THE CONSEQUENCES OF NOT MAINTAINING DUCTWORK CLEANLINESS

BY

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ABSTRACT

The author has been involved with ventilation system design and manufacturing from the time that he entered HM Royal Dockyard Devonport in 1962. He gained practical experience of fabricating ductwork during his time spent in 81 Shop as an apprentice. He became a Shipwright Liner on completion of his apprenticeship and was responsible for the "carding" of ventilation systems that were subsequently fitted into the carrier HMS Ark Royal refitted at Devonport circa 1967. He also spent a number of years in the Devonport Design Division working on compartment layouts to include the integration of the ventilation systems. Whilst serving with DG Ships in 1994 he took up the appointment of Equipment Project Team Leader for Heating Ventilation & Air-conditioning (HVAC), he was responsible for the introduction of textile ventilation into RN service. He continued to manage this specialist area of business until his retirement from the MoD in 2006. The author is currently the HVAC Project Coordinator with Wellman Defence Ltd (WDL) who is responsible for providing Submarine Atmosphere Purification (SAP) equipment and support to the Royal Navy. WDL is also the focal point provider for a number of partnered specialist companies that form "Team HVAC" serving the Royal Navy and other navies within NATO. The company has a worldwide reputation of excellence in this specialist field.

INTRODUCTION

A great deal has been written on the need to maintain ventilation ductwork and whole system cleanliness, many of those papers will have majored on one or more of the three main consequential effects if this work is not routinely carried out that will inevitably give rise to problems that could otherwise be avoided, they are: severe loss of system efficiency, reduced crew efficiency through poor personnel well being and ship and crew safety.

This paper seeks to inform the reader of the salient issues that should be taken into account such as taking due consideration of the need to design for system maintenance and support. There is also a need to regularly conduct operator and maintainer education to include onboard practical training. By undertaking these functions potential problems highlighted in this paper can be avoided. The author has in the main drawn upon his experiences within the Naval Warship sector to include RFA's however; much of the contents can also be related to the wider Marine environment and indeed the Civil Engineering industry. It is worthy to note at this point that ship HVAC system cleanliness within the commercial marine sector has become markedly improved in recent years. This situation was brought about by the introduction of much needed cleanliness legislation that inevitably required a significant financial investment in HVAC system hygiene by the specialist operators. As a direct consequence of the need to comply with these cleanliness standards a number of reputable specialist companies have developed the required equipment technology and processes to survey and clean all types of ductwork and their associated air treatment units. These companies offer a wide range of hygiene services that are principally focussed on the commercial passenger fleet and consequently they have become very well acquainted with the need to deliver an efficient and capable service often to extremely tight turnaround times. Indeed some of the cleaning systems employed today create the absolute minimum of disruption and are capable of being operated on systems whilst ships staff undertakes their normal daily duties.

The Naval Warship sector can and should take full advantage of this technology so as to ensure that deep system cleaning is properly and efficiently carried out on a regular basis. Professional examination and cleaning of HVAC systems should be conducted routinely. If this work is not carried out then it is likely that system efficiency will deteriorate to unacceptable levels and perhaps more importantly ships staff health and wellbeing may be adversely affected.

DISCUSSION

Air that is supplied to or being extracted from a ship and also air that is being recirculated within a ship by the ventilation and air conditioning systems will invariably contain a large number of impurities. These impurities or airborne contaminates are identified as having two basic sources, those which are naturally produced and those that are man made. Humans are undoubtedly responsible for the largest proportion of contaminates such as fumes, oxides, mist and dust that may include oil, grease, soot from the uptakes, also ash and smoke. Other impurities and contaminates originating from within the platform include odours and bacteria. Dust from internal sources is largely fibrous from clothing and bedding but may also be produced from tissue paper, cosmetics not to mention skin and hair shed by people. Ironically cleaning materials and deodorants also play their part. Dirt carried inboard on clothing and shoes will further compound the problem, add to this, natural impurities such as salt rich particles, sand and bacteria and it will be realised that maintaining an acceptable standard of ship husbandry and HVAC system cleanliness can be very challenging.

All of these impurities when allowed to build up within the ventilation system will collectively reduce the efficiency of the ventilation systems by clogging inlets and becoming attached to heaters, cooling coils and vanes, fan impellors and the internal surfaces of the ducting. The build up will initially be slow but will start to accelerate when organisms and particulate have been able to become attach to the surfaces providing an excellent key for larger particles and organisms. This situation invariably leads to what is commonly known as "graceful degradation" that will lead to "accelerated degradation" of system design performance. The consequence are that the degradation will inevitably impact on reduced air-conditioning capability since heaters and coolers will not have their surfaces in direct contact with air flow and so temperature exchange will be reduced. This situation can affect performance of electronic equipment often causing it to trip out due to the lack of cooling capacity within a compartment, particularly when operating in extreme tropical conditions. The lack of compartment conditioning may also impact on operator efficiency.

Having addressed the dust or particulate aspect of the problem it is worth pointing out at this juncture that poor cleanliness will inevitably encourage spores to also become attached to any internal build up that exists since the dirt within a system will act as a nutrient for microbiological growth. Spores are generally mould or fungi that gain entry via doors and poorly fitted filters at system inlets. Once a microbial growth has been established it becomes very difficult to remove using traditional cleaning methods. This type of contamination has the potential to pose health problems and general crew discomfort such as a sore throat. When a number of ships staff suffer persistent flue or cold symptoms it is often a good indicator that the air quality is poor and therefore worthy of a HVAC system examination.

Following a period of growth close to the inlet the spores will be distributed further into the ducting and will have the potential to spread throughout the whole platform, the most common types of mould are not particularly harmful but have the potential to play host to virulent fungi, bacteria and viruses which can present a greater health risk. It should be stated at this point that as far as the author is aware, to date no Legionella have been detected on any of the cruise ships or indeed in any other platforms surveyed and cleaned by any of the reputable specialist companies. There is however, no place for complacency since this does not necessarily mean that it is not present but merely indicates that it has not to date been found. All of the leading specialist cleaning companies are committed to looking for and examining contaminate samples following a survey to establish where there is the potential of risk to health.

Microbial contamination can be prevented, it has been established that microbial growth is actively encouraged where the relative humidity (RH) is allowed to exceed 80% in a system. It is also very important to ensure that efficient ventilation filtration is provided for the influent air. The design, correct installation and regular maintenance of the correct type of filter(s) will ensure that the air quality is delivered to a consistent and acceptable standard.

During the last decade higher cleanliness standards have been achieved within some selected compartments that have been fitted with Textile ventilation systems. The textile ducting or "socks" are permeable and so provide a second line filtration by passing the air through the material into the compartment, there are many different "bleed rates" and hence levels of filtration that are determined by the weave. Textile ventilation has a number of other advantages that have been previously addressed in an Engineering Journal paper[1].

It is essential that the maintainer recognises and becomes familiar with the rate of filter soiling or build up that will determine the required periodicity for cleaning or replacement of filters. It is also important for the maintainer to understand that this periodicity will further reduce as the system performance degrades during long periods of operational deployment. The system maintainer should be able to recognise that more frequent maintenance coupled with reduced system efficiency will make a particular system and it's associated ATU a prime candidate for a deep professional cleaning at some point in the near future.

CONVENTIONAL FILTRATION

Effective husbandry must be carried out on a regular basis to avoid this scenario occurring otherwise the systems if allowed to deteriorate will undoubtedly become detrimental to the health and the well being of ships staff. To combat this situation air will invariably be filtered, however, since maximum filter efficiency depends on designed face velocity of the filter then the regular cleaning of filters is essential, unfortunately this does not always get the necessary attention. Particle loading will gracefully degrade the filter efficiency to a point where airflow can become non-existent on occasions without ships staff recognising that it has occurred.

On one occasion when the author was visiting a Type 23 frigate many years ago he entered into dialogue with a Petty Officer regarding filter cleanliness in the operations room. The author had observed that the compartment recirculation filters were in very good condition having been it seemed regularly cleaned and properly refitted. The PO was duly praised for his diligence where upon he responded by saying that the regular cleaning of the compartment filters did not present a problem, he simply removed the filter turned the membrane over and refitted it so that the airflow then cleaned the dirt off what was now the back face! Needless to say the author was less impressed with the PO when informed of this "initiative" and rapidly educated the offender to the consequences of his actions. This true situation supports the need to ensure that such key personnel are properly trained and educated.

Particulate or dust filters are invariably fitted:

- At all fresh air-supply intakes usually at the NBC Air Filtration Unit (AFU) locations. Generally these filters are two stage commonly known as Pre-particulate and Particulate, the pre-particulate filters are designed to capture large particles and are often washable. The particulate filter is deigned to capture smaller air-borne particles, primarily Biological contaminates;

- At the inlet side of the Air treatment Unit (ATU) to capture particles returned by the re-circulating air from the compartments that are being served, this filter is invariably washable;

- At the recirculating ducting inlet within the compartment, these are panel type filters that are easily removed for regular cleaning. Both dust and odour filters are fitted to all bathroom exhausts (for totally air-conditioned systems [TACS] i.e. systems not discharged to ambient) platforms.

Other filters that will be fitted in specific locations are:

- Grease filters over galley fryers and ranges;

- Lint filters fitted in laundries;
- Flameproof gauzes in battery charging room exhaust systems.

In all instances where filters and gauzes are used it is essential that they are correctly fitted otherwise dust particles will inevitably bypass the filter since airflow will always follow the path of least resistance. It should be noted that since the change in smoking policy, tobacco smoke filters are no longer fitted and those that were have invariably been removed from platforms.

ULTRA-VIOLET FILTRATION

One extremely efficient method of dramatically reducing the number of germs and bacteria is by fitting Ultra-violet (UV) filtration. A trial carried out in the late 1990's by the Canadians established that by fitting UV lamps in a factory air conditioning ducted system both bacteria and fungi had been virtually eliminated. It was also established that a 20% drop in work related illness commonly known as "sick building syndrome" was achieved. Whilst this technology was new to the HVAC industry at that time UV had been around since the 1940's and often used in hospitals to kill off bacteria and disinfect the air. In simplistic terms UV germicidal irradiation works by breaking down the DNA strands of the bacteria and the viruses, this action prevents them from breeding and so kills them off.

Not so long ago UV filtration technology was considered to be very expensive to fit and was not therefore considered as a replacement for those technologies that already exist such as HEPA filters that have a capability of 99% efficiency. More recently UV technology has developed to a point where it is significantly cheaper to use whereas most conventional filters of any type have markedly increased in costs since the materials used in their manufacture has risen considerably. There is no mechanical resistance with UV filters and so the motive power required [fan unit] for moving the air can be reduced. Conventional filters invariably require periodic replacement and so it can readily be seen that UV offers the potential to deliver considerable through life savings.

COMBUSTION IN DUCTING

The most significant of consequences must be the risk of fire that may occur within a ships HVAC system. Regardless of severity, such an incident will always be of major concern to the crew since fighting a blaze will become the sole responsibility of those on board who will have been appropriately trained to deal with such a situation. Rarely is the crew in a position to call on external emergency agencies to assist in dealing with such an incident. The residual effects of extinguishing a fire will be dependant on the severity. The incident may also have a detrimental effect on the platform operational ability possibly through smoke and water damage to vital systems and equipment, in the extreme stability may be compromised having been brought about by flooding and the free surface effect of water moving across the deck.

Although ductwork fires are not the primary cause of incidents on platforms, ducting can easily provide the opportunity for such fires to spread rapidly throughout the ship and when this happens may prove to be very difficult to extinguish through lack of accessibility. When a duct is poorly maintained, deposits of flammable material accumulate within. Fire dampers can also become encrusted so instead of preventing the spread of fire they may contribute to the fire spreading often to inaccessible areas such as ceiling voids.

Traditional cleaning methods for ducting are invariably restricted to easily accessible areas even though contracts are placed to clean the entire system. This is of particular concern for galley systems where fat deposits in the form of carryover will coat the ducting down stream from the steam hoods and grease filters. It is worthy to note at this point that trials conducted by the Civil Engineering Industry at the building research laboratories at Bracknell have shown that any excess of more than 500 microns has the potential to initiate a fire within the ventilation ducting.

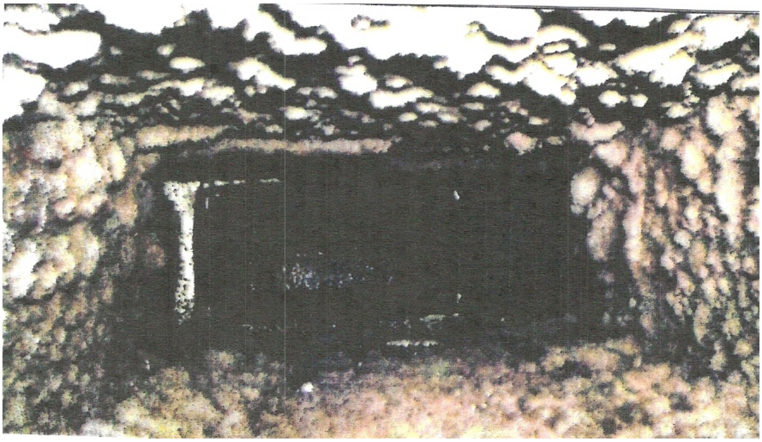

FIG.1 – GALLEY DUCTING – SHOWING BUILD-UP OF GREASE DEPOSITS DOWN STREAM OF THE GREASE FILTER

Most ventilation ducting fires occur in galley exhaust systems, whilst grease filters and emergency shut-down flaps are fitted they will continue to remain the most vulnerable of HVAC systems since the presence of high fat content and the subsequent carry over causes deposits to build up very quickly. In these systems high standards of husbandry are essential to prevent any risk of fire and also ensure that hygiene standards are properly maintained. Whilst this may seem obvious to the reader other systems in close proximity to the galley that take the re-circulated air back from compartments such as Dining Halls to the Air treatment Unit or indeed dedicated to exhausting gases and vapours to ambient can also have the potential to be vulnerable and therefore high risk fire or explosion hazards.

In the same way that a domestic vacuum in the home collects dust generated by people so the recirculation or ventilation exhaust system within a platform will collect and transfer particles through the ducting and eventually back into the Air treatment Unit (ATU).

The photograph provided below readily demonstrates how growth has been allowed to build in the upstream ducting through lack of cleaning due to restricted access past the fan unit, whilst the down stream section of ducting is relatively clear of build-up having been easily accessed and cleaned. This situation will inevitably reduce fan efficiency and therefore degrade the airflow. High levels of contamination can also adversely affect the impellor balance of the fan unit that may cause the bearings to fail prematurely.

The airflow is also likely to be turbulent in such circumstances and so increased noise can be expected.

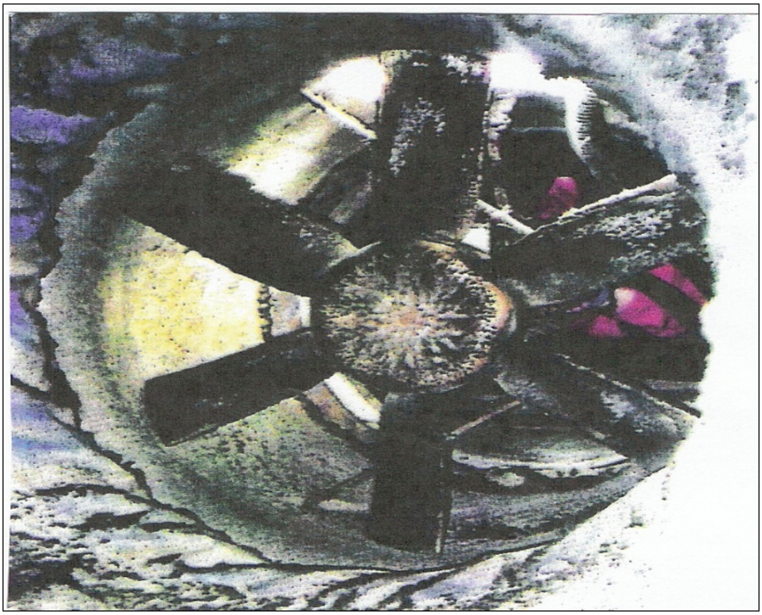

FIG.2 – BUILD-UP OF DEPOSITS ADJACENT TO AN AXIAL FLOW FAN

CONCLUSION

Neglecting to effectively carry out the routine maintenance of HVAC systems is not acceptable since contamination in ducting can dramatically increase the through life cost by compromising equipment efficiency and affecting the health of ships staff. These issues can further impact on platform operational efficiency.

Reduced airflow will also directly impact on plant efficiency leading to increased energy consumption and reduced working life. Inevitably equipment will be subjected to a greater workload than originally designed for leading to accelerated wear. Such equipments are frequently operated beyond their intended loading capacity in an attempt to compensate for the lack in system efficiency.

RECOMMENDATION

Where airflow measurements are found to be significantly below the system design and commissioning data then the first action must be to establish the extent of degradation and hence the required level of cleaning necessary to return the system to the original design performance. The most effective way to achieve this is to engage one of the many reputable specialist companies that will conduct a survey to establish the level and type of contamination. The survey will then be followed by a professional clean of the system which does not need to be a disruptive activity since modern cleaning methods now use state of the art technology that can accomplish this work during fleet time.

Wellman Defence Ltd are able to provide independent assistance in identifying the most appropriate technology and hence contractor to use for a given system problem. The impartial advice will ensure that the most appropriate companies are identified to undertake the necessary work.

References

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[1] Journal of Naval Engineering Vol 40, Dec 2002, page 488.