EXPERIMENTS RELATIVE TO VISIBILITY OF BUOYAGE

RESULTS OBTAINED IN GERMANY IN 1927

The various Committees and commissions of experts and navigators which have met in order to study the problem of the Standardisation of the Rules concerning the Buoyage of Channels and dangers, have emphasised the importance of experiments and technical research for strengthening the decisions to be taken by the Conferences.

It is only by such measures that the uncertainties which exist can disappear *i. e.* by measures to guide the choice of the experts where different systems present themselves.

At the Conference on Buoyage at Stockholm in August 1926, it was proposed to urge all the nations to undertake experiments the principal object of which would be to determine the visibility of the colours affixed to buoys, and it was emphatically demonstrated that it was of special importance that that colour should be chosen the visibility of which was greatest in the case of fog or bad weather, for, in calm weather, all the colours are equally visible.

Concerning the relative visibility of black and of green, experiments had already been made by France in Pilier Island, near Saint-Nazaire. These experiments had been conducted by means of boards corresponding to buoys of about two metres diameter afloat, placed at a distance of about 300 metres from the observer. The observations had been taken by different agents three times a day for a period of five months. Taking into account the degree of visibility, and establishing a co-efficient, they had arrived at the following average figures, which represent the comparative degrees of visibility of the colour in question :

Black	2263
Red	2376
White	2059
Green (plain colour)	2475
White-and-green checked pattern	1745

These experiments gave a favourable number for the visibility of green, but objection was made to them on account of the too feeble distance at which they had been carried out on the one hand, and on the other hand, on account of the fact that it would be preferable, also, to use real buoys and ...floating perch for those experiments ; the Conference at Stockolm therefore ... recommended that experiments should be made in conditions more closely resembling real practice.

In the documents annexed to the Minutes of Meeting of the said Conference and published by the Advisory and Technical Committee for Communications and Transit of the League of Nations, we find the following technical note concerning experiments relative to visibility which may be made on buoy beacons, or their top-marks.

NOTE

RELATING TO TESTS OF VISIBILITY OF BUOYS, BEACONS AND TOP-MARKS THEREON WHICH THE TECHNICAL COMMITTEE HAS PROPOSED TO BE CARRIED OUT IN THE DIFFERENT COUNTRIES.

Stockholm, August 12th, 1926.

The visibility of a buoy (or of a beacon or top-mark) may depend on:

1° The intrinsic properties of the *buoy itself* or of the manner in which it has been painted:

On its apparent outline;
On its shape;
On its dimensions;
On its colour.

2° The visual acuteness of the *observer*, whether provided or not with a telescope or binoculars, for the different colours (including astigmatism and daltonism), as well as on material conditions, physiological conditions or even suggestive conditions which may affect the observer while observing;

3° On the appearance and particularly on the colour and tint of the *background* against which the buoy is projected and stands out;

4° On the lighting of the buoy, *i. e.* on the nature and quantity of light it reflects (the buoy acting in fact as a mere light reflector) and which the retina of the eye may perceive, this lighting being itself a rather complex function depending on:

The source of light;
The type of that source;
Its shape;
Its intensity (power);
Its colour;
On the angle of *incidence of the light on the buoy, i. e.* on the geometric position of the source of light and on its direction, both in azimuth and in altitude, relative to a plane (approximately that of the horizon) which contains the source and the observer;

5° On the nature of the more or less transparent or opaque medium, in which the source, the buoy and the eye of the observer are all contained and through which the light rays are propagated, *i. e.*, in a word, which includes in itself all the complexities; on the atmosphere and the conditions thereof.

It should be added that the visibility in which the navigator is interested is mainly the extreme visibility, *i. e.*, the greatest range of visibility at which distance the navigator commences to search with a view to discovering the presence of the buoy, in the conditions of navigation. At a short distance, in fact, all shapes, all colours and all the combinations of different colours, *i. e.* stripes, checks or other, are nearly equally visible and, for the benefit of the sailor, it is more a question of searching for a criterion at longer ranges of visibility rather than at shorter distances.

Consequently the question is to experiment under the various conditions which may occur, not at a constant distance but in the vicinity of the limits at which, in the different cases, the separating power of the eye has to be exerted (both for the visual acuteness of the eye for the colour black and for other colours) and, for preference, when approaching the buoy rather than when moving away from it.

These considerations are set out here not in an over-careful spirit but with a view to drawing attention to the practical conditions in which the tests should be carried out as far as possible.

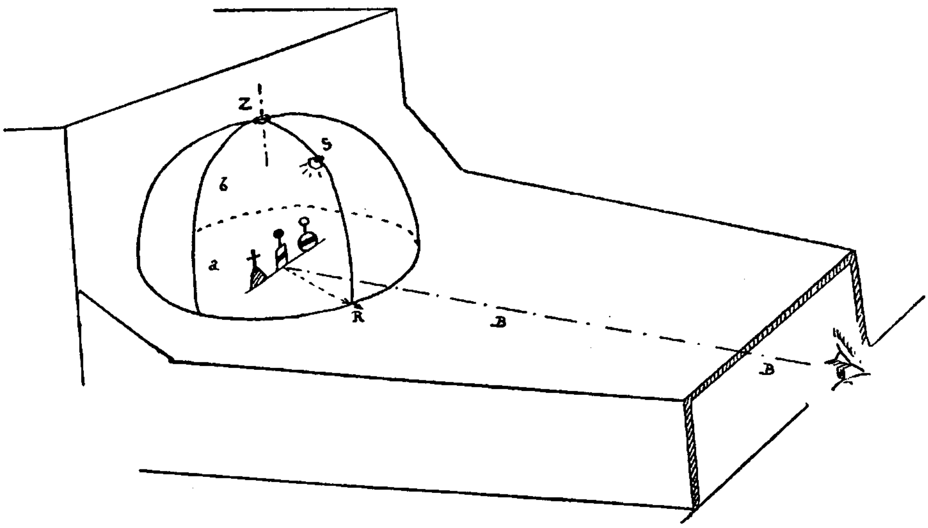
Besides, it must be noted that an estimate of the *relative* visibility or the various colours and various shapes is required rather than a definite numerical measurement of the absolute range of visibility for each type of buoy taken separately.

The preceding summary of requirements gives an idea of the problem under consideration and of the practical difficulties which will be encountered in carrying out effective experiments at sea and under the whole gamut of the various circumstances in which the captain of a ship is mainly interested.

It is evident from the above analysis, and it being, in fact, a matter of measuring small angles (*i. e.* those involved when operating near the limits of the separative power of the eye, approximately one minute of arc in the normal physiological constitution of the retina), associated, also, with photometrical estimation of relative lighting, that it would be easy and, *above all, much more rapid*, besides being much cheaper, to carry out tests in a dark room by means of an optical bench in order to illustrate the complete range of the various circumstances which it is intended to investigate. Even if, by this method, real practical conditions are somewhat disregarded, the great advantage is gained that it is possible to collate a great variety of observations within a period of a few days only.

Of course, it would be easy to check the particulars found during the reduced experiments later on under practical conditions.

The sketch given below shows an exemple of a very simple system for carrying out the experiments in a dark-room, by means of very few materials, including blackened cardboard.



One quarter of a sphere representing the celestial concave (restricted to the plane of the horizon), as it is called in astronomical navigation, will serve as the lighted field for tests in the interior of a container of a suitable shape blackened inside, in the centre of which may be placed small models, reduced to a predetermined scale, representing buoys and giving them their actual shapes and not only their silhouettes.

Then the following may be varied:

1° The colour or tint of backgrounds *a* and *b*;

2° The position of the punctiform source of light *S*, fitted with a diverging reflector, along the moveable arc *ZR*, also the position of this arc in azimuth relative to the direction of observation;

3° The intensity, and even the colour, of the light of the source *S*, either by means of a rheostat or with screens consisting of ground or coloured glass such as those which are used for nephelometers.

The numerical results of each test may be read off along the divided scale of the optical bench (*BB* produced) by approaching the eye just so far as to be able to distinguish the topmarks or colours. *(The placing of coloured «filters« before the eye may improve certain relative visibilities of colours)*

More accuracy may be obtained in this manner of observing by using a telescope fitted to slide along the optival bench. If this be done, the magnifying power of the telescope must be taken into account, for it increases, by the same factor, the value of the separating power of the eye.

The reduced scale for the models of buoys must be calculated in order to observe at distances, reckoned from the buoys, greater than 1.8 metres (6 feet), in order that the eye may work without accommodation fatigue; and if a telescope be used, it must be at the maximum extension for the focus.

Following the Conference at Stockholm, various countries have undertaken systematic experiments, and attention may especially be drawn to those which have been carried out in Germany on the initiative of the Department of Navigable Waterways of the Ministry of Communications of the *Reich.*

These experiments were made with the painting and the form of the buoys during a period extending from October 1926 to March 1927. Preparations for them were carefully carried out and models of printed notices (*Versuche über Sichtbarkeit von Austrichen und Formen von Seetonnen*) were distributed to the pilots and to the navigators concerning the channels under experiment, explaining to them in detail the information which it would be useful for them to collect and to note in view of the ulterior analysis of their observations.

We give below, for those of our readers who may be interested in the question of buoyage, the preliminary results which have been forwarded in connection with these experiments which concern both channel buoys and buoys marking reefs on the high seas.

A. *CHANNEL BUOYS.*

In about one-tenth of all the experiments that proved serviceable, the visibility of the green trial cone-buoys was better than that of the black cone-buoys in use in Germany, whilst in eight tenths of these experiments, the visibility of the black buoys was better, and in the remaining one-tenth the visibility of both kinds of buoys was equally good. The number of serviceable tests was about 2,000. It should be mentioned that (almost without exception) the visibility of the green buoys was better than that of the black buoys, only when the former were lit up by the sun and when the sun was behind the observer.

B. *OPEN-SEA REEF BUOYS.*

1) In about nine-tenths of the experiments made, the visibility of the test buoys placed to the north of shoals, *i. e.* black beacon buoys with two cones base to base for top-marks, was better than that of the white spar buoys with two cones pointing upwards for top-marks, which are used in Germany. In about one-tenth of these experiments, the visibility of the white spar-buoys was better than that of the test buoys, and for the remaining one-twentieth of the experiments the visibility of both kinds of buoys was equally good.

2) In about three-tenths of all the experiments made, the visibility of the test buoys placed to the east of shoals, *i. e.* white spar-buoys with red stripes and with a ball for a top-mark, was better than that of the white buoys with two cones placed base to base for top-marks which are used in Germany; in about two-tenths of these experiments, the visibility of the white spar-buoys was better than that of the test buoys; and for the remaining five-tenths of the experiments, the visibility of both kinds of buoys was equally good.

In about six-tenths of the experiments, the visibility of the top-marks of the test buoys was better; in about one-tenth, the visibility of the top-marks used in Germany was better, and for the remaining three-tenths, the visibility of both kinds of buoys was equally good.

3) In about four-tenths of all the experiments made, the visibility of the test buoys placed to the west of the shoals, *i. e.* white cone-buoys with black stripes and with a reversed cone as a top-mark, was better than that of the white spar-buoys or beacon-buoys with two cones placed point to point as a top-mark which are used in Germany. In about three-tenths of the

experiments, the visibility of the white spar-buoys or beacon-buoys was better and, in about three-tenths of the experiments also, the visibility of both kinds of buoys was equally good.

In about two-tenths of the experiments the visibility of the top marks of the test buoys was better; in about six tenths of the esperiments, the visibility of the buoys used in Germany was better, and in the remaining two tenths of the experiments, the visibility of both kinds of buoys was equally good.

It is interesting to note these experiments at a moment when every effort is being made to simplify and to facilitate navigation. They might, indeed, serve as a basis for all fruitful discussion and for all agreements tending eventually to standardise the systems of buoyage, at present so numerous, by assigning to each symbol a definite object (the conditions of which it would be necessary to make clear), in conformity with local requirements; and such assignation should be founded upon data and upon reasons universally recognised by all the departments interested.