Brian J.Smith AIMarEST, MIDGTE

Quality Monitoring Instruments Ltd.

&

Dr M H Holness PhD, C Chem, FRSC, M Inst Pet.

Oil Mist Detection In The Atmosphere Of The Machine Rooms

New regulations for atmospheric oil mist detection

BIOGRAPHIES

Brian J.Smith

Brian Smith, Managing Director of Quality Monitoring Instruments Limited has been involved with the development and selling of oil mist detection systems over the last twenty-one years. In the forefront of instrument design since the 1960's, he was approached in 1982 to develop equipment to overcome various problems inherent in oil mist detection systems. This became his main objective and he has since developed systems not only to overcome the difficulties associated with measurement within engines, but in other hazardous areas where information about oil mist is vital. He has given lectures all over the world on the subject. In 1997 his company was given a Highly Commended for Contribution to Safety at Sea Award for the design of an atmospheric detector to monitor the build up of oil mist in machine room spaces.

Presented with the Akroyd Stuart Award in 2001 for a paper given to The Institution of Diesel and Gas Turbine Engineers.

Dr M H Holness

Dr Malcolm Holness is now retired but worked from 1964 until 1995 with Admiralty Oil Laboratories specialising in matters connected with the use of petroleum products on board ships. Since that time he has served on many investigating committees where oil mist has been the contributing factor of these fires. He was also the main investigator for some major gearbox explosions caused by oil mist. Now he is responsible for running his own consultancy known as Petrohaz.

SYNOPSIS

You may be aware MCA and IMO, together with other Societies, are very concerned about the number of fires that start in machine room spaces. Figures produced suggest that up to 65% of machine room fires are the result of oil mist. Now IMO have published a circular No.MSC1086 June 2003 to try and overcome this problem.

BURNING OF LIQUID FUELS

Liquid fuels do not burn as liquid, they burn only as vapour. Inevitably, the conversion from liquid to vapour must require the input of some energy. This can be provided by compression in an engine or with a hot surface, a spark or a flame.

Outside of an engine or boiler, oil products not usually regarded as "fuel", may also burn under uncontrolled conditions producing a fire or explosion. Fuel from an injector, under pressure, may escape as a jet or spray so that it can reach a hot surface. At this point it will vaporise and form a cloud of vapour expanding away from the heat. As the vapour moves away from the surface, it cools and re-condenses, forming a cloud of fine mist droplets. During this time, the droplets of fuel near to the hot surface may reach a sufficiently high temperature for spontaneous ignition to occur and, after a delay period, the whole mist cloud becomes ignited. Similarly, hydraulic oil from a high-pressure line will follow the same mechanism if it contacts a hot surface. The same process can take place inside machinery if a mechanical failure occurs creating a high temperature.

PROPERTIES OF OIL DROPLETS

There is general agreement on the hazardous nature of oil mists and, unless we are considering volatile fuels whose vapour concentration in the atmosphere is sufficient to be flammable, the production and properties of mist in machinery spaces must be of prime concern. Fuel oils, lubricants and hydraulic oils can all become flammable via their mist, even though they are comparatively non-volatile liquids and have flash points higher than normal temperatures.

Droplets are more flammable than the bulk liquid because of the higher surface to volume ratio of the liquid. Thus, the droplet is more sensitive to heat input from potential ignition sources and more surface is in contact with oxygen in the air. The smaller the droplet and the lower the minimum ignition energy the more closely it resembles a vapour.

It is useful to consider droplets in three categories according to size. First, very small droplets (less than 1 μm); these are usually referred to as "smoke", they tend to appear blue in colour and are produced when oil is in contact with extremely hot surfaces (greater than about 800 degree C). Secondly, droplets in the size range 1 - 10 μm, described as "mist"; these appear white and are produced at surfaces between 200 degree C and 600 degree C. Finally, droplets greater than about 50 μm, described as "spray", which is produced mechanically (e.g. from a pinhole leak in a pressure line). It should be pointed out that the above categories are deliberately described in approximate terms and not all workers would necessarily accept all of the figures.

In practical terms we must consider the mists and sprays as the most important contributors to fire since less extreme conditions are required to produce them and they are, therefore, more likely to be present than smoke.

FIRES IN MACHINERY COMPARTMENTS

In the case of fires in machinery compartments where fuels, hydraulic oils and lubricants are supposed to be properly contained, the initial step must be the escape of oil. A second step is the contact between the oil and a heat source. There are, of course, numerous ways in which a fuel or oil leak may occur. Pipework which is subject to vibration (e.g. fuel lines to injectors) is a common source of oil escape) (3). In this case also the leakage may be near to hot components and be more likely to generate mist leading to ignition. High-pressure hydraulic Pipework, particularly if flexible hoses are in use, can produce finely atomised sprays, that can travel significant distances in a machinery space with the chance of contacting hot components. Overfilling of fuel systems, particularly during bunkering, is a common cause of fuel contacting high temperature areas.

The contribution to the fire hazards in machinery spaces of liquid fuels, lubricants and hydraulic oils can be considered as relying principally on the ease, or otherwise, of the generation of droplets in the atmosphere. This report will now concentrate on the properties of oil mists and sprays and how they behave in machinery space atmospheres.

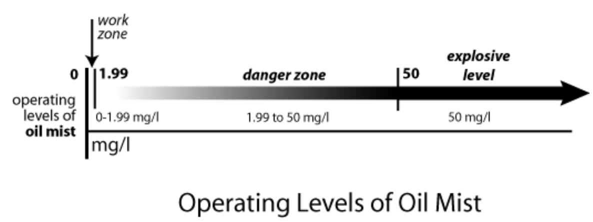
Protection of Compressors and Pumps

OIL DROPS IN THE ATMOSPHERE

As mentioned before, energy must be used to create a mist or spray from the bulk liquid. The distinction between mist and spray is only in the droplet size, although more energy is required to form a mist and its minimum ignition energy is lower than that of a spray.

A lower flammable limit mixture (50 mg/l) of oil mist of droplet diameter of (say) 3 μm would contain about 44×1015 droplets per litre. A 30 μm droplet diameter spray would contain about 44×1012 droplets per litre, at the same mass concentration. From this it follows that an oil mist at the lower flammable limit (LFL) is extremely dense optically. In fact, a 100W light bulb would be obscured at a distance of only a few centimetres. Mists of this kind have the properties of a meteorological fog, both optically and physically. The mist flows along a gravity or thermal gradient and persists in still air. As in the case of a meteorological fog, oil mists give rise to a disorientating effect to personnel present, or trapped, in the vicinity. The results of this alone can be extremely hazardous, often with fatal results.

Although spray has some of these properties, its obscuration effect is less and its rate of settlement is much greater. The minimum ignition energy of sprays is much higher than mist but the lower flammable limit by mass is lower than for mist (1,4). When a mist is ignited, the flame travels from drop to drop and, because the drops are small, each drop is consumed in the flame front, its energy going to sustain and accelerate the flame. The array of drops in a spray behaves somewhat differently from a mist. The drops are comparatively large and, although the flame, again, travels from drop to drop, not all of each drop is consumed. The surface layers of oil are burnt, leaving the core and, because the inter-drop distance is large, the flame "jumps" from drop to drop, leaving some oxygen in the air and some oil drops un-reacted. The concept of a clearly defined lower flammable limit thus breaks down. The fact remains that, with a sufficiently energetic ignition source, it is possible for a flame to propagate through a spray at lower mass concentrations than with a mist. While generally agreed figures cannot be ascribed to the LFL for sprays, the presence of spray in the atmosphere must be treated with alarm since it must be at least a potential fire hazard.



Operating Levels of Oil Mist

DETECTION OF OIL MIST

Having established that oil droplets, both mist and spray, present a potential fire hazard, it is necessary to decide how to recognise the presence of droplets and how to act thereafter. The installation of oil mist detectors to monitor the interior of crankcases and gear case is a well-established concept. As already stated above, LFL data for mists is widely accepted and methods are available for calibrating equipment using "standard" concentrations of thermally generated oil mist.

Equipment is on the market, which can be so calibrated. High quality oil mist detectors

(OMDs), manufactured by Quality Monitoring Instruments Ltd can discriminate between the large amount of large droplet spray and splashes of oil, which is always present in such machinery, and the mist, which is produced only in the event of a failure. This thermally generated mist can, if no action is taken, lead on rapidly to a devastating explosion. It is therefore necessary for the OMD to respond rapidly and to transmit a signal to the Machinery Control Room, where it can be used to trigger alarms, shutdown sequences or extinguishing systems. It should be appreciated that the thermally generated mist must have been produced at a component, which has become unusually hot. This is frequently a bearing or some other over-stressed component. If vulnerable components are adequately monitored, the onset of a high temperature can be detected and the consequent generation of mist can be avoided. Not every component can be so monitored, however, and the use of one or more OMDs with their larger "field of view" is essential. Thus it can be appreciated that a crankcase or gear case monitoring system should comprise both OMDs and temperature sensors, coupled to appropriate software and control equipment. The situation in the machinery space, external to the crankcase and gear case, is quite different.

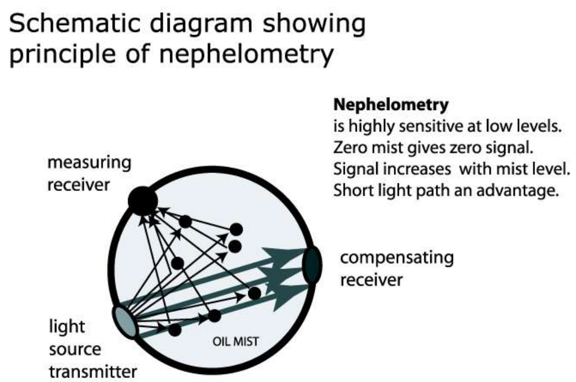
Detection in Main Engine Room

Here we have an atmosphere, which is expected to be substantially free from contamination; combustible liquids should all be safely contained in Pipework. However, there are a number of identifiable hot spots and the intention should be to keep the two separate. Should a leak, or burst, occur, droplets of oil may enter the atmosphere and may contact a hot surface. The provision of an OMD in the machinery space could detect the presence of oil drops before the oil contacted the hot zone. There are, however some important differences in the conditions.

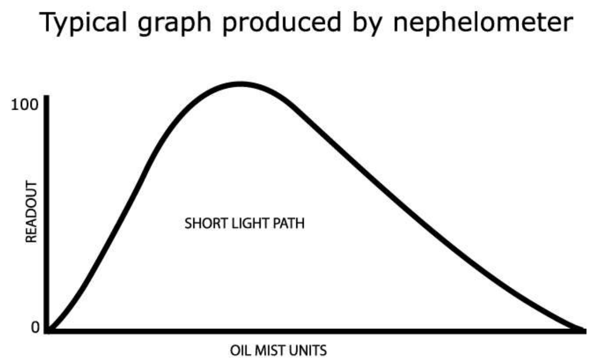
Acoustic Turbine Housing

In particular, the droplets are probably an order of magnitude larger than in a thermal mist, their sedimentation rate will also be greater. An OMD must therefore respond to these larger drops, and more rapidly. As mentioned above, the concept of a precise LFL cannot be applied to large drops, but the presence of oil mist where a clear atmosphere is expected should be sufficient to trigger an alarm. The detailed design of a machinery space OMD needs to be different from a crankcase OMD, since the former must observe all droplets while the latter must respond selectively to the fine mist droplets.

Their optical effects can observe oil droplets in the atmosphere. The effect of droplets on a beam of transmitted light is twofold. Some of the light is transmitted unaffected, and can be observed by a detector, and some is intercepted by the droplets. Of the light intercepted, the droplets absorb some but most is scattered away from the detector.



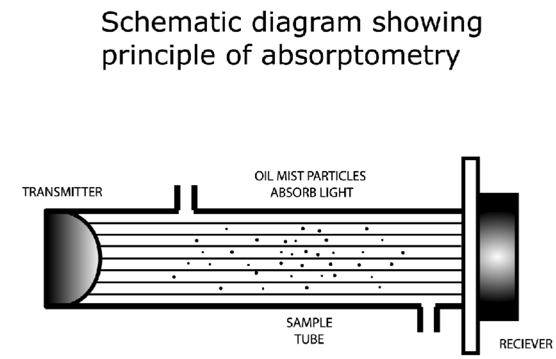
Schematic Diagram showing principle of Nephelometry



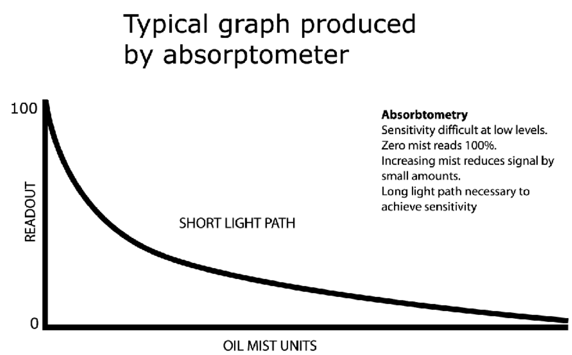
Typical graph produced by Nephelometer

Thus two methods of optical measurement are available absorbed by the droplets but most is scattered away from the detector. Thus two methods of optical measurement are available. We can measure the loss of signal in a detector placed in line with the light emitter or we can place a detector at an angle at which scattered radiation can be observed. In the first case the signal strength will decrease with increasing mist concentration and, in the second case an increase in signal is produced. An added feature of the scattering detector is that the angle of scatters changes with droplet size so that the detection angle must be chosen carefully.

Detectors using one or other of these principles are on the market. A major disadvantage of the obscuration OMD is that, if a detector or emitter should fail, no signal is observed, which may be interpreted as an oil mist alarm. The scattering OMD should always produce a positive signal except in a totally clear atmosphere; again failure of a detector or emitter would give no signal in the presence of mist.



Schematic digram showing principle of absorptometry



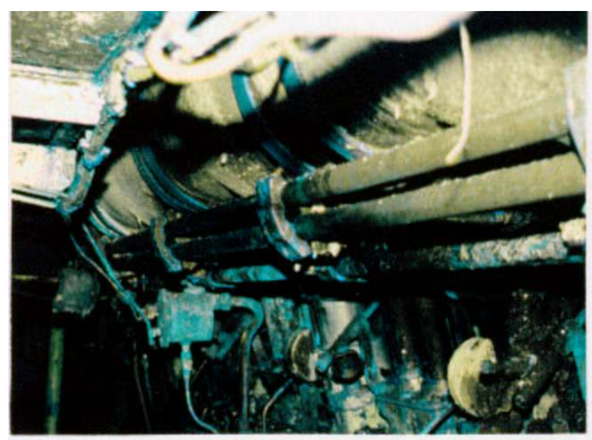
Typical graph produced by absorptometer

However, a further feature of the scattering OMD produced by Quality Monitoring Instruments Ltd is the provision of a second detector in line with the emitter, so that emitter failure, or dirt on the lenses, can be sensed. These basic features can be used for an OMD whether inside a crankcase or in the open machinery space. However, inside a crankcase, or gearbox, some provision must be made to avoid the effects of the large amounts of oil normally present. In some commercial instruments this is achieved by the use of lengthy pipe runs to the detector heads. This protects the detector from the large drops but also allows some of the fine mist to become trapped on the pipe walls. The lengthy Pipework also introduces an unacceptable delay in response during which a major failure could occur. The Quality Monitoring Instruments Ltd OMD achieves discrimination in favour of fine mist droplets by the use of a labyrinth, which is effective in trapping the large drops and returning them to the crankcase. Inclusion of this labyrinth allows the detector head to be placed very close to the atmosphere being monitored so that response time is greatly improved.

OMDs for the open machinery space do not require the labyrinth since it is necessary to "see" all the droplets in the air whatever their source. Quality Monitoring Instruments Ltd has now produced a specially designed OMD for machinery space monitoring. This embodies the principles described above and can be coupled to the same master multiplexing unit as the crankcase or gear case detectors so that all the possible hazard areas of a ship or industrial installation can be monitored continuously with rapid remedial response as necessary.

CLASSIC OIL MIST FIRE

In May 1998 there was an horrendous fire on board HMAS Westralia where from a small beginning and incorrect installation an oil mist fire occurred which ended up with 4 machine room personnel being killed.



Fire damage.

Taken from the Report of the Board of Inquiry into the fire in HMAS Westralia on 5 May 1998

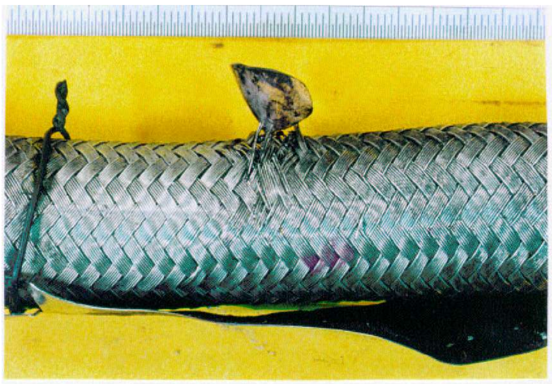
“9.5 Statistics contained in the IMO document show that 50 percent of MMS fires originate from the low pressure fuel system piping and fittings. Other sources of MMS fires originating in the fuel system include:

a. High pressure fuel piping (10 per cent);

b. Slack fractured or removed studs/bolts (7 per cent);

c. Loose/unscrewed or fractured bleed cocks, screws or valves (7 per cent);

d.Miscellaneous/undetermined fuel leaks (7 per cent)."



Cause of the fire

Here we have a typical example of what can happen when things go wrong. To see the whole report go to www.navy.gov.au/publication which will gives you an idea of the cost of this disaster. See the figure below taken from this report.

Then there is the case of the bulk carrier picture earlier in the paper where two engineers were working on the pump and forgot to fully tighten up a connector. Oil mist streamed towards the Turbo Charger, which then ignited the mist. The result , two dead engineers. Both of these accidents would more than likely never happened if they had oil mist detection systems installed

We would add the bulk carrier now has installed our detection system and also on the sister ships.

CAUSES OF FIRE BY OIL MIST

Sources of the mist

- Leaking injectors
- Fractured flexible hoses
- Loose or incorrectly fitted pipe fittings
- Broken welds
- Poor maintenance of machinery and Pipework

Causes of ignition

- Exhaust pipes
- Turbochargers
- Non-flameproof motor
- Electrical contacts
- Static electric
- Faulty wiring

SUMMARY

The processes that lead to fires and explosions involving oil products on board ship and in other large complex machinery installations are well known.

Except in the case of very volatile products or gases, the generation of oil mist is the essential prerequisite for the formation of a flammable condition.

Oil mist generated inside machinery must be distinguished from general oil spray, which, in this context can be regarded as innocuous. In the open machinery space, oil mist or spray of any droplet size must be treated as a potential fire risk.

Equipment is currently available, notably that manufactured by Quality Monitoring Instruments Ltd, which can be relied on to help detect mist and to trigger remedial measures rapidly.

RECOMMENDATION

The history of fire in large industrial installations, and in particular on board ship, clearly demonstrates that sensible warning and remedial measures are essential. The loss of life and material losses that have occurred and the fact that the causes and progress of fires and explosions involving oil products in these installations are well known and understood demand that atmosphere monitoring equipment is introduced.

While it is recognised that improvements in construction and materials are constantly being introduced, the human element is always a major influence. Monitoring equipment, for conditions, which may lead to fires, is available.

Always remember the old adage "There is no smoke without fire". Now it is possible to try to protect against a fire there being no need to wait for smoke to give a warning. In other words, you can help stop a fire before it starts.

REFERENCES

Walker, Harvey J. “Oil Mist Monitoring in the Atmosphere” *Scandanavian Shipping Gazette,* October 2004

Holness, Malcolm “Oil Mist & Machinery Room Space Fires”, *Marine Technology* Vol 39 No 1, Jan 2002

Iwamoto, Masaru Etel “ClassNK – Fire Risk in Machine in the Engine Room” *MER,* Dec 1994

Royal Australian Navy,”HMAS Westralia Board of Inquiry Report”, May 1998

Holness, Malcolm, “Oil Mist in Machine Room Space Fires”, *SNAME,* New York May 1999

“Regulations are plentiful but do they address every conceivable Fire Scenario”, *MER,* March 1997

Beck, Bill & Brian Mattherson of MSA “Three Essentials for a Safe Engine Room”, *MER* June 1995

“Fuel Vapour can be an Unseen Hazard”, *MER* March 1997

IMO Circular 1086 “Code of Practice for Atmospheric Oil Mist Detection”, *IMO,* June 2003