Development of Dutch sound locators to detect airplanes (1927 – 1940)

A.W.M. van der Voort[1], Ronald M. Aarts[2,3]

[1] *TNO-D&V Den Haag, The Netherlands, Email: aad.vandervoort@tno.nl*
[2] *Philips Research, HTC 36, 5656AE Eindhoven, The Netherlands, Email:Ronald.M.Aarts@Philips.com*
[3]*Technical University Eindhoven, Den Dolech 2, PT3.23, P.O Box 513, NL-5600 MB Eindhoven, The Netherlands*

Introduction

The first sound locator was invented by Alfred Mayer [1]; see Fig.1, and named the 'topophone'.

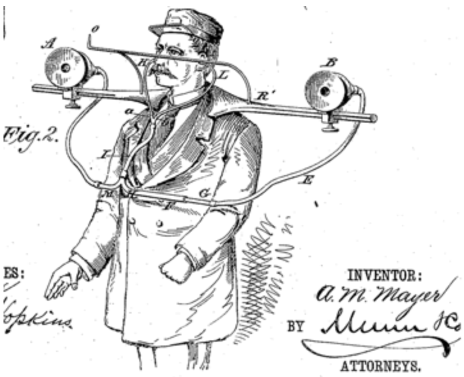

Figure 1: Alfred Mayer's topophone, from [1].

It was used to determine the direction of ships in the fog. In 1880 the topophone appeared in the popular press like the Scientific American in 1880. It even appeared on a fake stamp; see Fig. 2, which was designed by the artist Ben Mahmoud [2].

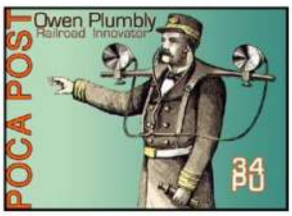

Figure 2: A fake stamp, see [2-4].

Mahmoud named 'Owen Plumbly' as the inventor in 1832. Both the name and year are wrong [4].

From the First World War until the 1930's air acoustics played an important role in air defense. As radar was still to be discovered, vision had to be supplemented by hearing using the sound of the engines. In the 1920's at least a dozen different acoustic locators for airplanes from different countries were available on the military market, see Figs. 3-5.

Foreign sound locators

In the late 1920's the Dutch Army was not satisfied about the performance of the foreign sound locators they had in use for airplane detection. Therefore the Measurements Building at the Plain of Waalsdorp in The Hague started an investigation on three of these systems.

Figure 3: The half of the Goerz, Czechoslovakia.

Figure 4: Barbier, Benard and Turenne, France.

Figure 5: Doppelt Richtungshörer, Germany.

These locators had two pick-up elements for determination of the chart angle (azimuth) and two for the measurement of the elevation. The transport of sound from each pick up pair to a corresponding pair of human ears was carried out by means of metal or rubber tubes. Each pair was adjusted until the two ears received the sound signals at the same time. This occurs when the locator is pointing in the direction of the incoming sound. The locator was manned by two listeners, one for observation of the chart angle and one for the elevation.

Initial acoustic research

J.L. van Soest started his investigations of the human capability of hearing the direction of a sound source in 1927 [5-8]. Of great importance for determining direction is the time difference between the signals received by each ear. This could be tested with the 'listening tube', a rubber tube with wooden ear pieces at both ends. The tube was tapped with a knife around and on the centre-mark of the tube. The listener had to report, whether he heard the sound from the left, the right or straight forward. To improve the accuracy the tube was cut into two parts and a brass bar was mounted in between the two tube ends. Due to the higher velocity of sound in brass than air, a higher accuracy could be obtained [5]. (The brass tube is-like many other artefacts-present in the army museum [9].) Very good listeners were able to perceive a time difference of one microsecond around the central mark on the tube. This appeared to be a factor of ten more accurate than the values measured by v. Hornbostel and Wertheimer earlier. This corresponds to a chart angle accuracy of about one degree. After testing the impulsive sounds, sinusoidal sounds were tested by putting a tuning fork on the tube [6]. Subsequently he performed listening tests in the free field [7]. In this research one of the conclusions was that small head movements improved sound localization considerably. Further investigations studied the sound path in the air, finding that it is dependent on temperature gradient, humidity gradient and wind speed [8]. Most times these effects give a greater misdirection of a sound source then one degree.

Figure 6: Inflatable cushion for listening tests present in the army museum [9].

Disadvantages of the foreign sound locators

Van Soest determined various disadvantages of the present locators, among those are:1. The wide base is not necessary, the ear base is sufficient. 2. Multipath effects of the sound through the metal or rubber tubes make a sound signal weaker and smear it out in time. 3. The great weight of the device meant manoeuvring could make a significant amount of noise. The target could be lost; this was noticed by others as well, see [10]. 4. The observations of two listeners (chart and elevation) had to be coordinated. 5. The foreign locators were very expensive

Own development

In the Measurements Building a new sound locator was developed. A parabolic sound mirror with a cross section of 120 cm was cut in two halves and each was focused directly at an ear of the listener, see Fig. 7. Each half was closed by a side-plate with a hole on the place of the focus of the paraboloids. Comparative tests showed that this arrangement performed much better than the current foreign equipment.

Figure 7: Sound locator Waalsdorp.

The half paraboloids were joined to a vertical column to which a seat was mounted for the listening operator. Around the ear-holes bearings were mounted for elevation movement. An inflatable ring shaped rubber cushion filled the space between bearings and the ears of the listener. The adjustment of the chart angle in the horizontal plane around the column and the elevation movement took place by muscle force of arms and legs. Helped by flat partition walls in each paraboloid the operator could reach an accuracy of less than two degrees in elevation using sound intensity. The advantages of Waalsdorp's locator were: 1. Better observation and sharper indication of the sound source. 2. Lightweight system. 3. Movable without bearing noise. 4. One listener for chart angle and elevation. 5. Cheaper than the foreign systems. To avoid wind noise a transparent jute cover was used, see Fig. 8.

Figure 8: Listening tent.

Correction cylinder

Because the airplane speed is not negligible with respect to the speed of sound in air, the actual location of the airplane differs from the location inferred by the operator. A correction cylinder was used to find the real direction. A reading operator handled this cylinder. The listening operator aimed the device towards the incoming sound of the airplane and by pressing a button he marked at least three successive positions in chart and elevation.

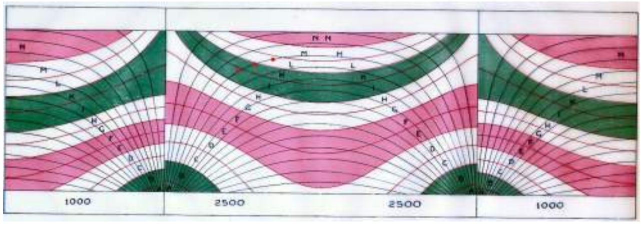

Figure 9: Flat projection of the template with several possible target paths and on path M 3 marks of an airplane. Horizontal the chart angle (azimuth), vertical the elevation.

These markings appeared as ink dots on the outside wall of the glass correction cylinder.

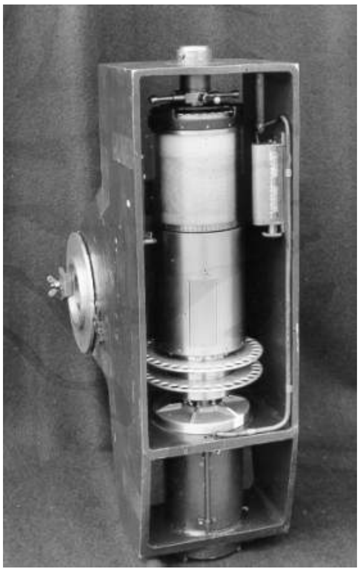

Figure 10: Correction cylinder.

Inside the glass cylinder was a cylinder with a target paths template. The reading operator rotated the template cylinder to find a best fit of the three (red) markings to one particular (M) target path. The reading operator made an extrapolation dependent on airplane speed and the position of the last mark on the template (M track). With this extrapolation from the last marking along the chosen target path the corrected values for chart angle and elevation was found.

Transport of angle values.

The sound locator co-operated with field glasses and a searchlight. It was important that the chart angle and elevation of the airplane were quickly available at the field glasses and later on at the searchlight. Therefore an electrical transport system (step system) was developed, see Figs. 11-13. The values for chart angle and elevation established by the reading operator were directly available at the field glasses. The operator of the field glasses used these values to locate the plane and made adjustments to the chart and elevation angles to account for the real position of the airplane. These adjusted values were directly available at the search light. The time taken for the listener to make the last marking, till the switching on of the searchlight had to be short and consistent. When the angles were received the light was switched on to catch the plane.

The Dutch industry produced around one hundred of this type of sound locator.

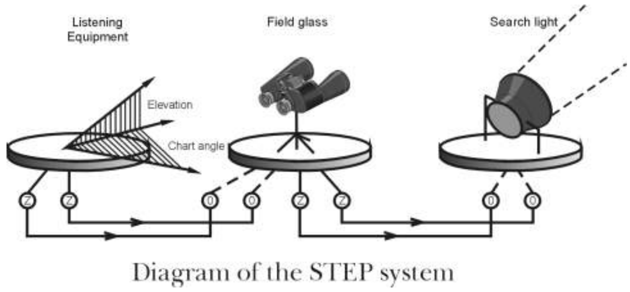

Figure 11: STEP system.

Figure 12: Sound locator in operation.

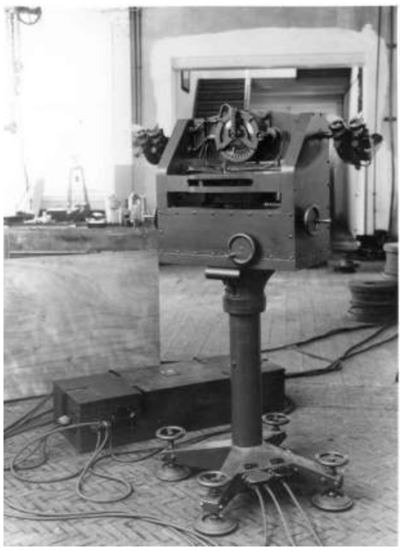

Figure 13: Field glasses.

New developments

As airplane speeds increased it was no longer possible to realize reliable extrapolations. A new sound locator and searchlight had to be developed. The new searchlight was a searchlight with three axes, see Fig. 14. The airplane was detected visually by sweeping the searchlight beam over an area of sky. They used an altitude plane (Dutch "standvlak", see Fig. 15). This plane was oriented so that it incorporated the straight airplane track and the position of the searchlight. When the chart angle and the elevation of the "standvlak" were known axis 1 of the searchlight was oriented to the chart angle direction and axis 2 to the elevation angle of the "standvlak". When this was ready the lamp was switched on and the lamp house was rotated around axis 3 to locate the airplane.

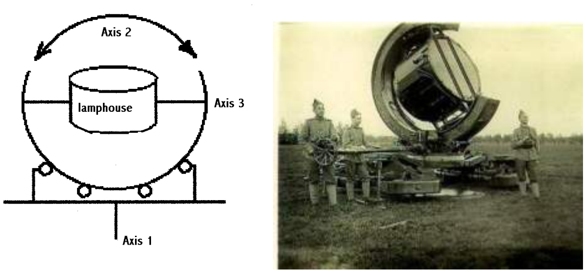

Figure 14: Three axis Search light.

To find the chart and elevation angle a new sound locator was developed, a three-axes locator with two floors. The top floor was for the listener and the ground level for the reading operator. After the listener made the necessary three markings, the reading operator could read off the chart and elevation angle of the "standvlak" which were then sent to the searchlight. How many of these locators were constructed is unknown, but at least one remains in an Army museum.

Miniaturized sound locators

In the 1930's the possibility of a surprise intrusion of many hostile airplanes became apparent. This initiated the concept of a permanently operated early warning system (Air Watch) comprising many listening locations distributed over a wide area. This necessitated the availability of a device to trace the sound of incoming airplanes with better capabilities than the unarmed ear. The Measurements Building in The Hague was asked to investigate the possibilities. From 1930 different versions were tested and it appeared that a miniature version of parabolic reflectors produced the best results, see Fig. 16. From 1935 hundreds of these locators had been made for the Dutch Air Watch Service.

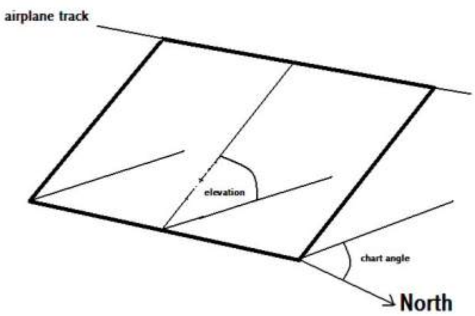

Figure 15: Set-up.

Figure 16: Miniature locator.

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[1] Alfred M. Mayer, Topohone, US patent No. 224,199, Filed Sept. 30 1879, Granted Feb. 3 1880.

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[3] A false explanation to the stamp is in: The newsletter of the Acoustical Society of America 'Echoes' Vol. 13(1), p.4, 2003.

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[5] J.L. van Soest and P.D. Groot, Stereoacoustische geluidsbeelden en kleinst waarneembare tijdsverschillen (in Dutch), Stereofonic sound images and just noticible time differences, Physica 9, pp.111-114, 1929.

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[8] J.L. van Soest, Rapport betreffende acoustische opsporing (in Dutch), Report on acoustical detection, unpublished report (in the TNO army museum collection), 1934.

[9] MUSEUM 'WAALSDORP' This museum reflects the history of TNO Defense, Security and Safety at location Waalsdorp (and its predecessors) since 1927, see http://www.museumwaalsdorp.nl/museumen.html

[10] E.R. House, Reducing noise in airplane sound locators, J. Ac. Soc. Am., 7, pp. 127-134, Oct. 1935.