FUNNEL FOG

BY

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During July and August 1950 while H.M.S. *Kenya* was operating off the West Coast of Korea between the 36 and 38 parallels, the phenomenon known during the Second World War as ' Blue Haze ' or ' Funnel Haze ' was recorded on many occasions.

Observations of sea, light, weather conditions, and humidity were taken and it is thought that the findings add something to the knowledge outlined in Vol. 3, No. 3 of the *Journal of Naval Engineering* in the two articles, ' Blue Haze ' by Wycliffe Killner R.N.S.S. and ' Aerosols ' by Instructor Lieutenant Commander J. R. Thorp, M.A., R.N.

Knowing what to expect from the information contained in these two articles and finding that observations, particularly of colour and height of formation, were sometimes so different from those reported in Mr. Killner's article, special care was taken in recording the details, and some examples of the types and positions of funnel fog experienced are contained in Table I. Whether a phenomenon is correctly described as a haze, mist or fog is dependent upon the limitation to visibility. The phenomenon referred to in this article is considered to be more correctly described as funnel fog.

Though the phenomenon had been observed previously it was a remarkable incident on 7th August that prompted a more thorough investigation. The ship was steaming with all boilers alight at 16 knots, the sea was calm, sky clear, bright sunshine, with a slight haze over the sea between the ship and the land. It had been noticed that this haze had been rising and falling during the forenoon and there was a clear gap between the sea and the lower edge of the haze.

At noon the ship passed a small rocky island, the top of which was enshrouded in mist, although there was no mist anywhere except farther inshore. The ship had no sooner passed to landward of the island than a very thick yellowish-white fog commenced to form in the wake of the funnel gases. The nearest description the writer can give is that it was very similar to a thick London fog.

Viewed from upper deck level it was seen to begin to form as whitish fog forward of the quarter deck at funnel height. Viewed from the bridge it appeared to form thickly 50 feet astern of the ship, spreading from funnel top height to the water ; this of course was due to the angle of sight—viewed from the quarterdeck there was a definite gap between the fog and the water until it was 400 yards astern of the ship, by which time it had dispersed thinly downwards. At 1205 the humidity on the quarterdeck was 83 per cent.

There was no trace of blue colour to the fog as viewed from the quarterdeck. As viewed from the bridge the only part one could possibly describe as blue was on the lower edge of the fog where it was thin and had the blue background of the sea.

At 1215 the ship turned 70° to port and a good beam view of this funnel fog bank was obtained. Viewed from this position the fog appeared thinner but still quite thick and was remaining along its original line of formation about two miles in length. Shortly after this the ship turned seaward again and the amount of funnel fog being produced gradually diminished as the humidity fell.

By 1230 the funnel fog had become comparatively thin and was only visible at funnel height ; below this there was no trace. By this time the relative humidity on the quarterdeck had fallen to 76 per cent.

It was then decided to record the humidity as near funnel-top height as possible, and readings at the after end of the bridge, which is level with the top of the after funnel, showed that the relative humidity was 83 per cent—a difference between upper deck (quarterdeck) and funnel top of 7 per cent.

The importance of recording the humidity at different levels was immediately apparent and it is estimated that at 1205, when the humidity at quarterdeck was 83 per cent, the relative humidity at funnel top was probably about 89 per cent.

Changes of Humidity

Experience has shown that humidity changed very rapidly at times in Korean waters and in five minutes there would sometimes be a change of four per cent or more in humidity, though all visible signs of sea, wind, and light remained the same.

When instances of funnel fog occur rapid and reliable readings are necessary and the wet and dry temperatures should always be taken with a whirling hygrometer. The fixed type of wet and dry hygrometer showed at times as much as a 10 per cent difference from that given by the whirling hygrometer.

Confirmation of Existing Information

The following information given in Mr. Killner's article was repeatedly confirmed :—

(*a*) Ship could not make it at will.

(*b*) Ship could not stop making it when present.

(*c*) Its position was influenced by any breeze.

(*d*) Light gives colour to the haze, to a certain extent.

Information not Confirmed

The following information was not confirmed :—

(*a*) It always appears at some 200–300 yards from the stern of the ship at a height well below the top of the funnel.

(*b*) It has been reported by all observers to be blue.

White or Yellowish-White Funnel Fog

The yellowish-white funnel fog was more noticeable when the sea was calm, humidity high, and the wind slight. It then formed astern, or on either quarter of the ship, on a steady line of bearing which had a cumulative effect. Even a slight fog would blot out a ship well astern but when viewed from the beam the fog was scarcely noticeable. A fog formed at 87 per cent humidity was very noticeable even when viewed on the beam.

It was thought that there must be occasions when the humidity at masthead height would be sufficiently high for funnel fog formation without forming fog below this level, though it was realized that it would not be practicable to measure the humidity at that height when such a condition existed. It was not until 29th August that an example of this was obtained and on 2nd September funnel fog forming above masthead height was experienced (Table I).

At 16 knots with a relative humidity above 82–83 per cent, funnel fog was formed quite readily, at 87 per cent it was thick. Against a blue sky very faint traces of funnel fog have even been observed where the humidity of the boiler

room fan intake and the air at funnel level have been as low as 72 per cent ; to a casual observer however this might not be noticed and it soon dissipated in the comparatively dry atmosphere.

The fog increases in intensity with increases in speed and it is considered that this is because the water vapour content leaving the funnel per distance run is increased.

Funnel fog has been noticed under auxiliary conditions in harbour on very humid days. Here there was little or no gap at the top of the funnel which presumably was because the velocity of the funnel gases was low. White funnel fog must not be confused with white smoke. White smoke is always visible with no gap at the top of the funnel. Humidity and boiler conditions need checking.

In *Kenya* the forward funnel top and the air intake to ' A ' boiler room were 8 ft and 22 ft above the after funnel and ' B ' boiler room intake respectively. Observations at sea showed that if the humidity was higher at bridge level than at ' B ' boiler room intake then there was a greater tendency for funnel fog to be formed from the forward funnel, and vice versa. Particularly in the evening when humidity tends to rise at sea-level, funnel fog was more noticeable from the after funnel.

Blue Colour

The only occasion when this fog was observed to have a bluish colour at sea was when the relative humidity was high near sea-level and the background, sea or sky, was dark. On dull days with a slightly broken surface to the sea it was bluer than at other times. If the relative humidity was low at funnel height and high at upper deck level then no trace of any fog forming over the quarter-deck was visible and it was not until the funnel gases had fallen about 300 yards astern of the ship that a bluish fog started to form. This was usually associated with at least a slight to moderate wind, which no doubt helps to produce a humid salt-laden atmosphere at a low level. The stronger the wind, the bigger the down draught and closer to the ship did this ' Blue Haze ' form.

These conditions are probably much more likely to be met in, say, Atlantic waters and may account to some extent for the large number of reports during the Second World War nearly always describing the colour as blue.

Temperature

Both air and sea temperatures appear to have little direct effect on fog formation, though indirectly they do because these factors decide the humidity and the height at which the most humid layer will form.

Causes of Funnel Fog

Formation of funnel fog appears to be due to a number of factors :—

(*a*) The water vapour content in the funnel gases (which is dependent upon the amount of fuel burnt and the humidity of the air supply) increasing the water vapour content in the air to saturation point or nearly so.

(*b*) Suspension of the products of combustion in the layer of highest humidity.

(*c*) Suspension of the products of combustion in a salt-laden atmosphere, when the characteristic ' Blue Haze ' is produced. On the other hand mists blown down from the hills by an off-shore wind often give ships inshore (against a dark background) a characteristic blue haze, which obviously cannot be caused by sodium chloride nuclei, but this is a ' haze ' and does not persist.

It may well be that in still atmospheres aerosols are lifted to great heights but are more limited in concentration and smaller in size than just above a disturbed sea. It is thought that possibly even in regions of high humidity these sodium chloride nuclei might still be sufficiently hygrostatic and sufficient in numbers to start fog formation when the water content is increased, without giving it a blue colour. Maybe it is started by a combination of nuclei in the funnel gases as well as sodium chloride nuclei when the humidity is very high.

Destroyers and other Small Ships

In the past ' Funnel Haze ' has only generally been associated with the larger ships. If this fog, for that is what it is, under certain conditions is largely caused by partial saturation of the water vapour content in the atmosphere by the water vapour in the funnel gases one may well ask, ' Why is it more often made by larger ships than by destroyers, and other small ships ' ?

It is considered that there are at least two factors which affect this, firstly, the amount of fuel burnt and air discharged by the boiler room fans per distance run is much greater for larger ships, and secondly most of these are fitted with preheaters or economizers which lower the temperature of discharge at the funnel top making fog formation easier. It is worth noting that this phenomenon was not observed before 1937 when preheaters for cruisers were becoming a general practice.

The writer can well remember when serving in H.M.S. *Newcastle* during convoy raiding exercises in the Atlantic in July 1938, in a disturbed sea, fairly high wind and slightly foggy conditions, that an objectional bluish-white ' smoke ' was made. No adjustments to the fuel burning arrangements could stop it except by lowering the air supply too much, when of course the colour changed to brown. This was the first cruiser in which the writer served which had preheaters fitted to all boilers. The significance of this incident was unfortunately not appreciated at the time. A considerable nuisance was the formation of a yellowish deposit on the forward side of the white stanchions when there was a large down draught from the funnels. It was considered that this was some sulphurous deposit from the funnel gases.

In atmospheres of high humidity in Korean waters destroyers following astern at 25 knots were observed making this yellowish-white funnel fog similar to but not as thick as *Kenya*, yet if the same destroyers took station on the beam of the cruiser scarcely any fog was visible. Whether such a funnel fog is visible from another ship will depend not so much on the light but whether it is being viewed along the line of its formation when, as mentioned before, the effect is cumulative. As destroyers usually operate on the beam of capital ships, no funnel fog would be visible from these ships unless the humidity is extremely high, though in atmospheres of high humidity one would occasionally expect a carrier to see it being made by her escort destroyer operating astern, during flying operations when high speeds were in use.

Boiler Trials Ashore

It is understood that the average relative humidity in England is 70–75 per cent. Funnel fog formation from shore boilers, particularly where the difference between funnel top and air intake levels may be great, would therefore only be observed on very rare occasions.

Forecast of Fog Formation

From these observations, if provided with the following information :—

(*a*) speed of the ship,

(*b*) strength and direction of wind relative to ship's head,

(*c*) relative humidity at different heights,

(*d*) state of sea,

(*e*) sky and cloud conditions and

(*f*) position of sun,

it became possible to forecast with a reasonable degree of accuracy whether funnel fog or ' Blue Haze ' would be made by H.M.S. *Kenya*, together with its position, strength, proximity to the ship, and its appearance as viewed from (*a*) bridge level and (*b*) quarterdeck level.

Position and Density of Funnel Fog Formation

With a calm sea, little wind, and clear sky the following is an approximate summary of the observations made :—

TABLE II

Humidity at upper deck	Humidity at funnel top	Funnel Fog	
		Colour and density	Position
High (above 83 per cent)	Low (below 75 per cent)	Greyish-white. Sometimes appears blue at the lower edge. Moderately thick.	Low lying, forming approximately 300 yards astern of ship. Funnels clear.
Low (below 75 per cent)	High (above 83 per cent)	Yellow-white. Very thick.	Could be seen forming just clear of the funnel top. Very concentrated astern of ship at funnel height.
High (above 83 per cent)	High (above 83 per cent)	Greyish-white tinged with yellow. Thick.	Could be seen forming just clear of funnel top. Thick at funnel height gradually spreading down to sea-level approximately 300 yards astern of ship.

ENGINEER-IN-CHIEF'S COMMENTS

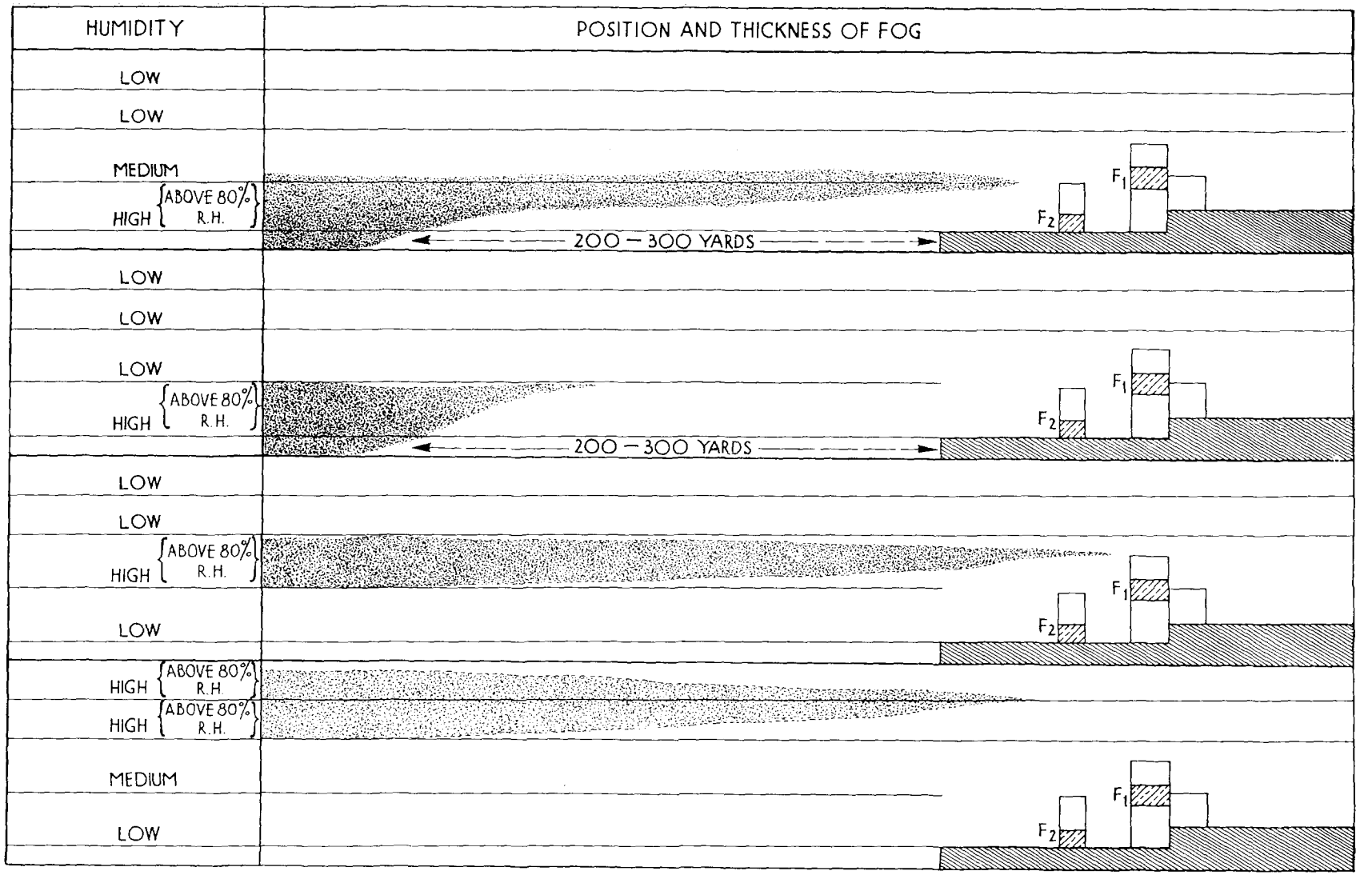
' Funnel Haze ' caused considerable controversy which has recently been resuscitated by Commander Smith's experiences off Korea in *Kenya*.

Several theories exist about the conditions and environment in which the haze forms. For instance :—

(*a*) Mr. Killner, A.F.E.S., has proved that a haze can be formed due to aerosols (minute particles of sodium chloride) in the air, extending above the sea, and allowing condensation of the super-saturated vapour under pressure and temperature conditions provided by the funnel gases.

(*b*) Then we have the purely vapour trail produced by aircraft, and *towed objects* where pressure and temperature conditions akin to funnel gases are not present, but the cause is still connected with the condensation of super-saturated vapour.

Date. Time.			7–8–50. 1205.	7–8–50. 1230.	7–8–50. 1300.	8–8–50. 1700.	9–8–50. 0930.	29–8–50. 0915.	1–9–50. 0845.	2–9–50. 1750.
Sun.			Green 85°. Altitude 64½°.	Green 45°.	Ahead.	Green 90°. Behind cloud.	Red 30°.	Red 30°.	Not visible.	Green 90°.
Sky.			Clear. Landward haze.	Clear. Landward haze.	Clear. Landward haze.	Dull. Cloudy in patches, clear overhead.	Clear. Bright.	Clear. Bright.	Heavy cloud. Black rain clouds on horizon astern.	Clear. Bright.
Wind.			Starboard bow. Very slight.	Ahead. Very slight.	Port bow. Very slight.	Starboard bow. Slight.	Port bow. Very slight.	Port bow. Very slight.	Red 80°. Moderate.	Green 90°. Very slight.
Sea.			Flat calm.	Flat calm.	Flat calm.	Slightly disturbed.	Calm.	Calm.	Slight 'white horses' just forming.	Calm.
Speed.			16 knots.	16 knots.	16 knots.	16 knots.	16·5 knots.	16·5 knots.	16·5 knots.	24 knots.
Funnel.			Clear. Fog beginning to form just abaft funnel.	Clear. Faint fog forming just abaft funnel.	Clear.	Clear.	Clear. Faint fog forming abaft funnel.	Clear. Fog forming above funnel.	Clear.	Clear. Fog forming above at masthead height.
Bridge.	Air temperature wet		Not taken.	77°F.	77°F.	78°F.	78°F.	70°F.	70·5°F.	73·5°F.
	Air temperature dry		Not taken.	81°F.	82°F.	82°F.	82°F.	74°F.	74·5°F.	79°F.
	Relative humidity.		89 per cent estimtd.	83 per cent.	79 per cent.	83 per cent.	83 per cent.	81 per cent.	81 per cent.	76 per cent.
Quarter-deck.	Air temperature wet		78°F.	77°F.	77°F.	78°F.	78°F.	72°F.	70°F.	75·5°F.
	Air temperature dry		82°F.	83°F.	83°F.	81°F.	81°F.	76°F.	74°F.	82°F.
	Relative humidity.		83 per cent.	76 per cent.	76 per cent.	87 per cent.	87 per cent.	82 per cent.	81 per cent.	73 per cent.
Funnel fog.	Density.	Sea-level.	Very thin.	Nil.	Nil.	Moderately thick. Dispersed.	Moderately thick.	Nil.	Thin. Dispersed.	Nil.
		Funnel top level.	Very thick.	Thin.	Very faint from quarterdeck. Not visible from bridge.	Thin.	Thin.	Very thin.	Thin. (Seen from quarterdeck.) Not visible from bridge	Nil.
		Masthead height.	Thin.	Nil.	Nil.	Nil.	Very thin.	Moderately thick.	Nil.	Thin. Moderately thick above masthead height.
	Colour.		Yellowish-white.	Greyish-white, slight trace of yellow.	White.	Blue at sea-level. Greyish-white above.	Greyish-white tinged with yellow.	Yellowish-white.	Bluish-white.	Yellowish-white.
	Position.		Port quarter.	Astern.	Starbd quarter.	Port quarter.	Starbd quarter.	Starbd quarter.	Starbd quarter.	Port quarter.
Remarks.			Thick fog forming just clear of after end of quarterdeck at funnel height. Clearly visible forming over quarterdeck.	Faint fog visible forming at funnel height over quarterdeck.		Faint fog visible forming over quarterdeck at funnel height. Moderately thick 300 yards astern at sea-level	Faint fog visible forming over quarterdeck at funnel height. Thick 300 yards astern at sea-level.	Thin fog visible over quarterdeck at masthead height.	No fog visible forming over ship. Cloudy overhead. Fog visible 400–500 yards astern of ship.	Fog visible forming above funnel at masthead height. Moderately thick abreast qurtrdeck. Thicker when



FUNNEL FOG FORMATIONS

(*a*) F1 and F2—Boiler Room Intakes (*c*) Ship at Cruising Speed

(*c*) Again, we have the most recent and perhaps the biggest step forward in Commander Smith's observation in which he established *beyond all doubt* that the relative humidity of the air does play a principal part, but, and here lies the prime difference to past observations, the relative humidity at *funnel height* is the deciding factor ; in the past the observations have been made at deck level. Commander Smith tried both and found very different conditions at funnel height.

(*d*) With the knowledge of (*c*) comes a renewed interest in the effect of sulphur in the fuel, i.e., hypo-sulphurous acid will fume like the ' haze.' An extremely interesting subject, which is being ' played at ' by the R.N.S.S.

AUTHOR'S REPLY

I much appreciate the Engineer-in-Chief's comments but I would like to elaborate a little on the reference to relative humidity at *funnel height*. My findings were that it was important to take the humidity readings at *different* levels. The thickness of the fog and level at which it formed was dependent upon at least three principal factors—the relative humidity at the boiler room air intake, the level of the layer of maximum relative humidity in the atmosphere, and the path of the gases after they leave the funnel. Sometimes the funnel gases rise and sometimes they fall dependent upon the speed of the ship, shape of the funnel, prevailing atmospheric conditions, and speed and direction of wind. The figure illustrates a few conditions. Another point which should not be overlooked in examining the reasons why the question of relative humidity had not previously been considered a principal factor, is that not only were readings apparently taken during the Second World War at quarterdeck level but they were probably taken with the fixed type of hygrometer, which my experience showed tended to lag behind the actual conditions, and the best way of recording accurate and quick readings was with the whirling hygrometer (supplied only to medical officers). It is understood that even this hygrometer is now obsolescent but I have not yet been able to find what instrument is replacing it.

One interesting physiological aspect was that the writer, while suffering from a mild attack of ' prickly heat,' noticed that his body acted as a form of human hygrometer. It was found that skin irritation caused by this annoying complaint was considerably increased by a rise of humidity at sea-level. On experiencing this increased irritation the writer went on deck on more than one occasion to find that funnel fog had started to form where previously there had been none.

Paragraph (*d*) of the Engineer-in-Chief's comments is most interesting, for the colour of the fog at times and the yellowish deposits on ship's stanchion, etc., have suggested the possible effect of sulphur in the fuel. If this fog is partly caused by the presence of the oxides of sulphur in the products of combustion under conditions of high humidity, it raises an interesting point in connection with the formation of ' smog '. The description of the funnel fog experienced on the 7th August, 1950 as being like a thick ' London fog ' was made in 1950, i.e., two years before the great London ' pea-souper ' which gave rise to the word ' smog.' In other words, ' smog ' may be partly produced—without smoke—like funnel fog and in any case as the products of combustion from whatever source, such as furnaces, household fires, motor vehicular traffic, steam locomotives, etc., will tend to lie in the layer of highest humidity, smoke abatement is not the sole answer to the lethal effects of ' smog ', it must also be combined with ' fume abatement ' which is a much more difficult problem.