"BLUE HAZE"

by

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Although it has been suggested that certain of H.M. ships, notably the *Town* Class cruisers (1937-38) with their raked funnels, probably experienced the phenomenon before 1939, it was not until the early stages of the Second World War that " Blue Haze " came into prominence as constituting a danger to the Fleet.

" Blue Haze " is described as being blue or bluish-white in colour ; it clings to the sea-level and, when viewed from the ship making it, appears as a cloud extending to the horizon. The haze does not form until it has moved some distance from the funnel which itself appears reasonably clear. This haze is not to be confused with white smoke caused by using an excessive amount of air in the combustion of furnace fuel oil.

Early Reports

Early reports showed that, under certain conditions, ships were unable to prevent this haze which became a matter of considerable importance ; on one occasion at least it had been so dense as to obscure a flagship from her consorts. The reports suggested that the phenomenon was peculiar to cruisers and battleships operating in Northern and Arctic waters, but later information showed that it occurred also, under varying weather conditions, in the Eastern and Western Mediterranean.

It was at first thought that this haze was due to inefficient burning of the furnace fuel oil, and certain measures were adopted in one battleship to enable the fuel oil to be burnt more efficiently, but the haze still persisted.

Although in general " Blue Haze " only occurred intermittently, a case was reported where, in July, 1942, it persisted for three days from Latitude 76° North to Scapa ; and H.M.S. *Kenya* experienced this haze from Gibraltar for the whole of a Malta convoy.

As no solution to the problem was forthcoming, a Funnel Haze Panel was formed to advise the Admiralty on the phenomenon.

Sulphur Trioxide in Funnel Gases

The Funnel Haze Panel turned its attention to the sulphur trioxide in funnel gases, as it was known that boiler installations on land, using coal of high sulphur content, produced a bluish-white haze and these instances were definitely due to sulphur trioxide formation.

As, as far as the Fleet was concerned, the phenomenon was stated to be a new one, changes in the characteristics of fuel used were examined. The sulphur content was about the same, but the war-time fuels were in some cases vanidiferous, and as vanadium compounds had a catalytic effect on the formation of sulphur trioxide from sulphur dioxide it was possible that boiler dust containing vanadium might have a catalytic action in the oxidation of sulphur dioxide to sulphur trioxide, in which case the sulphur trioxide content in the funnel gases might be sufficiently high to elevate the dew-point to produce haze. The investigation into the catalytic action of boiler dust showed that the dust had definite catalytic properties.

A number of factors, however, suggested that the sulphur trioxide theory was not a solution of the problem as :—

(i) Ships burning fuel oil free from vanadium compounds made " Blue Haze."

(ii) During the shore trials of prototype boilers, extending over periods of several months under all conditions and powers, in all kinds of weather conditions and where vanidiferous fuel oil was used, there was never a suspicion of " Blue Haze." During these trials humidity conditions must have been met which existed at sea when " Blue Haze " was encountered, particularly as the trials were carried out on the bank of the Clyde.

(iii) It had been stated by ship's officers that when " Blue Haze " was present and a ship turned over from furnace fuel oil with a sulphur content of over 1.5% to a Diesel oil containing only 0.5% of sulphur no difference was observed in the appearance of the " Blue Haze," in so far as its density or position of formation was concerned. It would therefore appear that the reduction by two-thirds of the oxides of sulphur present in the funnel gases had no effect on haze formation.

(iv) Reports from ships in general agreed that " Blue Haze " appears at some 200-300 yards from the stern of the ship and at a height well below the top of the funnel. After losing the initial velocity at which they leave the funnel the gases being hot will rise, but when they have cooled to the temperature of the surrounding air they will fall owing to their density being greater than air. Long before they begin to fall they will have reached the dew-point, and under these conditions it is difficult to see why the mist does not form at or above funnel height, if it is due to the raising of the dew-point by sulphur trioxide.

(v) The oxides of sulphur are always present and, when taken together, are always in the same ratio to the water vapour coming from the funnel whereas " Blue Haze " is an intermittent phenomenon.

Widely different Conditions

Reports received from many ships did not lend support to any of the theories or suggestions which had been advanced; if anything, they made the position somewhat more obscure as they showed that the haze was produced under more widely different conditions than had been supposed.

Some ships reported that although making " Blue Haze " themselves, other ships of the same class did not appear to be making it. One case, reported by a battleship, stated that when in company with two other big ships only two of the three ships were making haze. In addition to the information already obtained it was confirmed that :—

(i) Ship could not make it at will ;

(ii) Ship could not stop making it when it was present ; and

(iii) Its position was influenced by any breeze.

During the shore trials of prototype boilers, it was noticed that although several trials were carried out on the bank of a river, where the boiler house was only a few feet away from the water and where the funnel gases frequently carried on to the water, haze never appeared.

The obvious inference is that " Blue Haze " appears at sea and not over rivers or on land, and it must therefore be in some way connected with the sea. Another feature of great importance is that whatever agent may be

present it must be situated near sea level and be invisible until it is reached by the funnel gases.

Ship Variables

In general, the composition of the fuel carried by a ship is sensibly constant, although, due to mixing of various cargoes, the composition may vary slightly from one tank to another. It is therefore impracticable to make a marked change in the composition of fuel being burned at a particular time except by changing over to Diesel fuel. Apart from this, the variables the ship is capable of making are :—

(i) in the burning of the fuel ;

(ii) the quantity of fuel consumed ;

(iii) the speed of the ship ;

(iv) the course of the ship relative to the direction of the wind.

In this connection, it is interesting to note that in October, 1943, it was reported that a battleship was making " Blue Haze " at 1120 but not at 1430 the same day, although the speed of the ship, wind, and humidity were the same at both these times. This report does support the suggestion that some agent other than the gases and material coming from the funnel is necessary for haze formation.

Variables outside control of the ship

The variables outside the control of the ship are the weather conditions and these may vary as follows :—

(*a*) Temperature.

(*b*) Humidity.

(*c*) Bright sunshine.

(*d*) Presence or absence of nuclei which may cause fog or mist to form.

In considering these variables one must bear in mind the fact that " Blue Haze " has been observed in various parts of the world. Temperature does not appear to be a controlling factor, as this haze has been reported in both hot and cold climates.

Light gives the colour to the haze and the fact that the haze has been reported by all observers to be blue lends support to the theory of the presence of nuclei in the air, in a finely divided state, causing the preferential scattering of the shorter wave lengths to give the haze a blue appearance. Since the density of the scattered light, *i.e.*, the visibility of the " Blue Haze ", varies greatly with the direction from which it is viewed, relative to the source of light, observers in different positions ought to see different intensities, and from some positions it may not be visible at all. The density appears to be the greatest when viewed from the direction of the source of light, and the lowest when viewed from the opposite direction.

Cases have, in fact, been reported where a ship could see the haze made by a ship in line but could not see the haze being made by the ships disposed abeam.

Mists are not only produced under conditions of super-saturation, they may form when the relative humidity is well below 100%, provided that hygroscopic particles are present to act as nuclei of condensation to produce minute droplets of solution of which such a mist consists. Sodium chloride is hygroscopic, and not only picks up water very rapidly, but reaches the state corresponding

to the surrounding humidity conditions very rapidly, whether it is picking up water or drying.

Aerosols

Under certain atmospheric conditions sodium chloride in the form of finely divided particles, or aerosols, is present just above sea level. These particles can be so small as to be invisible, but if water vapour such as that in funnel gases is present and comes into contact with them they will form larger particles of sodium chloride solution, visible to the eye, yet small enough to be air borne and form a mist. It is observed that furnace fuel oil contains approximately 12% of hydrogen in combination with approximately 86% of carbon, and every 100 tons of dry oil fuel burnt produces 108 tons of water vapour which is emitted from the funnel. There is, therefore, ample water vapour in the funnel gases to take the aerosols of sodium chloride, when they come into contact, into solution, and thus increase their size.

Such a mist may be looked upon as a chemical fog, and it has been produced and its characteristics demonstrated both in the laboratory and on a larger scale with the aid of the funnel gases from an experimental boiler at the Admiralty Fuel Experimental Station, Haslar.

Laboratory Experiments

In the laboratory, sodium chloride was volatilized by playing coal gas/oxygen flames into cavities in firebricks and feeding sodium chloride into the cavities as required. The presence of sodium chloride in the air was shown by the colour of the flames of gas burners in the laboratory. On a dry day, the air in the laboratory remained clear and free from haze or mist. Water vapour was then produced by boiling water in open vessels on burners on the benches and, as the atmosphere became moist, a characteristic " Blue Haze " was produced.

If weather conditions were such that clouds were passing across the sun, the intensity of the haze varied very markedly with the light. Also, the denseness of the haze varied when viewed from different positions relative to the source of light. Even in a building approximately 60. ft by 30. ft, the haze can be made sufficiently dense to render it difficult to discern objects across the length of the building.

Sodium chloride was volatilized in a fume cupboard fitted with an outlet pipe passing through the wall into the open air. On a dry day the discharge into the air remained clear but on putting water vapour into the outlet " Blue Haze " was discharged. It was clearly demonstrated that the production of " Blue Haze " could be controlled at will by controlling the presence or absence of sodium chloride aerosols.

By volatilizing sodium chloride in a hood fitted with a pipe terminating near the top of the funnel of a steaming shore boiler " Blue Haze " was formed, and its presence or absence controlled by the presence or absence of sodium chloride aerosols to mix with the funnel gases.

Presence of Nuclei

It might be suggested that if " Blue Haze " is due to the presence of nuclei to act as a condensation medium, and as water vapour and solid particles are always being discharged from the funnel, this haze should always be present, except when there is sufficient wind to disperse the funnel gases, or rain to carry them down.

The particles which come from the funnel are not, however, as effective condensation nuclei as particles of sodium chloride, and being insoluble they do not attract or hold water vapour in the same manner as the hygroscopic sodium chloride nuclei.

Conclusion

Evidence points to an agent not produced by the ship being a necessary factor for haze formation, and such an agent must be supplied by the sea. It is an established fact that sodium chloride aerosols are, under certain weather conditions, present at sea and not visible to the eye. It is known that such aerosols will rapidly take up moisture when it is available, which causes them to increase in size and, becoming visible, form a mist.

This mist if formed by contact with the water vapour in the funnel gases would only do so some distance clear of the ship, and evidence shows that there is always a gap between the ship and this " Blue Haze."