FORUM

THE AVOIDANCE OF COLLISION BY AIRBORNE AND SHIPBORNE MEANS

THE papers presented at the three-day conference on collision-avoidance held in London last June by this Institute, the French Institute of Navigation and the Ausschuss für Funkortung, have been published in the last two numbers of the *Journal*. It has not been possible to publish the fairly lengthy discussion that took place on these papers but a summary of some of the contributions follows. Some contributions printed here do not relate to the conference itself.

One subject which aroused a great deal of interest at the conference was the impact of radar on the International Regulations for Preventing Collisions at Sea, and as a result of the conference a Working Group has been set up by the three sponsoring bodies to consider the problem and if possible formulate positive recommendations. A great deal of the discussion at the conference (on the marine side) was on this subject and a brief summary of the various suggestions put forward has been made available to the Working Group.

Numbers printed thus (10, 230) in the Forum, refer to the volume and first page number of a paper in this *Journal*.

The Use of Infra-red as a Warning Device

from Professor F. Schroeter

MY comments refer to those papers dealing with the use of certain parts of the electromagnetic wave spectrum as a means of overcoming bad visibility, and especially those concerned with the prevention of collisions at sea. Here, fog is the source of danger in almost all cases, whereas in aviation fog and clouds cause only a minority of accidents. In the case of aviation, moreover, height above the ground plays a decisive part; the atmosphere becomes more and more transparent to infra-red rays with increasing height. In these zones, therefore, and in all zones without rainfall and with a very rarefied atmosphere, the prospects for systems using infra-red rays are far better than at sea-level.

To start with, I should like to remind you of very early measurements of atmospheric transparency carried out by Coblentz, of the Bureau of Standards, at the beginning of this century and apparently forgotten by the present generation. It is again and again assumed that fog and mist are far more transparent for the infra-red zone than for light waves and ultra-violet. On the basis of measurements by Granath and Hulburt, also of the Bureau of Standards, and by myself, I can say that this assumption is wrong. I will not mention uses where the required range is very small. There of course infra-red—or for that matter light—can be used. The results of Coblentz and of Granath and Hulburt show what may be expected. Coblentz found that between 4μ and $7{\cdot}5\mu$, almost all wavelengths are heavily absorbed in the infra-red zone. This leads one to a division of the infra-red spectrum which fits in well with the various methods

https://doi.org/10.1017/S0373463300038959 Published online by Cambridge University Press

of detection. So we have a range of about $0 \cdot 8\mu$ to 3μ (the range of application of photoelectric semi-conductors with low inertia) and a second zone, starting above about 10μ, where the atmosphere again becomes increasingly transparent. In the latter, however, we are dependent on thermic detectors (bolometer, thermopile, Golay detector, the most sensitive instruments at present). These are inert indicators, unsuitable for methods using moving scanner beams and, since they integrate, can only be used where the radiation from the warm zones they are supposed to indicate (exhaust gases from jet planes, heat radiation from ship's funnels, &c.) is not cancelled out by one's own radiation into colder zones in the same direction. For a radiation equilibrium must always occur in the integration period. Nevertheless, a range of 20 km. from land over the sea in fog was obtained with large reflectors and bolometers. However, such equipment would be out of the question for aviation and even for shipborne instruments, all the more since focusing would cause enormous difficulties.

We now come to the zone between the light waves and about 3μ. While there are photoelectric semi-conductors which are sensitive to infra-red waves longer than 3μ, the photo-effect constantly decreases very rapidly in this direction, so that not much is gained. Now it is correct that in this spectral range too the atmosphere has certain 'windows' of spectral transparency. But it must not be overlooked that these 'windows' exist only for molecular absorption by steam, oxygen and carbon dioxide. Apart from this influence, however, there is the far more important one of the dispersion by drops of water in the atmospheric condensation. As a result the overall dimming becomes far greater and less dependent on the wavelength of the spectrum. Granath and Hulburt measured the permeability of river fog over the Potomac in the zone of light waves and infra-red up to 3μ, and found striking proof of the slight difference between visible light and infra-red between 1 and 3μ. My own results were even more negative, instead of offering the hoped-for confirmation of the great superiority of infra-red. If, for a rough estimate, we take the area along which parallel radiation is dimmed to 1/100 of the intensity of incidence, and if we ignore the divergence of radiation in space, which of course makes the result even more unfavourable, then, according to Granath and Hulburt, the area for

$\lambda = 1\mu$ to 3μ average 977 m. (970–980 m.)
$\lambda = 0 \cdot 6\mu$ average 910 m.
$\lambda = 0 \cdot 5\mu$ average 843 m.

If, somewhat more optimistically, we set the standard area in the range of 1μ to 3μ equal to 1 km., then according to Beer's exponential law the intensity of incidence sinks to 1/10,000 at 2 km. and to 1/1,000,000 at 3 km. If we use reflection, the exponent has to be doubled. This means, at only 3 km., a reduction in the ratio 10^{-12}. If we now assume this limit of sensitivity of 10^{-12} watt to be sufficient for the detector (unfortunately the frequency of modulation and scanning is not given), then the radiation of 1 W. would give a range for the reflection procedure of just 3 km., whereas for 4 km. we already need 10 kW.! In addition, a superiority by one order of magnitude for infra-red as against visible light would mean very little in view of the law of $4\sqrt{}$ for reflection technique. These figures show the true position, which I was able to confirm by my own measurements. In particularly thick fog the case for infra-red is even less favourable compared with light waves, for which we have the most sensitive, simplest and cheapest detector in the shape of the eye.

When one realizes that this circumstance favours the use of the visible spectrum one can go one step further and consider using the nearby ultra-violet, for which we can also use the eye as a direct indicator with the aid of a fluorescing disc, and for which we have sensitive, non-inert detectors. Today we are in a position to send out a large impulse power of ultra-violet rays in very compact beams and to receive them with such detectors. We could therefore also use them to make a radar instrument. I think such an experiment, using modern materials, might be a worthwhile experiment in order to explore the possibilities.

I should also like briefly to mention the use of reflectors, preferably triple mirrors, which have been the subject of a number of papers and comments. Radar is obviously developing in the direction of microwaves (e.g., 8·6 mm.), which are undoubtedly far superior to infra-red in all respects, especially since in the case of larger objects, such as ships, they give a good image of the shape and position. An obvious step, therefore, seems to be to use suitably mounted reflectors, e.g. on the stern and bows of a ship, to show the aspect of a vessel appearing in the radar area, i.e. her manœuvres. This could, for instance, be done by inclining the reflectors towards each other and observing the relationship in their reflection intensity; this would make it possible to recognize a change of course. Furthermore, such reflectors could be used as transmitters by modulating their reflection. For slow identification the reflector openings could be changed mechanically, perhaps by shutters. But quick modulation with telephone frequencies is also possible with a method which I saw in 1935 in the laboratory of the Radio Corporation of America. A gas discharge valve with a to-and-fro winding, whose current strength is modulated practically without inertia, is placed in the exit plane of the reflector. This can be done by fairly simple means. The ionization in the gas causes a dispersion of the emitted reflected beam which is dependent on the momentary discharge intensity.

Finally, we must consider the question of using the selective gas radiation from the exhaust gases of jet aircraft. It is known that these are partially ionized at the exit opening as a result of the high combustion temperature. This part is indicated by the 3-cm. radar wave and so forms a useful additional reflection cross section in addition to that already represented by the metal aircraft itself. If, therefore, one uses radar waves of, e.g., 3 cm. or 8 mm. to irradiate the object, its reverse scatter section appears considerably enlarged compared with the section of its own radiation, which alone would be able to affect an infra-red indicator. The use of infra-red radiation alone for such objects is in my opinion less hopeful than detection by normal radar instruments, especially in thick fog, which would make passive location largely unsafe. It would also be impossible to measure distances, which is done using normal radar with reflected micro and cm. waves.

Radar and Visibility Distance

from Dr. H. Koschmieder

I suggest that the term we should use instead of Visibility is *Range of Visibility*, which defines the maximum distance at which a black object can be identified on the horizon. This distance can nowadays be measured. But to my mind even