THE 200 FOOT SOUND MIRROR

Denge, District of Shepway, Kent

by

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Historical Analysis & Research Team
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ENGLISH HERITAGE

THE 200 FOOT ACOUSTIC MIRROR, DENGE, LYDD, DISTRICT OF SHEPWAY, KENT

Peter Kendall, Ancient Monuments Inspector for the South-East Region, has asked for documentary historical information regarding the construction of this early anti-aircraft detection device on the south coast, close to Dungeness. A Scheduled Ancient Monument, the wall is included on the EH Buildings at Risk Register and is regarded as being in very bad condition. This report —supplementary to the full account provided in Richard Scarth's 1999 book Echoes from the Sky— *offers an outline historical account, surveys the documentary evidence, outlines the construction of the mirror and offers an initial assessment as to its significance.*

The Military Uses of Sound Detection

Land, sea and air warfare were each affected by the developing technology of sound detection, which advanced in great strides during the First World War. Sound detection (the origins of which pre-date the war) was used to determine the range of enemy artillery; ship-borne hydrophones were developed for the detection of submarines; and from 1917 research was undertaken into the possibility of providing early warning of in-coming aircraft (and airships) through the use of sound mirrors.

Britain had been subjected to her first air attacks from Zeppelins in late 1914; by 1917 serious dangers were posed by Gotha bombers. The technology of acoustic aerial detection thus became a pressing item on the agenda of military research. The earliest experiments in sound detection were made in 1915 by the Royal Aircraft Factory, Farnborough under the guidance of Professor Mather: the first concrete sound mirror was erected in April 1915 near Maidstone. Subsequently the Royal Engineers' Signals Experimental Unit at Woolwich took the lead in this field.

This latter body was responsible for the earliest operative sound mirror of all: that at Joss Gap, Thanet, set up in late 1917. Another followed soon after at Fan Bay, at the South Foreland close by. Between them they covered the approaches to London from as far apart as Zeebrugge and Calais. Another range of sound mirrors was installed on the north-east coast. Sound mirrors at their best could provide advance warning of incoming aircraft several minutes before they were audible to the unassisted ear; information on bearing, height and numbers was far harder to determine. Moreover, the system was very much at the mercy of atmospheric conditions.

By the end of the First World War, acoustic detection of aircraft was a widely accepted method: there was very little else to go on, after all. So widely accepted was it that even the 1919 Royal Institution lectures for children, on *The World of Sound*, given by Sir William Bragg, contained the following remark:

> It is obvious, of course, that there are ways of finding from what direction the sound of an aeroplane has come. We might, for example, make use of the power of a concave mirror to focus a sound... the hum of an aeroplane is low in pitch, the sound waves are long, and therefore the mirror must be correspondingly large.[1]

Capturing these low sound waves was to be the aim of the most remarkable sound mirrors of all: the 200 ft walls at Denge and on Malta.

Post-war Developments in Sound Detection

The key figure in developing this early warning system was Dr William Sansome Tucker (1877-1955), a lecturer in Physics at Imperial College, who ended the war with the rank of major in the Royal Engineers. An experimental unit, the Searchlight Experimental Establishment, was established at the air station at Biggin Hill in 1923. Renamed the Air Defence Experimental Establishment in 1924, this branch of the Air Ministry developed the work of the Woolwich unit on sound detection under Tucker's supervision. The Royal Engineers, which established the Acoustic Research Station at Hythe, Kent in 1923, had overall responsibility for this research programme.

By 1923 a number of acoustic mirrors were in place. These followed a standard design: vertically mounted concrete slabs with a central shallow dish, 15 ft in diameter with a frontal plinth mounting for a microphone.[2] In this year a new 20 ft mirror was erected at Hythe, the first of six mirrors to be built here during the 1920s. Hythe was not only remote, and hence quiet: it faced France squarely, and thus faced the direction of the greatest perceived threat to British airspace at that time. However, the site was selected more for reasons of research than of military consideration: 'the Dungeness mirror was not built for defence but for experimental reasons, and its axis is oriented for the latter purpose' wrote a member of the General Staff in 1932.[3] Moreover, gravel which could be used as aggregate in the concrete mix was in plentiful local supply, and the narrow-gauge Romney Hythe and Dymchurch railway made the transport of materials an economical prospect.

Results from air trials held in 1926 led to the conclusion that sound mirrors provided five minutes of extra warning. These findings were regarded as sufficiently encouraging for the Air Defence of Great Britain committee of the RAF (hereafter ADGB) in 1927 to request government funding for a comprehensive system of mirrors around the British coast. This was agreed to in principle in 1928, with the significant proviso that further experimentation was essential before so costly a programme was embarked upon. This in turn led to an intensification of research in this field under Tucker, encouraged by Maj-Gen. Bernard

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[1]Bragg (1920), 193.

[2]Dobinson (1999), 8.

[3]PRO, AVIA 7/2764, minute of 1st February 1932 by Maj. C.E. Ryan.

Ashmore, Inspector of Anti-Aircraft and founder of the Observer Corps, the leading figure in air defence and author of a 1929 book on this subject. The first of the mirrors at Denge, a 20 ft mirror, was erected in early 1928. This phase of sound mirrors incorporated a new design feature: a far deeper-sunk central disc for the better capture of sound. A larger 30 ft pattern was subsequently erected at Denge in 1930.

The Search for Greater Results: the 200 ft Mirror Project

Doubts about the effectiveness of the mirror method of sound detection continued to be voiced, however. Atmospheric conditions made a great difference to the quality of data received from the resonator (or dish) and amplified by microphones. So too did other noise. At the same time, aeroplane speeds were steadily increasing, thus making the time between sound detection and actual arrival ever shorter. Tucker therefore looked for a new technique. In order to maximise effectiveness a new sort of sound mirror was to be constructed: a wall 200 ft in length, with multiple microphones leading to a listening chamber, intended to locate aircraft at a greater distance than ever. The earliest discussion of such a scheme appears to date from 1927, and on 27th August 1927 the DCRE (Deputy Commanding, Royal Engineers) Shorncliffe was requested to prepare working drawings for such a structure[4]. Percy Rothwell of the ADEE was instrumental in advising on the structure's form.

The Theory of the 200 ft Mirror

The problem with smaller circular mirrors was their inability to detect aeroplanes at a distance. Long distance detection was of course vital if sufficient advance notice was to reach the central controllers and get intercepting aircraft aloft in time: at the outset of the trials it was estimated that a 200 ft wall could locate sounds from as far away as twenty five miles, which would provide ten minutes of advance warning (given the relatively slow speeds of aircraft then currently in service).[5]

A greatly enlarged mirror could detect low-pitched long wave sounds which were inaudible to the human ear. Greater emphasis was placed on the electric detection of sound, as opposed to reliance on the human ear to locate fine nuances in aural data. Whereas operators had previously had to search the different parts of sound mirrors for sounds, the rank of multiple microphones enabled readings to be taken automatically from numerous places.

The large mirror was sometimes referred to as the 'Sentry Mirror' and the smaller mirrors

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[4]PRO, AVIA 7/2764, ADEE minute. The construction of the mirror was estimated at £2,000.

[5]PRO, AIR 16/304, ADGB minute to Air Ministry, 21st February 1928.

as 'Track-plotting Mirrors'.[6] The two types of mirror were thus complementary, with the larger mirror giving advance notice and indicating where the smaller mirrors should be searching. Smaller mirrors were more accurate in terms of locating position and number of aircraft, but the 200 ft wall gave longer warning time.[7]

The Design of the 200 ft Mirror

The principle of the new mirror was simple: a long curving wall with a gently sloping forecourt, along which were ranged 20 microphones spaced 5 ft apart. The microphones were connected to a listening chamber: low frequency recordings activated a galvanometer, and when the operator noticed such activity on the dial, he could check by listening directly to the signal. Should he detect aeroplane-generated sound waves, he then informed the controller who would notify ADGB HQ at Uxbridge. Outdoor listeners, equipped with rubber-soled shoes, also pounded their acoustic beat along a given stretch of the wall, or could be despatched by operators to verify reported soundings.[8]

The Construction of the 200 ft Mirror

The 200 ft mirror (hereafter 'the mirror') constituted the apogee of sound detection. Its purpose was to provide long-distance detection of aircraft: the conventional circular mirrors would continue to provide more detailed information concerning bearing and height. Scale models were tried before construction of the mirror was commenced in 1929.

If the ADEE had requested drawings way back in August 1927, and late in October approved drawings were returned from the ADEE to the Royal Engineers at Shorncliffe.[9] Lieut. (Subsequently Lieut-Col) Francis RE was the officer responsible for detailed design of the mirror, while Maj. J.D. Inglis took the lead on behalf of the ADEE. However, the War Office were reluctant to approve payment for the new large mirror and work was suspended for a period.[10] by November 1928 it was still waiting. By late January 1929 the site of the mirror was pegged out and construction was carried out during the latter part of that year and into 1930. A minute dated 14th November 1929 described the work as 'well underway'[11]. Despite requests, the mirror was not ready in time for the summer air defence

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[6]PRO, AIR 16/316, Royal Engineers Board minute of ?October 1933.

[7]Idem., notes of Royal Engineers Board meeting, 24th October 1929.

[8]See Scarth (1999), 102-04 for an account of the mirror's operation.

[9]PRO, AVIA 7/2960, memo. of 28th October 1927.

[10]PRO, AIR 16/304, ADGB minute dated 21st February 1928.

[11]PRO, AVIA 7/2764, DCRE minute.

trials of 1929, the purpose of which was to plot in-coming aircraft and send the information back to the HQ of ADGB at Uxbridge; indeed, no start had been made by late June 1929[12]. By June 1930 it was found necessary to erect barbed wire around the mirror to keep over-inquisitive civilians at bay; by August 1930 the mirror was complete and ready for record photographs to be taken.[13]

The actual construction was in the hands of civilian contractors: Concrete Structures Ltd fabricated the 30 ft mirrors[14] but it is not known whether they also undertook the construction of the 200 ft mirror.

Dr Tucker described the method of construction thus:

> A wall of concrete is built up with shuttering on a reinforcement of vertical rods, so that the overhang at the top is well supported. Buttresses 10 feet apart form a structure capable of resisting the strongest winds. The surface of the mirror is vertical at the ground, which is finished as a sloping forecourt of concrete, with suitable drainage and sumps to hold the surface water. The forecourt slopes down to a flat platform, bounded by a circular wall concentric with the mirror surface. The vertical cylindrical wall which bounds the listening trench coincides approximately with the focal surface of the mirror.[15]

Documentary Evidence on the 200 ft Mirror's Construction

A report on the construction of the mirror was subsequently prepared by the clerk of works, A.W. Letford, in mid-1934 which sheds much light on the construction techniques employed.[16] **[see Appendix A]**. The wall consisted of shuttered reinforced concrete of the 'Vitrocrete' variety, laid in successive lifts 3 ft 6 ins high. The counterforts (or buttresses) were laid simultaneously with the wall. Smoothness of finish was paramount: all excrescences were rubbed off with Carborundum stone, and no patching or filling was found necessary. The final finish of the inner wall surface was left unpainted, a finish subsequently altered when wartime camouflage was applied. As early as February 1935, problems of cracking were reported which exposed the reinforcement and led to surface excrescences forming.[17]

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[12]PRO, AIR 16/304, memo. on acoustic experiments dated 24th June 1929.

[13]PRO, AVIA 7/2764, ADEE minutes of 11th June 1930 and 29th July 1930.

[14]PRO, AVIA 7/2764, CRE minute of 20th March 1930.

[15]Quoted in Scarth (1999), 94; source uncited.

[16]PRO, AVIA 7/3180.

[17]PRO, AVIA 7/2764, memo. From ADEE, 11th February 1935.

Working drawings remain untraced, despite appeals to the RE Museum at Chatham[18], to Dr Colin Dobinson and my own searches in the PRO. The final working drawings were prepared by CRE: one bore the number AC.462.I.1.L.[19] Other related drawings held by the War Office bore the numbers S4501 and D9120/1.[20] A schematic cross section of the mirror's listening trench is contained within PRO file AVIA 7/2764 **[see Appendix B]**.

A full specification of works survives for Denge's sister mirror, that erected in 1935 at Maghtab on Malta[21] **[see Appendix C for extract relating to concrete construction and reinforcement]**. The reinforcement consisted of straight steel bars, augmented with meshwork, ties, links and stirrups; these were tied together with pliable iron wire. Working drawings were supplied to the contractors detailing the precise configuration of this reinforcement. A proposal for constructing future sound mirrors with prefabricated cast concrete sections[22] was advanced by Percy Rothwell in March 1933 but was not proceeded with.

Further documentary evidence into the construction of the Denge wall is afforded by an album of photographs (probably taken by Lieut. Francis while overseeing the construction of the mirror in 1929-30: copies provided by Roger Thomas in English Heritage's York office. **See illustrations 3-8**). These photographs[23] reveal much about the construction and show the reinforcing elements prior to their concealment by poured concrete. They indicate that substantial shifting of shingle had to take place before the foundations were laid.

Subsequent History of the Mirror

Once constructed, the mirror attracted considerable local speculation as to its purpose. It

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[18]The library has carried out a search but has located nothing; Richard Scarth has also looked there for the same, to no avail.

[19]PRO, AVIA 7/2764, drawing dated 28th February 1930. The drawing is not to be found in the file.

[20]Idem.

[21]PRO, AVIA 7/3180, specification dated 8th November 1934.

[22]PRO, AVIA 7/3182, including drawing of proposed 7 ft section. The main advantage was that of cost.

[23]These photographs are different from those reproduced in Scarth (1999), which are taken from originals in the Royal Artillery library, Woolwich and from an album compiled by Percy Rothwell of the ADEE, now in the possession of his daughter.

was known familiarly as 'the Thing'[24] and an unwelcome number of curious sight-seers made theur way to this once remote spot to examine one of the stranger concrete structures ever built.

The 200 ft mirror played a central part in the annual Air Defence of Great Britain exercises from 1931onwards. Given the short notice of advance warning that the mirrors —operating at their very best— gave ADGB, rapid notification was essential. Automatic transmission of findings to a central control room at West Hythe was achieved in 1934 and telephone links with ADGB HQ at Uxbridge put in place. Such arrangements were the forebears of the celebrated advance warning system established within Fighter Command by Dowding during the late 1930s, and hence of some importance. However, the early warning was insufficient to prevent in-coming aircraft from reaching their targets, according to the 1934 air exercise: three out of five night bombers made it past the defences and were able to bomb the centre of London (hypothetically).[25] The depressing findings seemed to confirm Baldwin's prediction that 'the bomber will always get through', and led to an intensified search for anti-aircraft defence mechanisms which resulted ultimately in the discovery of radar.

The location of the mirrors had originally been remote, quietness being an essential pre-requisite of the installation. Coastal development threatened to challenge this, however. Picnickers had had to be kept at bay from as early as 1931, when a barbed wire fence was erected,[26] but by late 1931 real concerns were voiced by Major Tucker about the sound pollution arising from increased motor traffic along the improved coastal road leading to Dungeness. A holiday camp was built to the north-east which posed problems: were all to go to bed early, sound sensitivity would not be affected; but 'should a band start up matters would be different'.[27] By early 1932 no fewer than eighty new houses had been constructed in the general vicinity of the mirror; one contratsing ground of optimism was the attempt to create a wildlife sanctuary in the immediate surrounds.[28] Early in 1934 the coast road was extended past the mirror to service the new Bungalow Estate at Greatstones; later that year proposals were advanced by the Southern Railway to install a railway line to Lydd which would cross directly in front of the mirror. Little wonder, then, that Tucker wrote to the supervisor of the ADEE in May 1935 that 'the district is rapidly becoming built up by ribbon development of bungalows near the sea... The coastal road...in summer is very

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[24]Letter on Scheduling file AA 53134/1 from Mrs Maddison of Lydd, 25th October 1978.

[25]John Bushby, *Air Defence of Great Britain* (1973), 98.

[26]PRO, AVIA 7/2764, ADEE memo. of 11th June 1931.

[27]Idem., RE Board memo. of 20th February 1932.

[28]Idem., memo. from Eastern Command to War Office, 25th February 1932.

detrimental to the use of the mirror'.[29] The mirrors are now separated from the sea by a belt of bungalows; behind it lies Lydd airport.

The Mirror on Malta

Malta, the crucial port which controlled access to the Eastern Mediterranean, was undergoing an upgrading of its defences in the early 1930s. Its proximity to otherland masses made acoustic detection ofin-coming aeroplanes especially important: hence it was an obvious location for a long-distance sound mirror of the sort pioneered at Denge. Col. George Goldney, President of the Royal Engineers Board, concluded in February 1933 that

> We are of the opinion that the sound mirrors have a definite application to defence problems of this nature and that they should be included in the defence scheme. In the case of Malta they would appear to supply a real need and have an important role.[30]

The 1934 Estimates requested £2,600 twice over for the construction of mirrors at Malta and Gibraltar: nothing came of the latter, but the former was duly constructed from late 1934 at Maghtab. Trials were conducted with the finished mirror in September 1935, which demonstrated that the mirror could provide six minutes' advance warning of incoming aircraft travelling at 250 mph, the speed which advanced monoplane bombers were soon to be capable of.[31] The governor of Malta prepared a report on the mirror which was not wholly in praise of the mirror: friendly aircraft flying in the vicinity (unavoidable on an island the size of Malta) ruined detection, weather hampered findings, and visual observers were sometimes beating the sound detectors in reporting incoming aircraft. The mirror's total cost had been £4,400.[32] It remains in generally sound condition.

The Advent of Radar and the Eclipse of Sound Detection

Sound mirrors had always been victim to numerous factors which affected sound waves. The weather affected sound transmission hugely and background noise affected hearing. Besides, information concerning bearing, altitude and numbers was scanty at best; moreover, enemies could not be differentiated from friendly aircraft. And most serious of all, the length of advance warning was constantly being reduced as aircraft speeds increased.

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[29]Idem., letter of 17th May 1935.

[30]PRO, AVIA 7/318o, memo.of 13th February 1933.

[31]Idem., report dated 9th January 1936.

[32]Idem., report of 20th June 1936.

All of these problems were ultimately overcome through the development of Radar, or Radio Direction-Finding (RDF) as it was initially called. It is no exaggeration to say that the advent of radio direction-finding techniques, pioneered by Robert Watson-Watt and his team at the National Physical Laboratory from 1934 onwards, revolutionised Britain's aerial defence and made possible the defeat of the Luftwaffe in 1940-41. Had the country been reliant on sound detection, this victory would have been infinitely more difficult to achieve.

Nonetheless, it is interesting to note that as late as August 1942, senior officers in the Anti-Aircraft Command were contemplating a return to sound mirror trials in order to assist with the problem of low-flying intruder aircraft which were plaguing the South Coast at that time.[33]

Subsequent History of the Denge Mirror

The effective abandonment of acoustic research can be dated to May 1939, when the Royal Engineers Board met with Tucker and agreed to the winding-up of the research programme and the destruction of the mirrors at Denge.[34] Experiments were carried out early in 1940 regarding the effect of explosives on the structures but full demolition was never carried out. The mirrors were camouflaged during the Second World War but were effectively demobilised. Abandoned by the military, the mirrors have been left to decay.

The shingle expanses of Denge led inevitably to gravel extraction. By the late 1970s it was being carried out by Hall Aggregates of Maidstone and it was beginning to affect considerably the immediate surroundings of the mirrors: a large gravel pit filled with water in front of the mirrors, dramatically altering their setting and threatening to undermine the 200 ft mirror. Subsidence (blamed on natural causes by the aggregate company, blamed on the company by local residents) ate away at the foundations of the mirror's forecourt while the gravel pit waters lapped at the footings. Part of the front wall collapsed, and the listening chamber behind the wall was destroyed, leaving the window in the centre of the wall. The first pleas for the protection of the mirrors date from 1978, when a concerned local resident contacted the local MP.

Initial suggestions that the wall might be listed met with disapproval from high places.[35] However, the Denge listening devices were first scheduled in July 1979. A policy of non-intervention was resolved upon, leaving the concrete structures to the assaults of wind, rain and sea spray (as well as vandalism). Cracking of the concrete has led to water penetration

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[33]AVIA 7/3180, memo. of 4th August 1942 from Lt-Gen. W. Gordon White, commanding 2 AA Corps.

[34]Scarth, 245.

[35]'To list them would place an unacceptable strain on the credibility of the listing system': minute of 29th September 1978, DoE file AA53134/1 (EH Registry).

and the deterioration of the reinforcement, which was always close to the surface of the structure from the outset). A further question mark over the long term future of the mirrors was posed by the intentions of the gravel extractors: was the land to the north of the mirrors be quarried, they would be left on an island, inacessible to all but the most determined.

The first serious study of the mirrors appeared in 1982: David Collyer produced *Kent's Listening Ears. Britain's First Early Warning System* (Aeromilitaria Special published by Air Britain). Further research was undertaken on Yorkshire sound mirrors by E.W. Sockett in the late 1980s. Richard Scarth of the Hythe Civic Society wrote *Mirrors by the Sea* in 1995, the outcome of a proposal to celebrate the society's 50th anniversary (and that of VE day) by conserving the mirrors. This led to an expanded work: *Echoes from the Sky*, published by the society in 1999. The listening devices all appeared on the 1999 English Heritage Buildings at Risk register.

Summary of Significance

With the benefit of hind-sight, sound detection of aircraft was an early chapter in the history of aerial defence, and one which did not inform the subsequent course taken by anti-aircraft research. However, the Denge mirror is much more than a curiosity, the relic of a cul-de-sac in military technology. It significance lies in an number of grounds:

a) Rarity. Apart from the Malta example the 200 ft mirror is unique.

b) Technology. The mirror represents the acme of acoustic research in the military field of aircraft detection.

c) Historic Context. Given the importance of aerial defence to the modern history of Britain, all aspects of its development acquire particular importance. The sound detection trials were instrumental in setting up the advance warning system which was operated by Fighter Command during 1940.

d) Group Value. The 200 ft mirror, together with the adjacent 20 and 30 ft mirrors, constitute an unsurpassed group.

e) Local Context. The Dungeness landscape is remarkable enough in its own right. The mirror and its smaller counterparts enhance the special character of the headland, by introducing striking abstract sculptural forms of considerable historical interest. Kent is exceptionally rich in modern defence structures: the mirrors at Denge (and elsewhere) compound this asset.

Roger Bowdler
Historical Analysis and Research Team
30th November 1999.

SOURCES

Public Record Office:
AIR 16/304: 'Acoustics - General Development'
AIR 16/316: 'Sound Discs and Mirrors Development'
AVIA 7/2764: 'Denge Sound Mirrors'
AVIA 7/2960: '200 ft Mirrors'
AVIA 7/3180: 'Mirrors at Malta and Gibraltar'
AVIA 7/3182: New Method of Mirror Construction

English Heritage Registry
Ancient Monuments scheduling file AA53134/1: Greatstone on Sea Listening Devices

David Collyer, *Kent's Listening Ears. Britain's First Early Warning System* (Aeromilitaria Special 1982)

Colin Dobinson, *Twentieth Century Fortifications in England VII.1. Acoustics and Radar. England's early warning systems 1915-45* (E.H. commissioned report 1999), esp. Chaps. 1 and 2

Andrew Graham, 'It Was All Done with Mirrors', *Country Life* December 4 1986, 1820

Richard Scarth, *Echoes from the Sky* (Hythe Civic Society 1999)

E.W. Sockett, 'Yorkshire's Early Warning System', *Yorkshire Archaeological Journal* vol. 61 (1989), 181-88.

E.W. Sockett, 'A Concrete Acoustical Mirror at Fulwell, Sunderland', *Durham Archaeological Journal* 6 (1990), 75-76.

Information from Roger J.C. Thomas, York office.

ILLUSTRATIONS

1 Denge: scheduling map

2 map of sound mirrors in Kent, proposed and constructed (from David Collyer 1982)

3-6 Denge: 200 ft mirror under construction, 1929 (via Roger J.C. Thomas

7 Denge: 20 ft mirror (via RJCT)

8-15 Denge: illustrations from R.N. Scarth, *Echoes from the Sky* (1999)

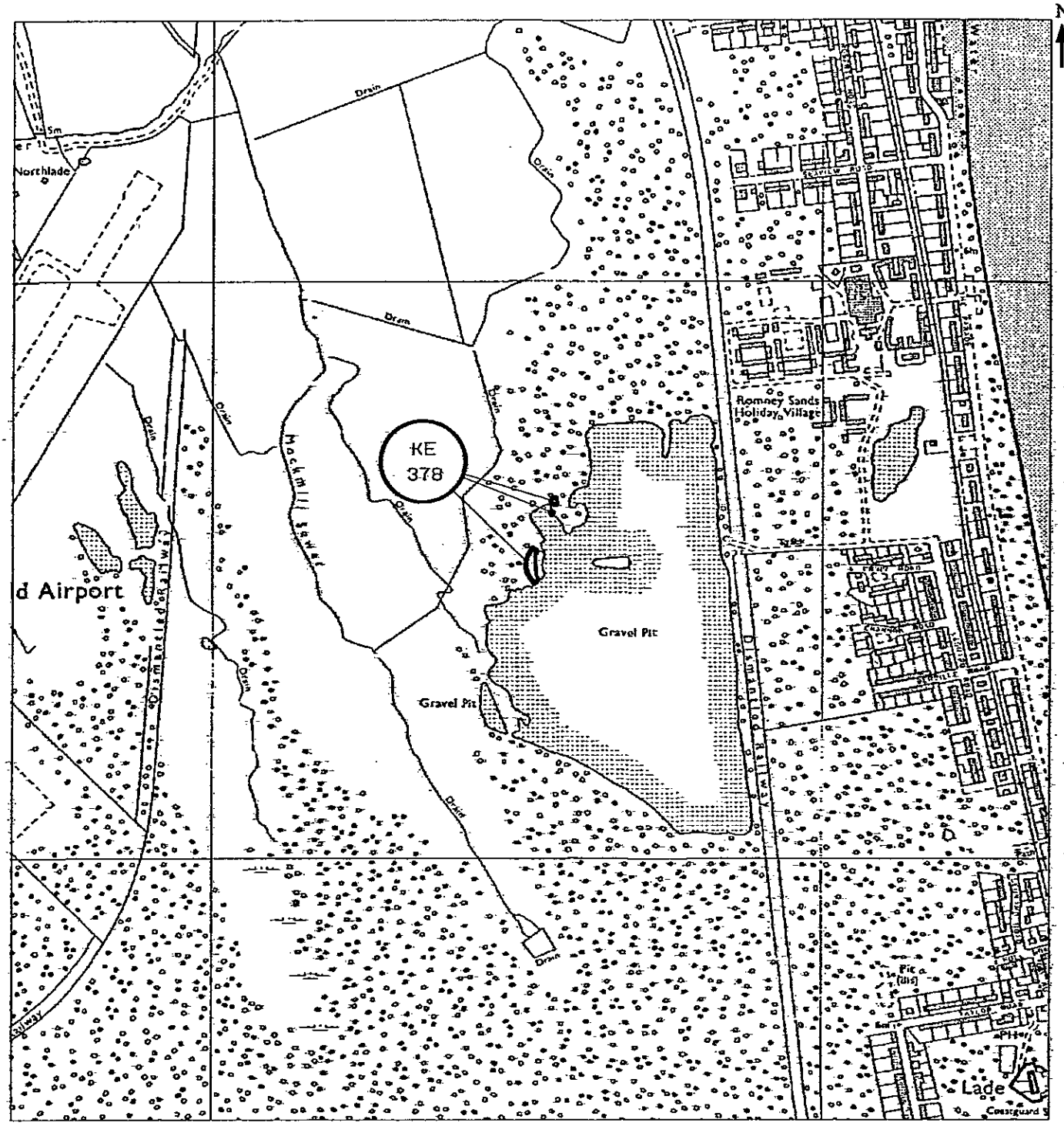
APPENDICES

A Notes on the construction of the 200 ft mirror at Enge by A.W. Letford, clerk of works, 14th July 1934 (PRO, AVIA 7/3180).

B 200 ft Acoustical Mirror: section of listening trench, April 1930. (PRO, AVIA 7/2764).

C 200 ft mirror at Maghtab, Malta: extract from specification of works concerning reinforcement and concreting, 8th November 1934 (PRO, AVIA 7/3180).

Scheduled Monument



 For identification purposes only

Site Name: Listening devices, Greatstone

County: Kent	**District:** Shepway	**Parish:** Lydd

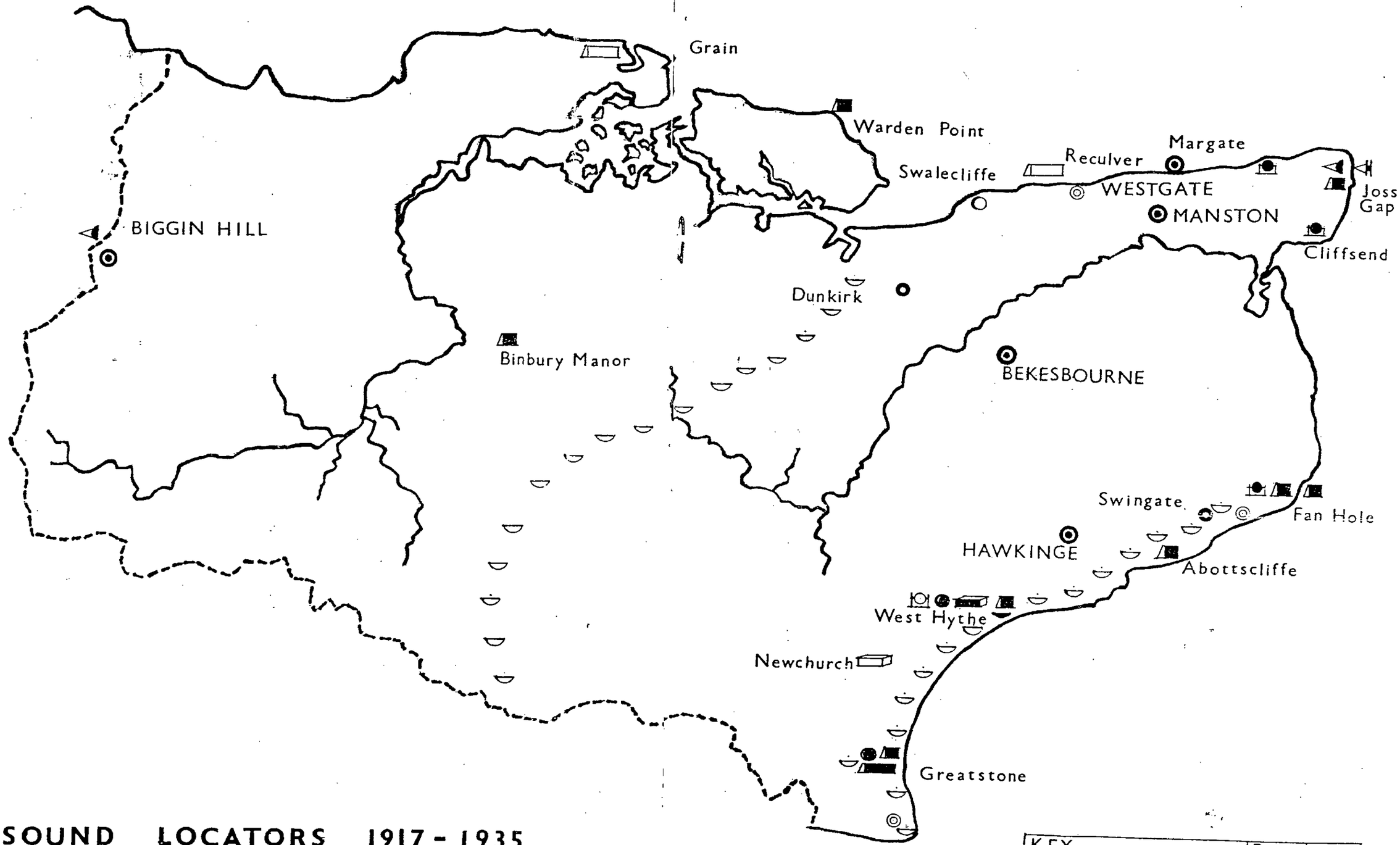
Notes: 3 land parcels: other NGR's are TR 0755 2160 & TR 0756 2161

Key: Monument No. Location/extent of site

Scale: 1:10000 **Derived from:** 1:10000
Centred on NGR: TR07522150
Extract from OS sheet: TR02SE

Date: 28.8.96 **Monument No:** KE378

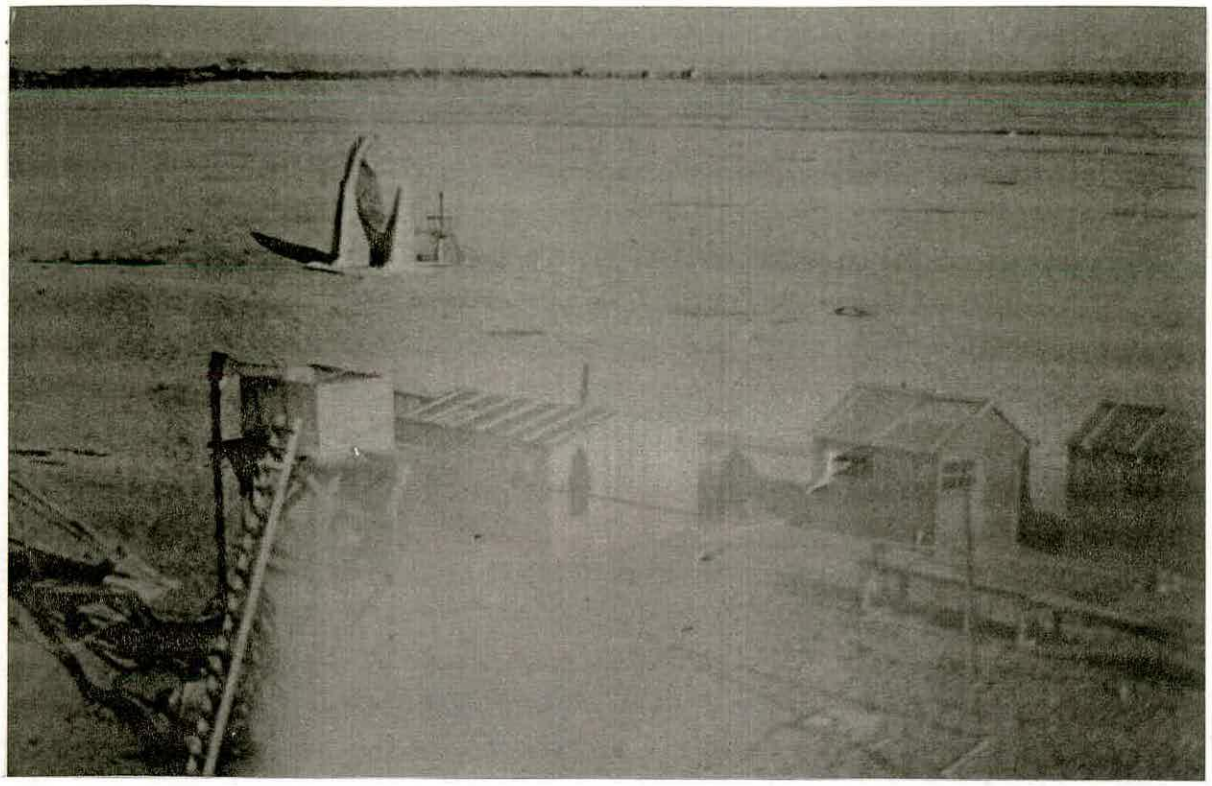
English Heritage
Fortress House 23 Savile Row London W1X 1AB Telephone 071-973 3000 Fax 071-973 3001



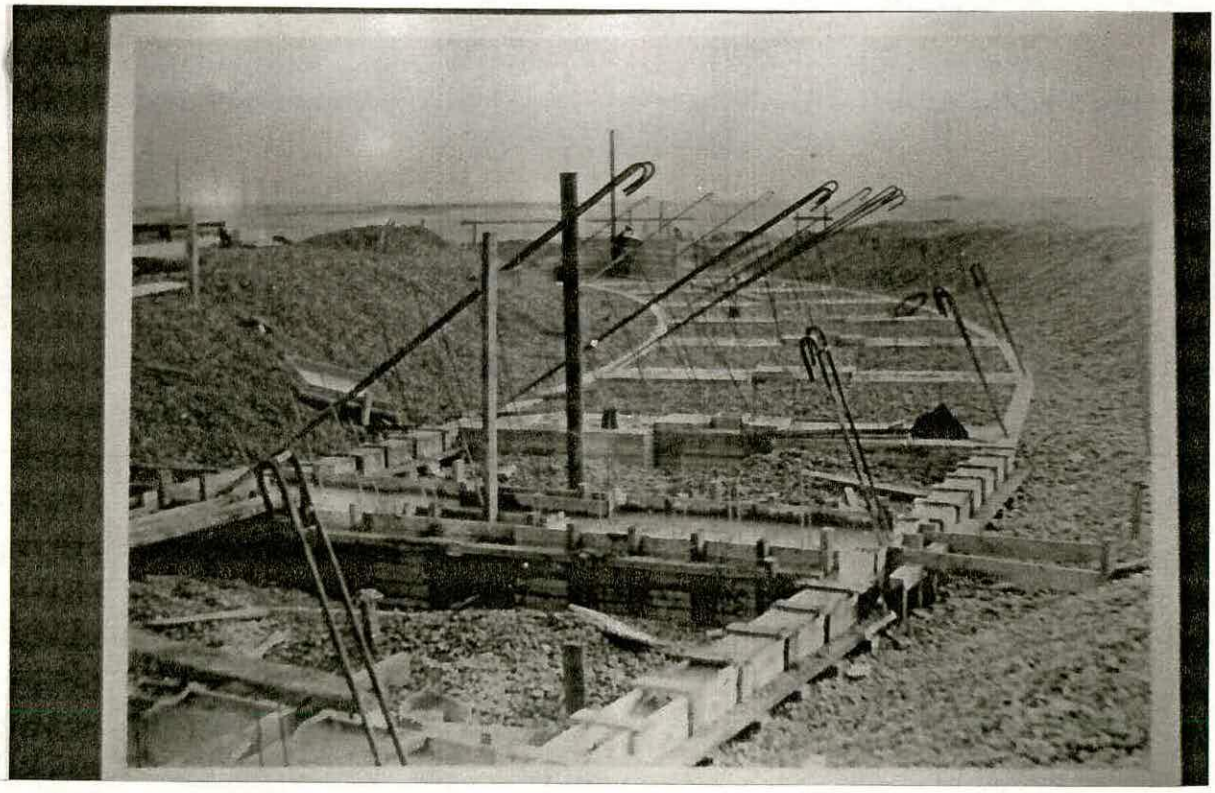
SOUND LOCATORS 1917 - 1935

INSTALLED AND PROPOSED

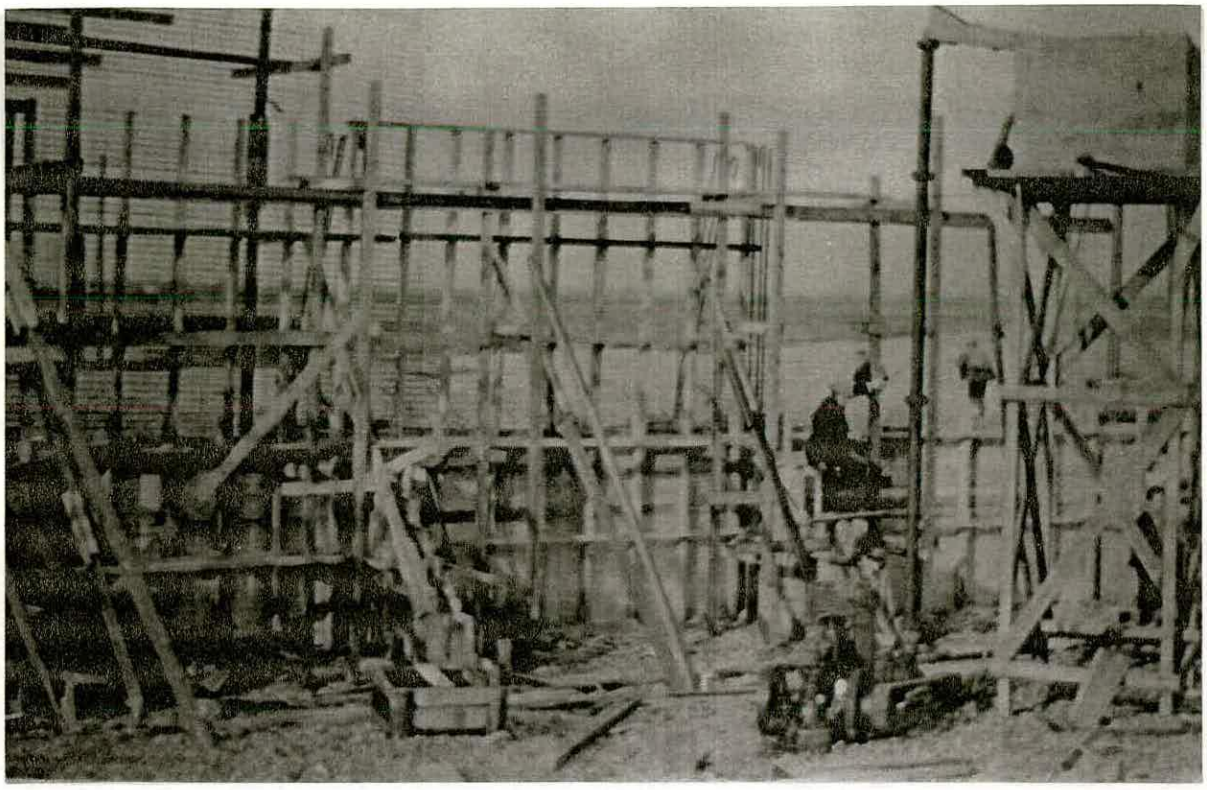
KEY	Prop.	Inst.
Fixed Slab		
Fixed Bowl		
Fixed Strip		
Fixed Disc		
Adjustable Bowl		
Adjustable Disc		
Portable Bowl		
Control Room		
R.D.F. Stations		



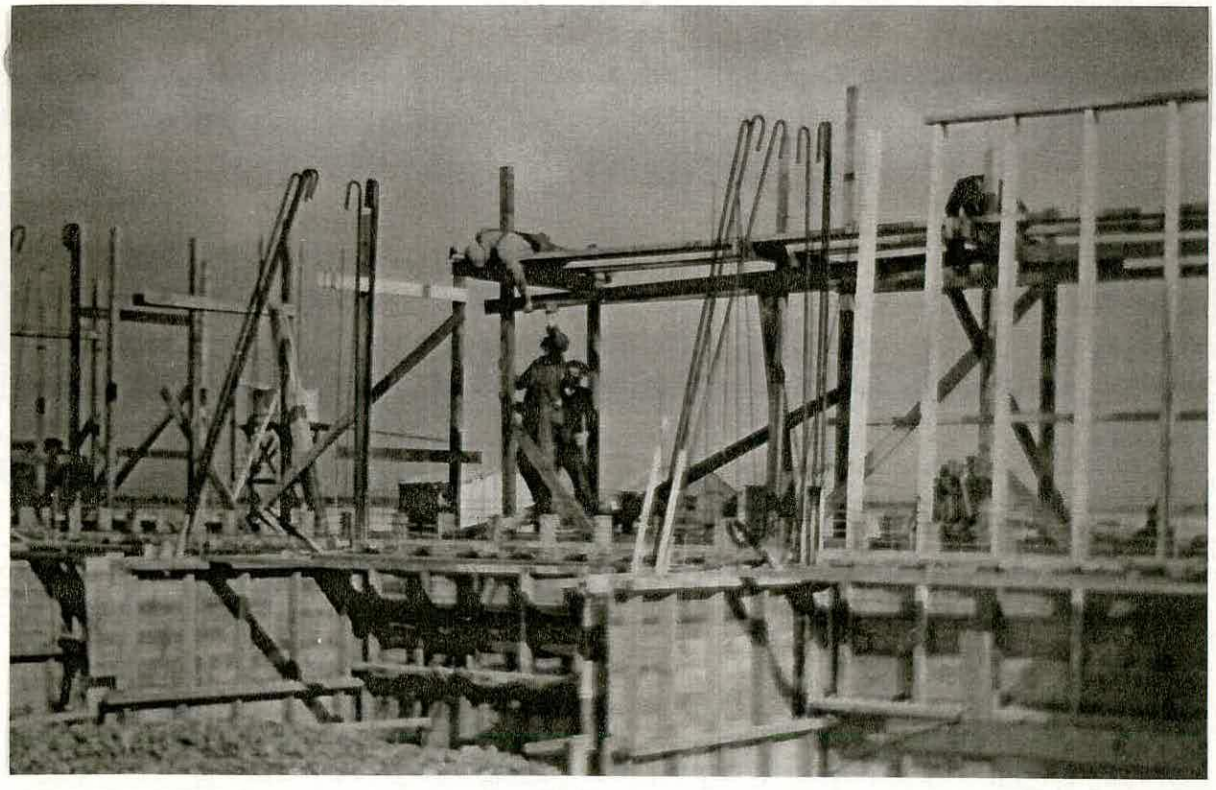
Denge: 200 ft mirror construction site, 1929



Denge: 200 ft mirror, footings, 1929 (via Roger J.T. Thomas)

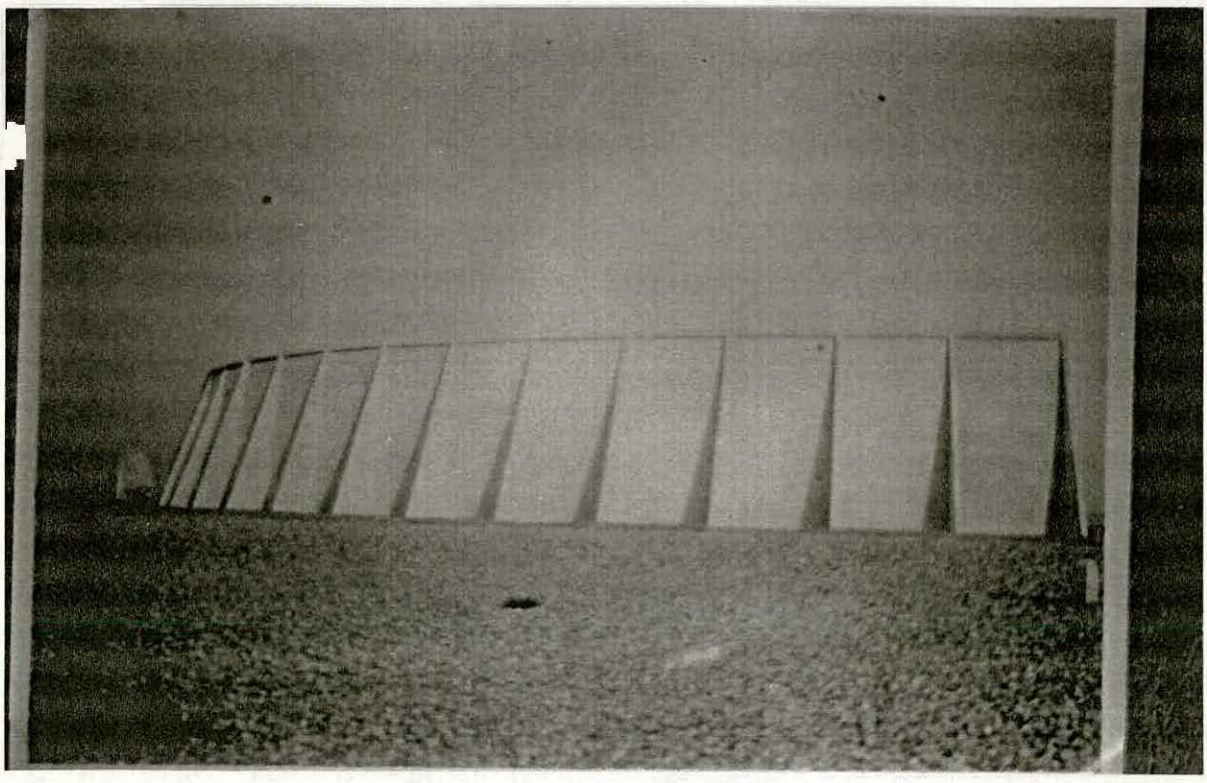


Denge: 200 ft mirror under construction, showing reinforcement of buttresses (via RJCT)

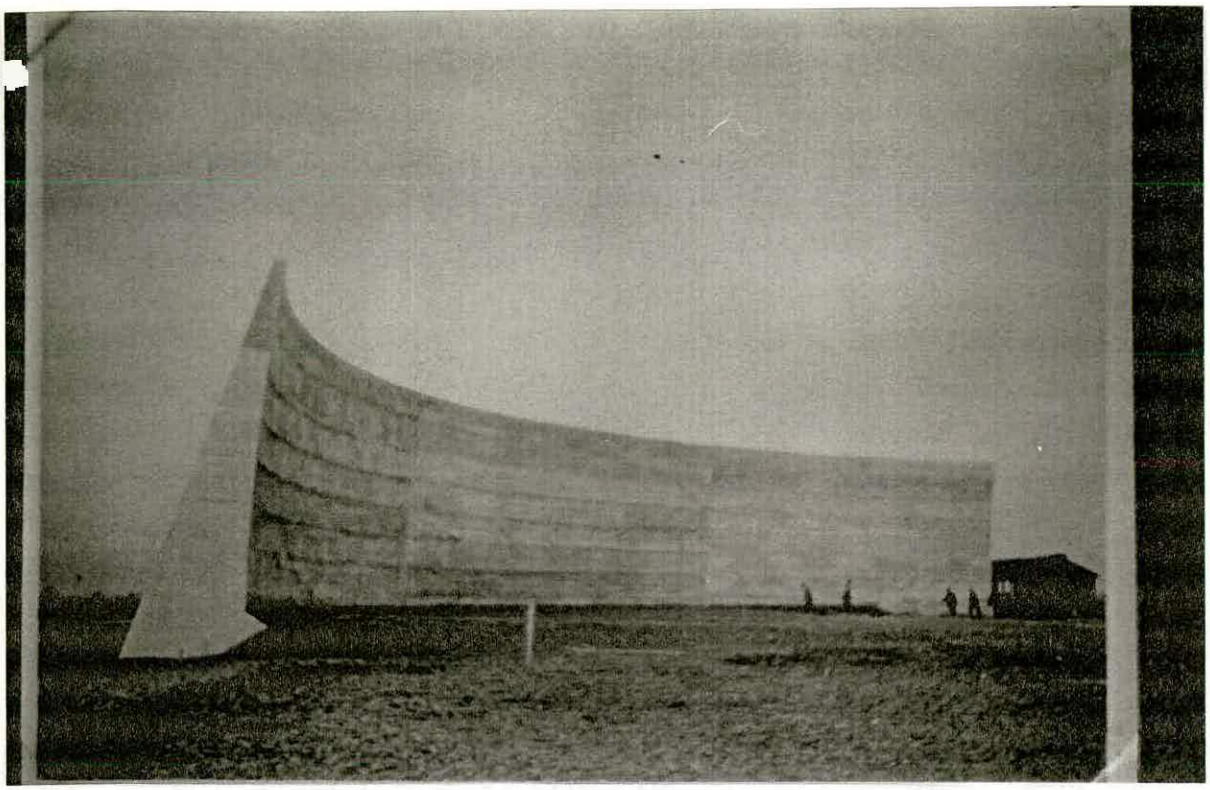


Denge: 200 ft mirror under construction, showing shuttering and wire mesh reinforcement (via RCCT)

Denge: 200 ft mirror, near completion (via RJCT)



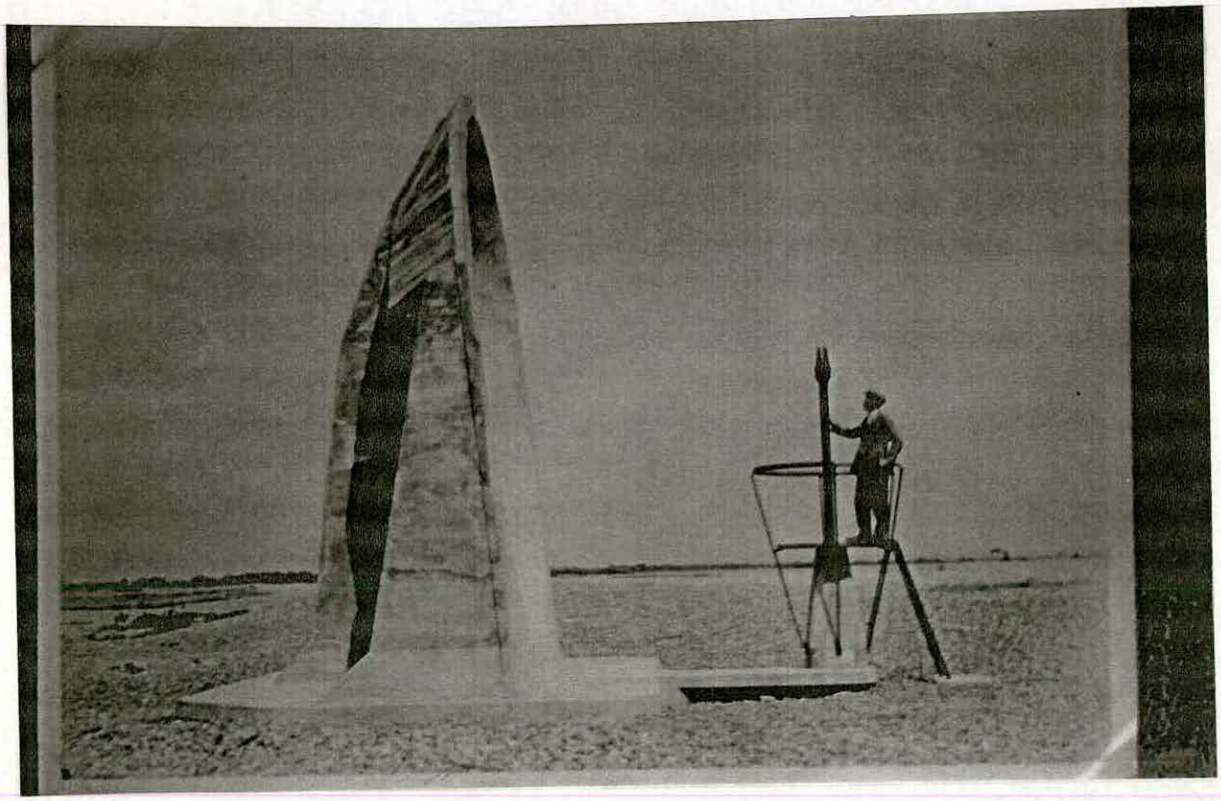
Denge: 200 ft mirror from rear after completion of wall (via RJCT)



Denge: 200 ft mirror from south end, before construction of forecourt (via RJCT)

Denge: 200 ft mirror from south-east, before cosntruction of forecourt (via RJCT)

Denge: 20 ft mirror from south showing microphone stand, 1928 (via RJCT)



Denge: 20 ft mirror from north-west, 1928 (via RJCT)

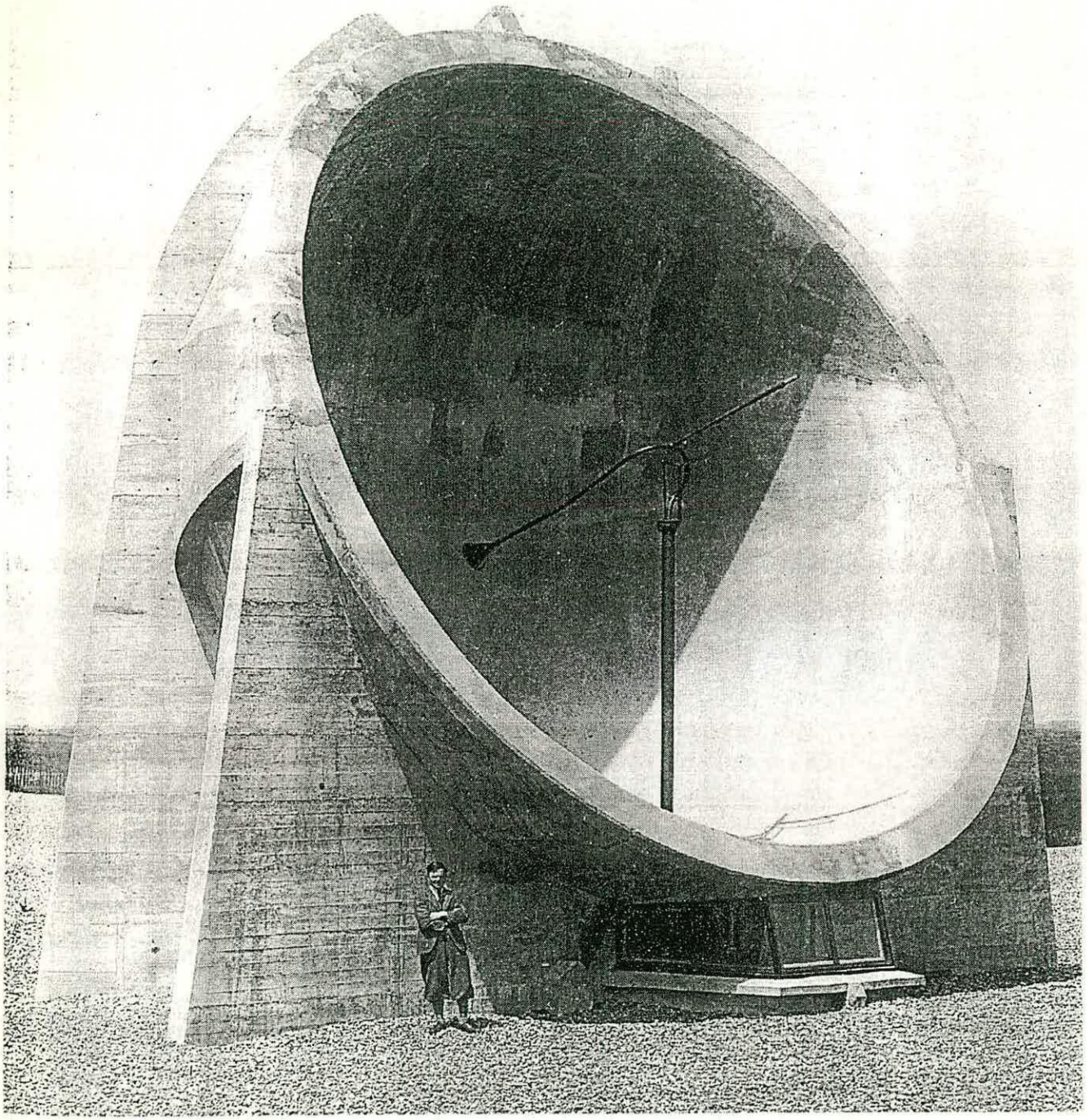


Plate 19 The 30 foot mirror at Denge shortly after completion in April 1930, with Percy Rothwell. Note the windows in the listening chamber.

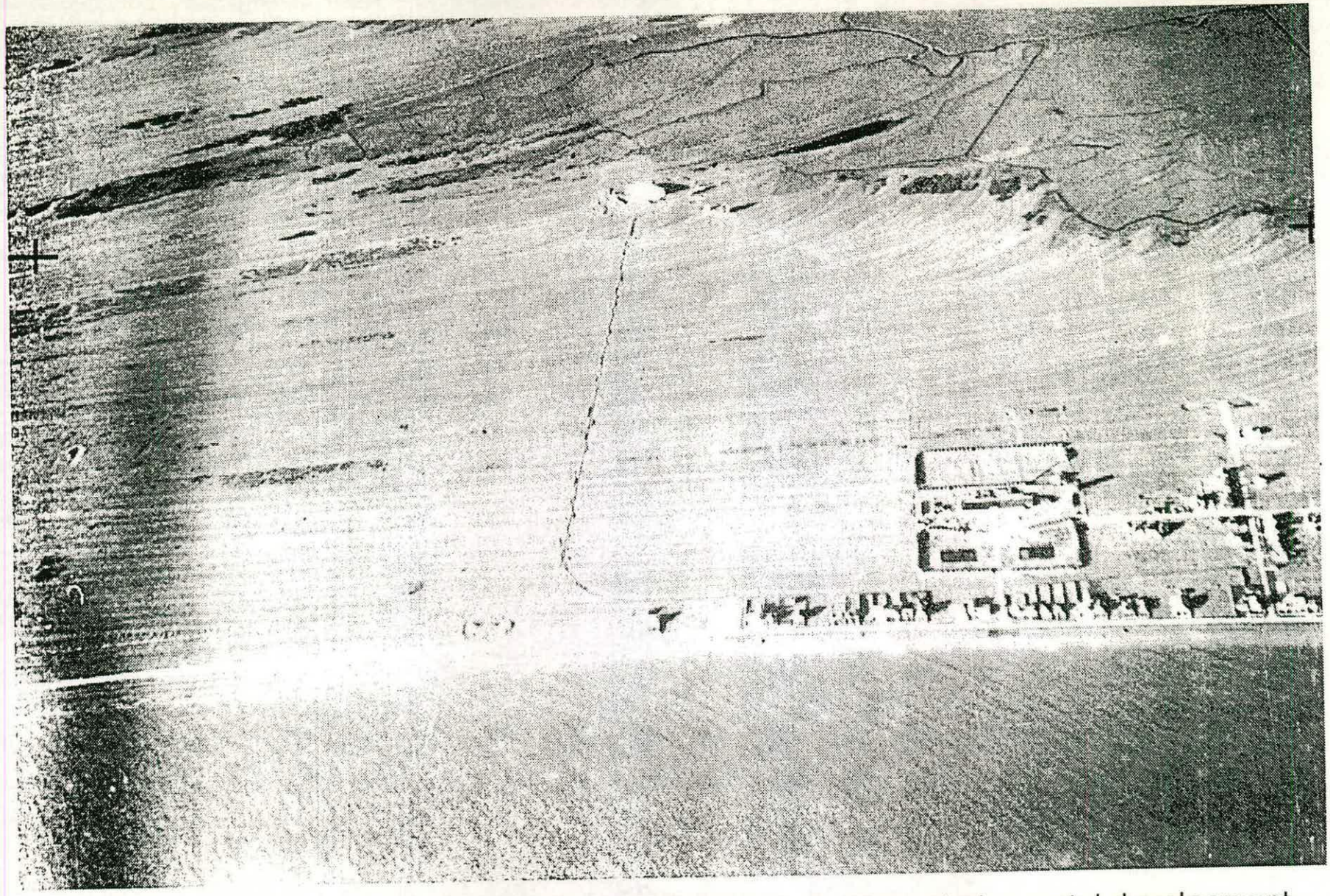


Plate 24 Aerial view of the Denge mirror site c.1930. At this period, coastal development ends near the track to the mirrors. The branch railway to New Romney can be seen on its original course behind the mirrors.

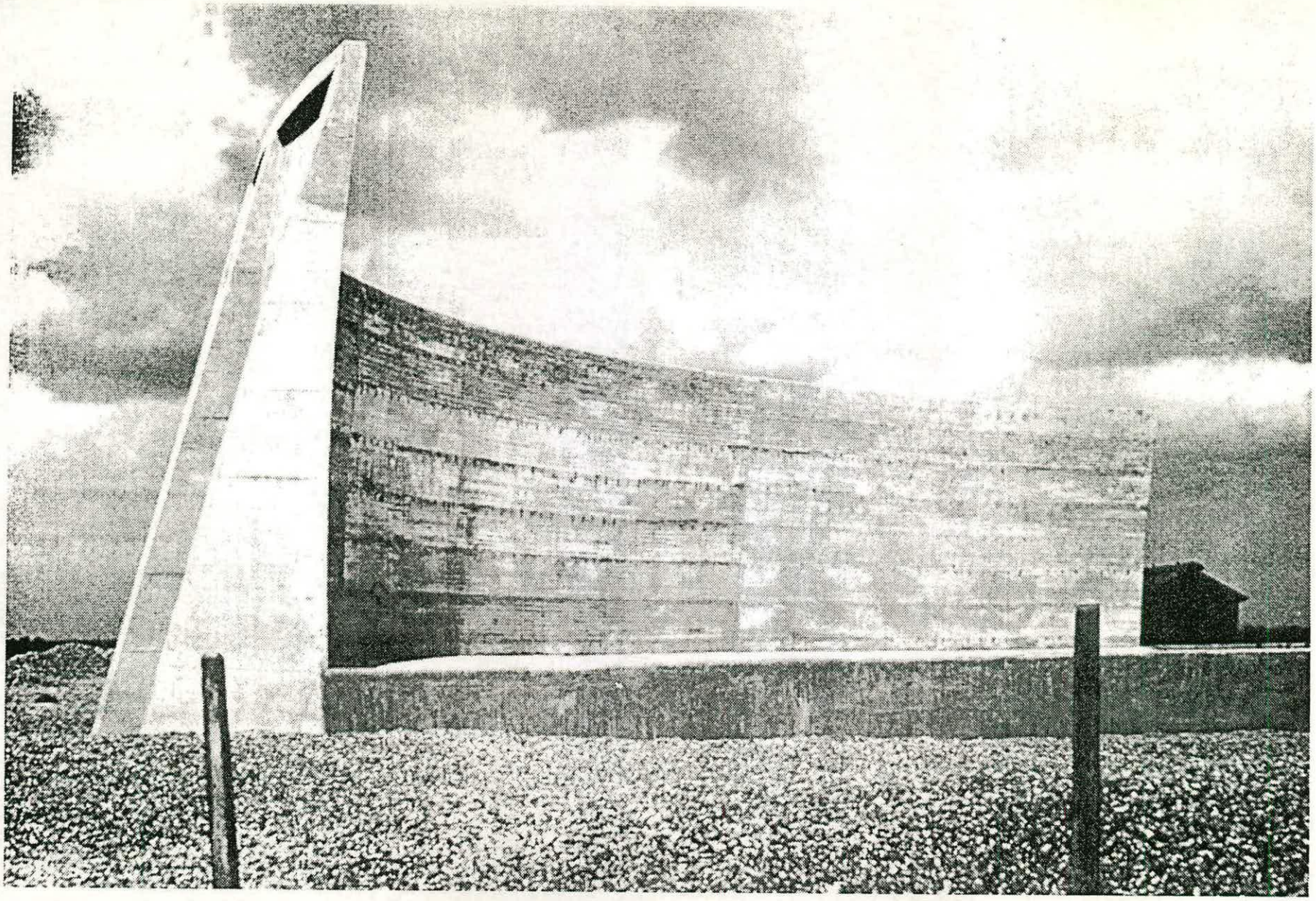


Plate 22 The newly completed 200 foot mirror at Denge c.1930. Note hut in background, probably used as a control room in this early period.

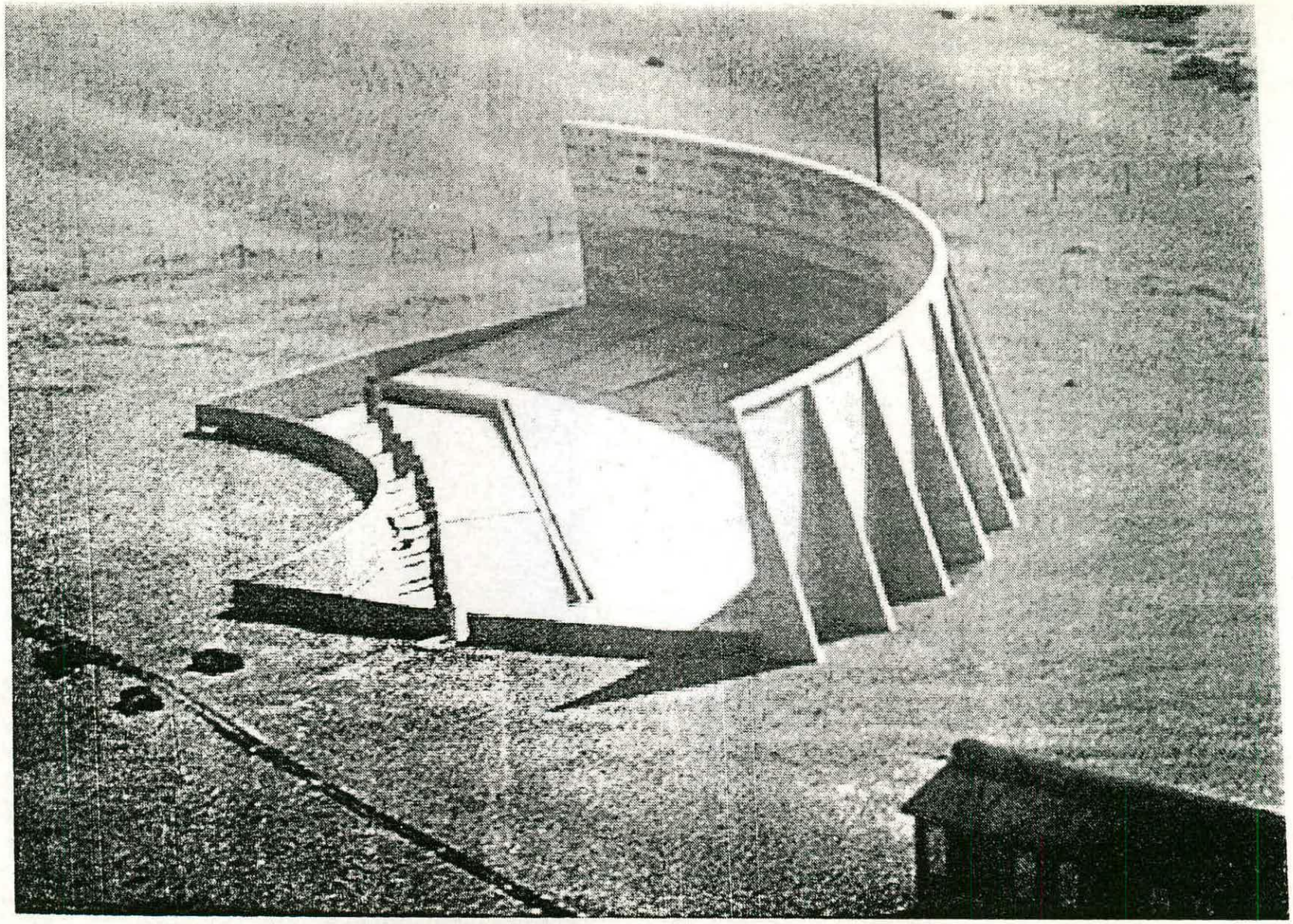


Plate 23 Denge 200 foot mirror, forecourt, 'trench' and microphones, c.1930.

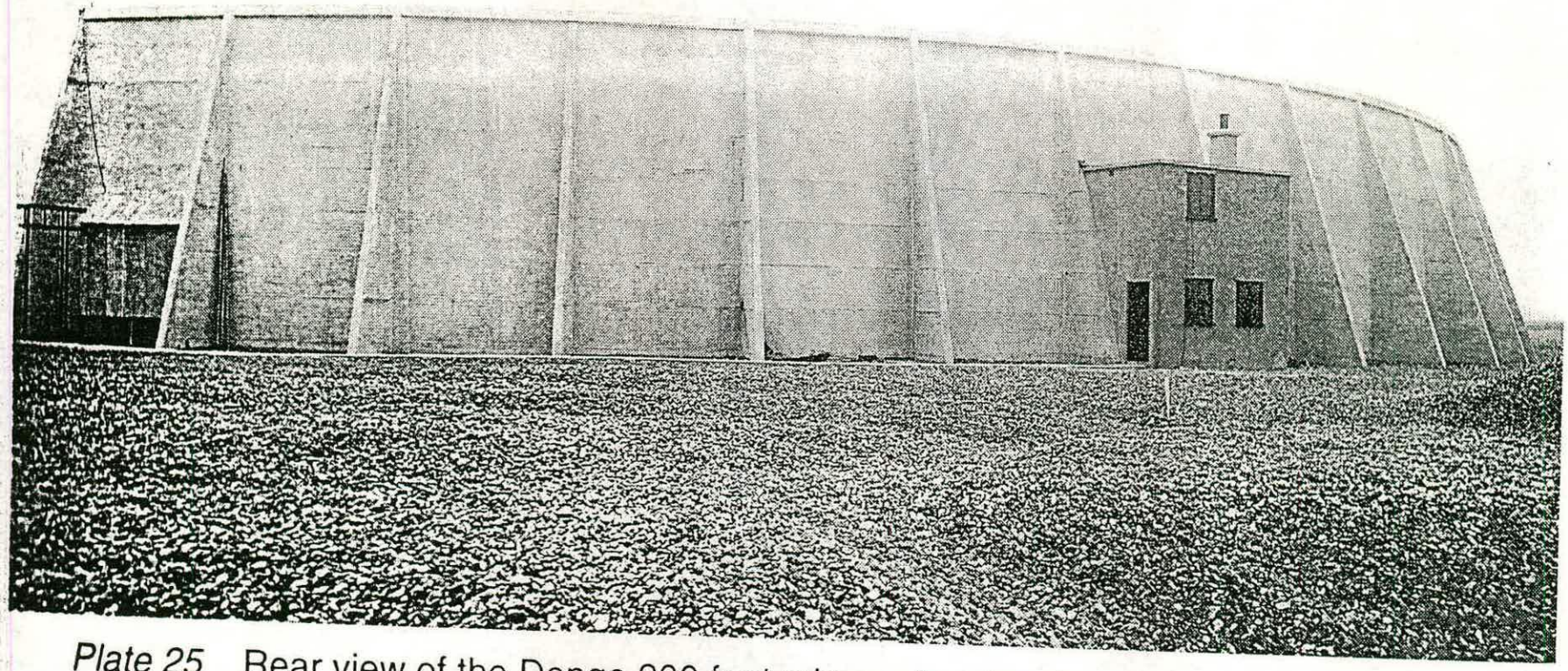


Plate 25 Rear view of the Denge 200 foot mirror, showing the central control room or listening chamber, c.1933.

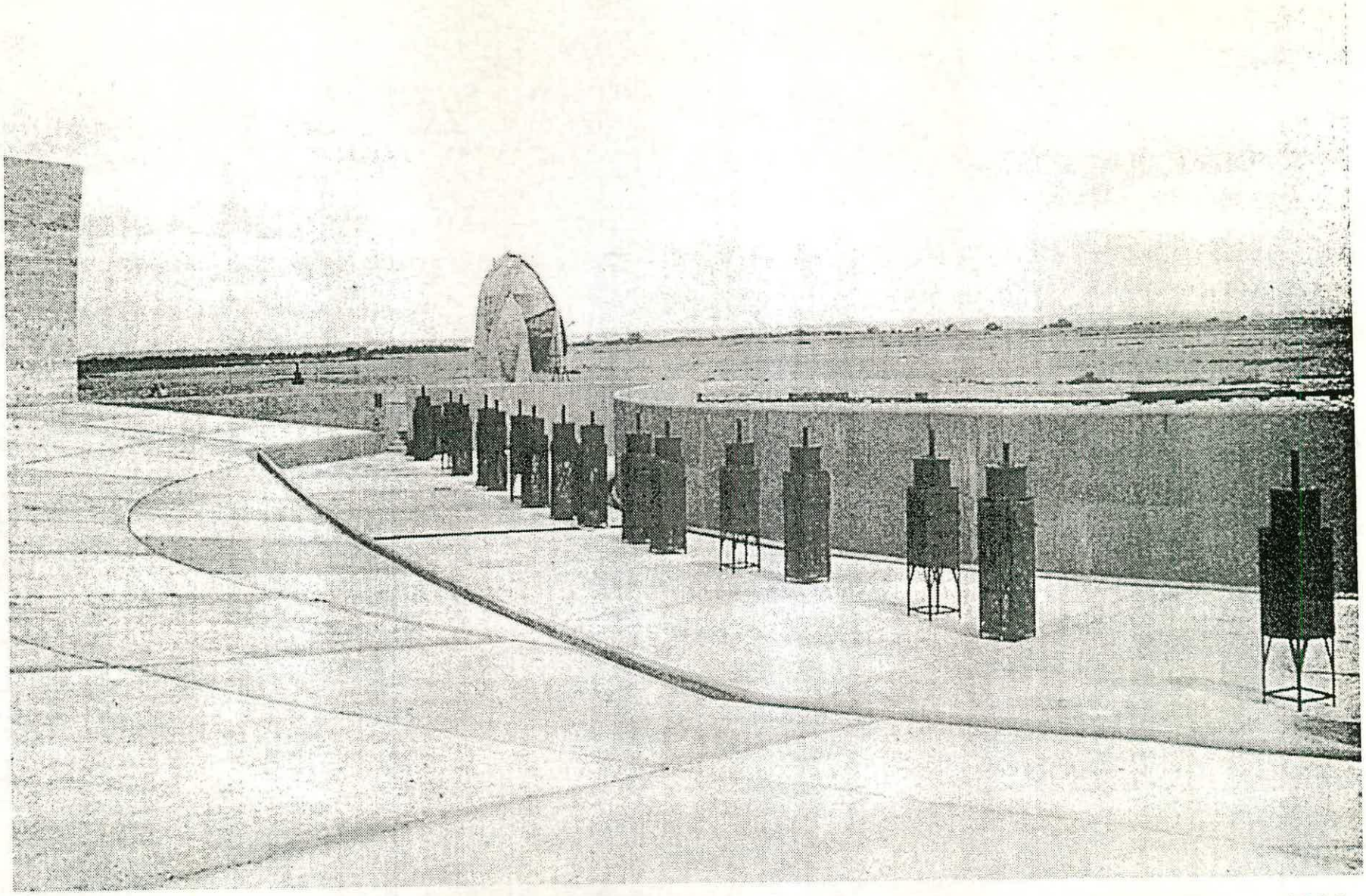


Plate 21 Forecourt of the 200 foot mirror at Denge, showing microphones in position. c.1930.

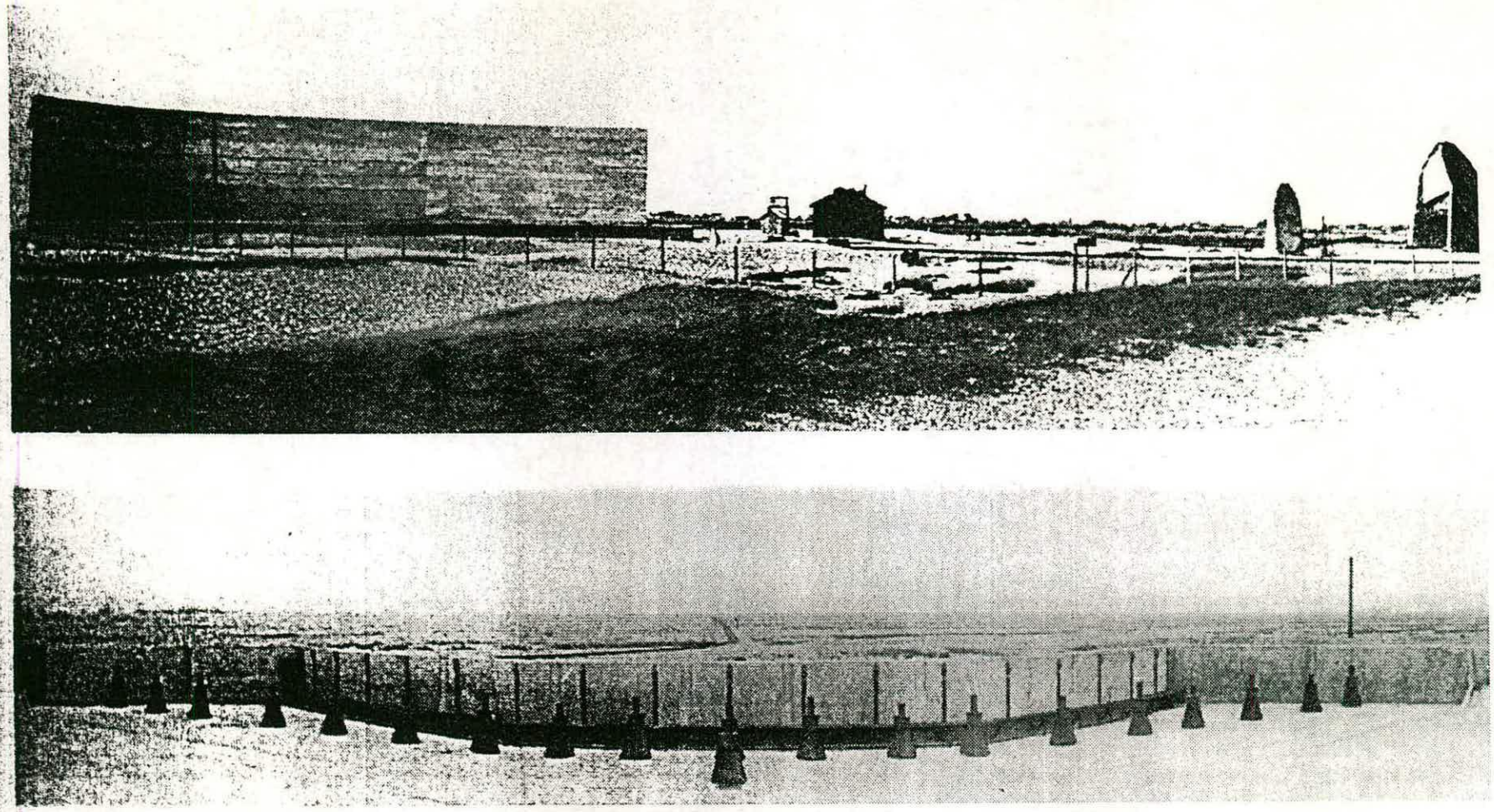


Plate 41 Denge in the 1930's. Note microphones on the forecourt of the 200 foot mirror, and the track of the War Department branch from the Romney Hythe and Dymchurch Railway to the mirror site.

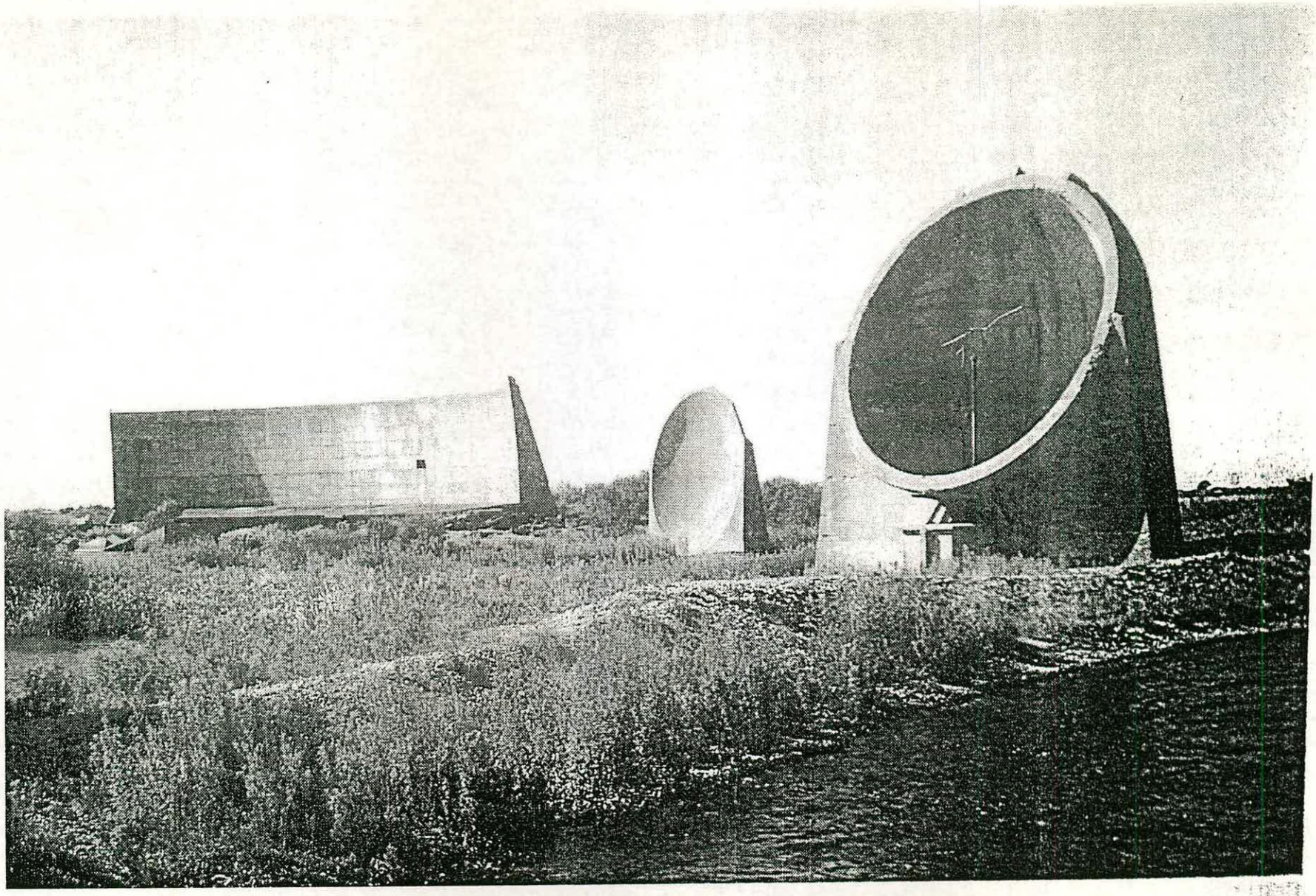


Plate 49 The 20 foot, 30 foot and 200 foot sound mirrors still standing at Denge, Kent in the 1990's.

Report on Construction of Piers Mirror

1. A brick or concrete pier about 18 inches square should be built from which radius of mirror is to be struck and checked. A centre pin with swivel joint should be fixed o on the top. The pier should be 8 feet above founsation level as datum point. The top edges should be shamfered off so that theodolite can be used if required. A line from the centre of pier through centre counterfort should be the correct bearing of the mirror.

2. Radius should be struck out or checked with a steel tape and care taken that tape is not allowed to sag in the length. It was found necessary to employ several men to keep the tape absolutely straight when checking. Experiments were made with piano wire for checking radius but was found unsatisfactory.

3. The casing for bases of counterforts was formed as for boxes with timbers across the top for holding reinforcing bars in position. Casing for beams to be connected to casing for counterforts.

4. Casing to face of mirror was done by making ribs of 7"x 2" or 8"x 2" in about 10 ft. lengths cut to exact radius (which was done on a setting out board) fixed vertically, lapped about 2 ft., fixed together by bolts, runners of 4"x 4" fixed on outside (or concave side) from which it was strutted to uprights of scantling about 3 ft. away. These uprights were then strutted from the ground. Casing must be wrought, fronts cleaned off, and the whole well soaped or lime washed. Bearers were fixed from runners to uprights to form scaffolding. Casing at back of mirror can be made in panels (whole length between counterforts) and fixed to upright ribs of correct curvature vertically.

5. Concrete to counterforts should be taken up at the same time and at same lifts as concrete in mirror. Casing for sides of counterforts can be made in section of depth of lift, and if made correctly can be used afterwards in similar positions on other buttresses without alteration. The back edge however should be continually checked for slope otherwise they will not intersect correctly with top beam.

6. Casing can be removed after perhaps four or five lifts have been completed. Any edges or excrescences through defects in casing should be rubbed off with carborundum stone before concrete gets too hard. No patching up with cement should be necessary or allowed.

7. No undue force should be made in removing casing so that danger of fracture may be avoided.

8. Vitrocrete for concrete gave excellent results both for quick setting and strength.

9. All concreting was done from the front of mirror in 3 ft. 6 in. lifts. Counterforts taken up at same time. Plenty of labour should be employed in tamping, round iron bars with end turned over very suitable for tamping. Wood blocks should be placed temporary between B.R.C. and casing and taken out as concrete proceeds.

10. Concrete was taken to site from mixer by means of inclined running boards. Care should be taken to see that scaffolding should be well supported at these points otherwise weight of wheelbarrows, concrete, etc. may effect correct position of casing.

11. Top edges of concrete to top beam should have bullnosed edge to prevent noise of wind over sharp angles.

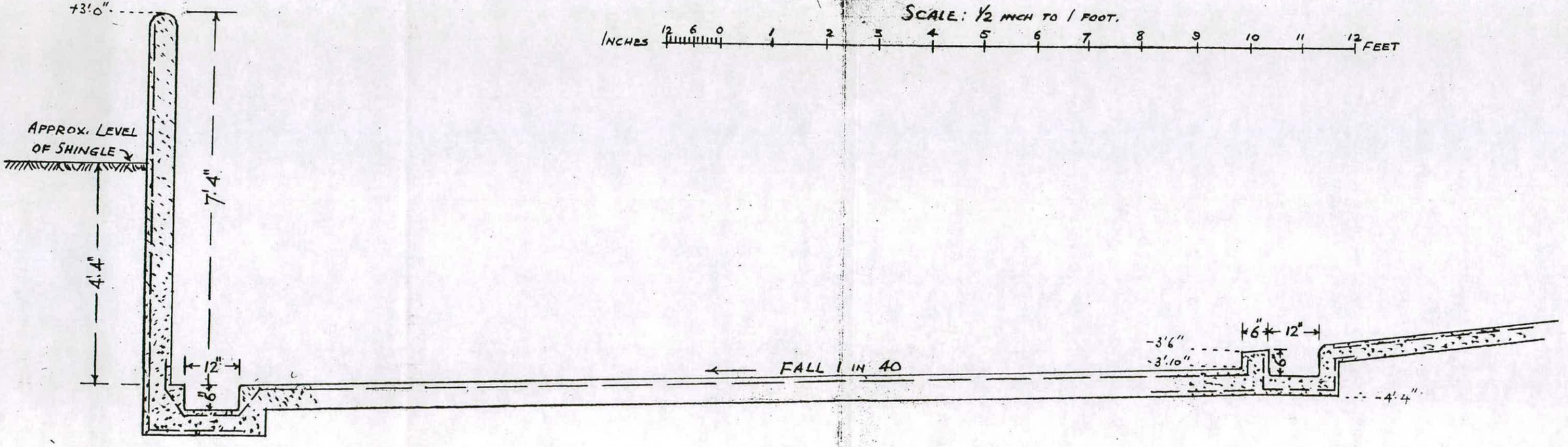
12. It was specified that concrete to mirror should be laid continuous throughout its length but approval was given to

ACOUSTICAL MIRROR ~ 200 FEET.

REVISED SECTION.

SCALE: ½ INCH TO 1 FOOT.

INCHES 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 FEET



CROSS SECTION OF LISTENING TRENCH AT CENTRE.

Spec. for Asphalt

The C.R.E. may permit hand mixing in certain cases and such cases the mixing must be done on a hard, clean, impervious and even surface of adequate size and properly supported. The materials must be mixed as follows:-

(a) The measured coarse aggregate must be spread to an even level.

(b) The measured fine aggregate must be spread evenly over the coarse aggregate.

(c) The requisite quantity of cement must be spread evenly over the layers of fine and coarse aggregate.

(d) All the ingredients must be turned over dry three times or more until they present an even colour throughout.

(e) A measured and sufficient quantity of water must then be added through a rose while the ingredients are being turned over three times or more in a wet state, long pronged rakes being used if required.

(f) The consistency of all small batches of concrete must be uniform throughout.

40a. Test blocks.

The ultimate compressive strength of the concrete will be determined by tests by the C.R.E. The Contractor will therefore deliver, at his own expense, 4" test cubes of concrete whenever directed by the C.R.E. from batches being mixed.

41. Reinforcement.

The whole of the reinforcement, mild steel bar and fabric as detailed and enumerated on the drawings will be supplied on site by the C.D. The Contractor must check the reinforcements on delivery before signing a receipt for them. He must off-load and sort for easy access; he will be entirely responsible for them until they form part of the completed structure.

Material which is found to have developed brittleness, cracks or other imperfections must be rejected, and will be replaced by the C.D.

All reinforcements when placed in position should be of the sectional area specified.

All reinforcement must, before the concrete is deposited, be clean and free from all loose mill scale, dust and loose rust and coatings, such as paint, oil, cement grout, etc.

Bends, cranks, and other labours on metal reinforcements must be carefully formed. Otherwise all bars must be perfectly straight. The bends, etc., on members made before delivery to the Contractor are indicated on the drawings, these however must be checked by the Contractor before placing them in position. The remainder must be carried out by the Contractor on the site. Bends must be made cold round a former having a diameter at least six times that of the diameter of the bar to be bent.

The number, size, form and position of all steel meshwork bars, ties, links, stirrups and other parts of the reinforcement must be placed in exact accordance with the working drawings. Nothing must be allowed to interfere with the required deposition of the reinforcement, and the Contractor must make

a particular point of seeing that all parts of the reinforcement are placed correctly in every respect, and are temporarily fixed where necessary to prevent displacement before or during the process of tamping and ramming the concrete in place.

Bars and fabric must be bound together with pliable iron wire or other approved form of binding where directed, so that the reinforcement may not be displaced in the process of depositing the concrete.

Wire for binding must be thoroughly annealed soft iron No 16 S.W.G. and the binding must be done tightly with proper pliers. This wire is to be supplied by the Contractor.

Metal reinforcement left exposed to the weather for eventual bonding with future extensions must be protected from corrosion.

42. Formwork.

The Contractor is to supply and must be responsible for the sufficiency of the formwork. but, if required by the C.R.E. he must before commencing work submit for approval details of the formwork proposed to be used.

All formwork must be securely braced and supported to prevent any sagging or bulging during the construction. All forms must be fixed to proper grade or curve and trued up immediately before depositing the concrete. This is particularly necessary in the case of the front face of the Mirror. All joints must be close enough to prevent leakage of liquid from the concrete.

The formwork must be so arranged as to permit of easing and removal without jarring the concrete. Wedges, clamps and bolts must be used wherever practicable for securing the true position of the forms.

All timber formwork must be wrought on the concrete face and thicknessed, with edges shot and close joints. It must be White Trieste or Red Venetian of good quality, and to be approved before use.

Care must be taken that, when any formwork is re-used its surfaces are smooth and clean.

Concrete sloping at an angle exceeding 30 degrees with the horizontal must be shuttered on the upper surface.

The bottoms of beam boxes must be cambered when necessary, or when required by the C.R.E.

Formwork for moulds for beams and allied members must, where so required, be designed and supported in such a manner that the sides may be removed without interference with the remainder of the formwork.

The supporting struts must be supported and fixed in position by suitable means. They must be placed upon proper sole plates and so arranged that they may be released or lowered gently before or at the time of final striking.

The responsibility of the safe removal of the whole or any part of the formwork shall rest entirely with the Contractor.

The period which is to elapse between the complete filling of the concrete into the forms and the releasing or removal of such forms will vary with the particular design of the several members of the structure and other conditions, and where the C.R.E. specifies a minimum period such period must not be reduced, but whether a minimum time is specified or not, the full responibility of releasing or removing the formwork of all descriptions must devolve on the Contractor, and the greatest discretion is necessary.

43. Concreting.

Immediately before any concreting is commenced all formwork must be carefully examined to see that all dirt, shavings, or other refuse has been removed by brushing or washing with a hose. All traps and temporary doors must be carefully made good before any concrete is put into place.

The inside of the forms must be treated with a coat of limewhite. In warm weather the inside of the forms must be wetted shortly before concreting is commenced.

All concreting must be done as quickly and as efficiently as possible to the satisfaction of the C.R.E.

The concrete must be conveyed from the mixer to its place as rapidly as possible and in such manner that there shall be no separation or loss from the ingredients. It must be deposited in the forms as near as is practicable to its final position.

The use of concrete distribution shoots at an angle of more than 45 degrees from the horizontal will not be permitted unless specially agreed to in writing by the C.R.E.

The concrete must be sufficiently tamped and consolidated round the steel reinforcement and into all parts of the formwork. Care must be taken that the steel reinforcement is thoroughly surrounded by the concrete and that no voids or cavities are left.

Care must be taken that the reinforcement bars projecting from concrete which has recently been put into position shall not be shaken or disturbed.

Before executing the reinforced concrete work in foundations any moist or soft ground must be excavated to a further depth as directed and filled in with rough concrete (1 cwt cement 5 cubic feet fine aggregate 10 cubic feet coarse aggregate) which must be spread and levelled by spade finish, or dealt with otherwise as the C.R.E. may direct.

The concreting generally must be in layers of thickness sufficient to ensure proper tamping and the full thickness must be made up in immediate consecutive similar operations.

Where cessation of work is essential or unavoidable the break must be at right angles to the span and at its centre. The joint of the new concrete must be squared to the main reinforcement (see detail drawing).

Before depositing fresh concrete upon or against any concrete which has already hardened, the surface of the hardened concrete must be thoroughly roughened, thoroughly cleaned from all loose and foreign matter and laitance, and well washed,with clean water. Before the concreting is commenced the hardened surface must be covered with mortar composed of one part of cement to two parts of sand about half-inch thick. Special care must be taken to ram the mortar and fresh concrete thoroughly up against the hardened concrete.

Reinforcement must in all cases be covered with not less than the minimum thickness of concrete specified or shown on the drawings.

When concreting in hot weather the surface must be kept moist as long as may be directed and in a manner approved by the C.R.E. The work must be protected from the direct rays of the sun and from drying winds.

If, when and where, considered necessary by the C.R.E., and after formwork has been removed sacking must be utilised and kept wet as directed in order to keep the concrete face thoroughly moist. This applies especially to the front and rear faces of the Mirror itself.

Care must be taken that no shock or vibration shall reach the concrete during the process of setting and preliminary hardening.

LF 11