not those in Britain.

As a result, the British general public knew very little about Operation Outward until the documents were declassified in the 1970s. It was because of this secrecy order that even the people who worked on the project could only receive recognition for having caused the enemy what was termed "…damage equivalent in naval parlance to the loss of a capital ship…"

Similarly, the electric supply industry wanted to publish details so that they could incorporate lessons learned from the German experience with disruptions into their own electric power system, but were also denied permission to publish.

German Acknowledgement of Damage

Because of wartime secrecy on both sides, it was not until the end of World War II that the effect of Operation Outward balloons (called störballons, or "disturbing balloons," by the Germans) was known. However, there were some leaks, and intelligence acquired useful information during the war. There were reports about damage from the balloons from occupied France and as far to the east as Hungary.

In 1943, an internal German report acknowledged that high-voltage lines were being disrupted throughout the country. While, as expected, the report minimized the damage, it also pointed out that emergency crews were standing by to correct future incidents. Naturally, diversion of personnel and resources was precisely one of the intended effects of the program.

An extract from a late 1943 German 65th Infantry Division Special Q Orders reported:

> The enemy is using recently balloons carrying beneath them spiral coils of wire with a hook at the end. If these balloons become entangled in power lines, serious shorts occur, and often the damage lasts for days, causing work of units and state of readiness to be held up…

Also, British intelligence received a report from occupied France that "reliable source reports balloons with hanging cables highly effective electric railways. Suggest continue." They did.

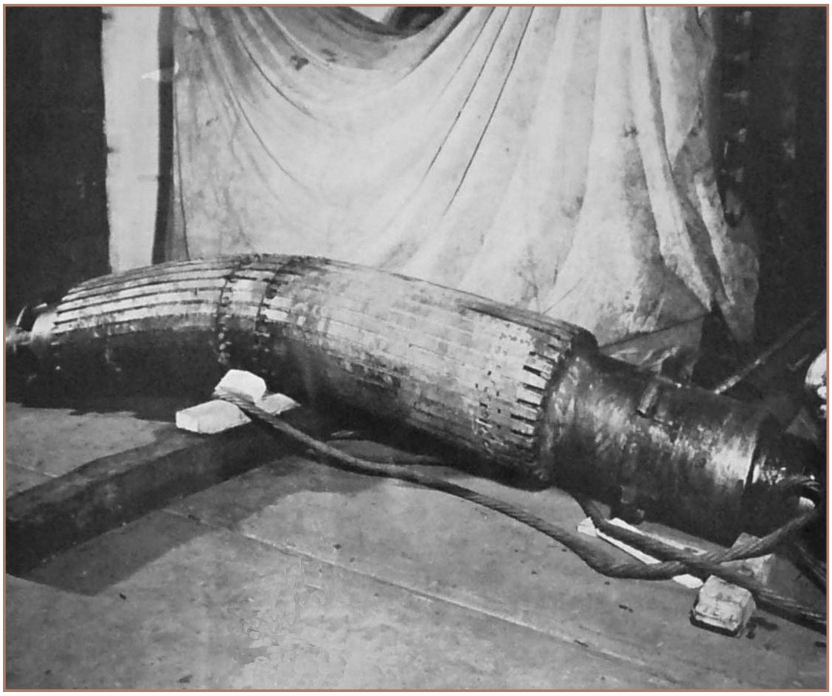

figure 5. Bent rotor from the Böhlen power station near Leipzig that was destroyed by an Operation Outward balloon on 12 July 1942 (from The National Archives of the United Kingdom, folder #ADM 199–848).

German Attempts to Protect Power Lines

One of the problems for the Germans was when the balloons severed a line on one side of a power pylon, the resulting unbalanced mechanical forces on the tower or crossarms sometimes damaged the crossarms or even collapsed the whole tower.

The Germans developed a device to help prevent this additional repair burden—a new clamp that would let the power line conductors drop to the ground if there were large and unbalanced longitudinal pulls due to conductors breaking. Over a million of these clamps were manufactured. However, normal swaying in the wind or ice loading caused the clamps to disconnect the wires, causing even further damage. Because the new clamps were designed by a high-level Nazi engineer, it took some time for the transmission engineers to prove that his clamps were not a solution. Eventually, they were all removed and the original clamps reinstalled.

The British learned that the Luftwaffe was sending up aircraft, in one case as many as 250 fighters, to shoot down the balloons and took that as a sign of their efficacy and that the Germans had not yet developed an effective countermeasure.

Cutback

Because hydrogen was the gas of choice for all the British balloon projects, there were constant disputes over access to hydrogen supplies. As the June 1944 Normandy invasion approached and Allied air operations over Europe increased, Operation Outward received fewer and fewer permissions for balloon launches to avoid collisions between Allied bombers and the balloons. The ground rules were changed and the project was cut back to only a few balloons with wires a day, instead of fleets of hundreds, as had been the case. Eventually, in mid-1944, all hydrogen supplies were withdrawn, and the last balloons were launched on 4 September 1944.

Postwar Analysis

The balloon attacks were carried out between March 1942 and September 1944. During this time, the launching sites released 45,599 balloons that carried trailing wires. During the war, it was hard for the British military to collect detailed information on the balloons' effects. But there was an indirect source, because when balloons happened to stray into neutral territory and cause damage, there was strong diplomatic protest. Thus, the British concluded that if the balloons were doing their job in Switzerland and Sweden, they should be working in Germany as well.

After World War II, an assessment team from Britain's Central Electricity Board was sent to Europe to gather what information it could. The team learned that the balloon weapons had indeed been successful.

One of the most important instances of damage was the 12 July 1942 complete destruction of a power plant at Böhlen near Leipzig due to an Outward balloon that had been launched on 11 July 1942. A phase-to-phase short on a 110-kV overhead transmission line caused the circuit breakers to malfunction, causing one of the 16.5-MW generators to be thrown out of synchronism and begin to vibrate. Its rotor shaft bent, causing mechanical interference with the fixed stator, followed by an explosion and a fire that destroyed the power station. This event put 250 MW of generating capacity out of operation for an extended period. The value of that material loss was estimated by the team at £1,000,000 (US$4,250,000) in 1942 currency, not including the value of production time lost (see Figures 5 and 6).

The assessment team learned that the Germans realized the potential damage of the balloons and gave orders to shut down power lines in their path and make the circuit breakers more sensitive. However, the latter change made the system more sensitive to normal occurrences such as bird strikes and overloads and exacerbated the power outage problem.

There were far more incidents on the more common lower-voltage lines, some of which would suffer from

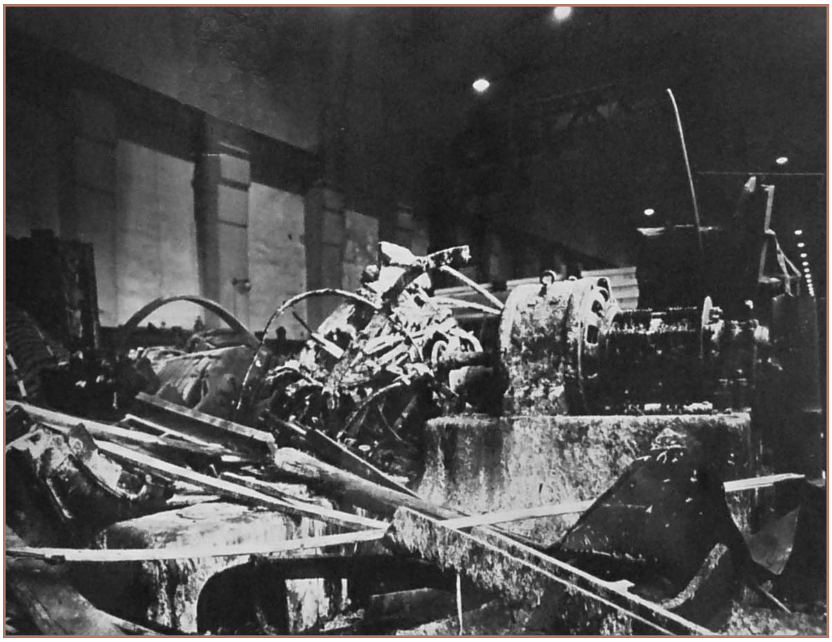

figure 6. Interior of the Böhlen power station near Leipzig after the explosion and fire that destroyed the power station on 12 July 1942 (from The National Archives of the United Kingdom, folder #ADM 199–848).

multiple failures. Worse, even though the breakers might have been reset and power restored, the lines often suffered damage to the wires that would become apparent later under heavy loads or adverse weather, when they would break.

The team retrieved a report that showed that in the period from March 1942 through the end of January 1943, there were 520 major disturbances on German high-voltage lines of 110 kV and higher. In that same period, there had been about 25,000 Outward balloons launched. Belgian, Dutch, and French transmission lines also suffered. In France alone, over the entire program, there were 4,946 recorded incidents of power interruptions. The postwar assessment reports were quite specific in most cases about Operation Outward balloons being the cause of the damage cited.

The team's conclusion was "…the evidence obtained shows that these Outward attacks were a continual menace to the whole German Electric Supply system for even minor incidents caused continual interruptions to the power supplies with damage to the equipment involving diversion of manpower on repair work, to say nothing of production delays. The destruction of Böhlen alone however was an ample reward for these operations." In another communication, the team wrote "the result of the operation was out of all proportion to the man-power and material employed." In fact, in some months, there was more damage done to electrical systems by the balloons than there had been by bombers—and at a much lower cost to Britain.

During the war, the German headquarters reports naturally tried to put a happy face on the interruption events, but a report from engineers from the British Central Electricity Board on the team reported "that regional disorganization of electrical supply which had been dismissed as unimportant by the national load controller was, in fact, frequently widespread and serious."

The Admiralty estimated the total costs for the operation at a little more than £2 (US$8.50) per balloon in 1942 currency. Even the Air Ministry had to opine that “The total damage caused by these attacks, particularly in view of the small effort expended, therefore, appears to be very high.”

After the war was over, in December 1945, Captain Banister wrote a letter summarizing Operation Outward and commenting on relations with the Air Ministry. In praising Sir E. Leslie Gossage, Air Marshall and commander of the Balloon Command, the source of Outward’s hydrogen when supplies were scarce, he took the opportunity to point out that “the Air Ministry were using every excuse to obstruct the scheme…” This praise was not just politicking. Had it not been for Gossage’s cooperation, Operation Outward would not have been able to obtain the necessary hydrogen for its balloons.

Epilogue

In spite of the constant bickering between the RAF and Admiralty about Operation Outward, after the program had been shut down there was a glimmer of good will between the two services. On 16 September 1944, although he must have been gritting his teeth, Captain Banister wrote to Air Marshal Gell that his staff would “…always look back upon the good fellowship which has prevailed throughout our combined operations with pleasure.” Gell wrote back “The helpful and friendly cooperation I have received from the Naval Authorities at all times in carrying out these tasks, has been greatly appreciated.”

And thus ended the saga of Britain’s not-so-top-secret, trailing-wire, offensive balloon weapon.

For Further Reading

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