THE DESIGN, DEVELOPMENT AND PROCUREMENT FOR TEXTILE VENTILATION IN WARSHIPS

BY

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ABSTRACT

MAES5B is the Design Authority in respect of NBC Filtration and HVAC for the Royal Navy. The Equipment Project team has recently completed a programme of development work to provide a cost effective, efficient and quiet alternative air supply system to the fleet. The development and trials work has ensured that the system delivered can be fitted at build. It is also able to supplement or replace existing systems to improve efficiency and reduce through life costs. The development and introduction into service of textile ducting has provided the opportunity to redress unacceptably poor conditions and deliver real savings at the same time as meeting future RN environmental requirements.

The History of Ship Ventilation Systems

History has well documented the lack of fresh air between decks; on the early 'man o war' slow clearance of spent powder on the gun decks severely restricted the crew's ability to efficiently reload and consequently vessels suffered greatly as the result of relatively slow rates of fire. Personal injuries were often attributed to the lack of vision and hence peripheral awareness. ADMIRAL LORD NELSON made reference on several occasions in his diary to the lack of fresh air below decks and the effect on his men. With the advent of steam the problem increased and eventually 'stovepipes' were fitted at the bow and stern to provide a supply and extraction system which utilized the ships forward motion to provide a ram effect. It was not until 1912 that the first ventilation fans were fitted into a warship.

Ventilation systems became more sophisticated incorporating chilled water coils, moisture eliminators, and heaters until the arrangements evolved into the present Total Air-Conditioned Systems (TACS) with passageway recirculation that we have in today's modern warship.

The ongoing development of ventilation systems has seen many improvements, however, one element of the system that has not appreciably changed to date is the supply ducting medium which has remained solid and secured to the deckhead by means of hangers often heavily insulated with cork or an alternative material. Conventional systems may be natural or mechanical supply but all have air terminals delivering the air into the compartments through grills or louvers at set points along the trunking.

The Introduction of Textile Ventilation to the RN Fleet

With the change in the political climate around the globe, the role of the Royal Navy has by necessity become more flexible. Ships built to operate in specific waters are now expected to perform as part of a global multinational task force and therefore deploy for long periods anywhere in the world. Vessels are required to operate for extended periods in climates that are environmentally very different from those envisaged by the original operational requirement. Add to this situation the changes in technology and the need for increased capability that may result in the requirement to fit additional equipment and hence create greater wild heat generation. This situation may lead to poor equipment reliability and also adversely affect operator maintainer efficiency. Latent heat produced by ship's staff engaged in operating and maintaining the systems is another contributory factor.

It will be appreciated that ventilation systems designed and installed at build to meet the required standards will gracefully degrade in efficiency through life unless they are regularly cleaned and properly maintained. Add to this situation the demands associated with ever increasing cooling loads and it will be readily seen that there is a need for greater system efficiency that will be capable of totally or partially replacing conventional ventilation ducting to achieve the revised performance requirements.

It was at a commercial HVAC exhibition that the writer first became aware of a system of flexible ducting manufactured from textile. Textile ducting has been used in the food and pharmaceutical industries throughout Europe for many years and is known to perform particularly well in sub zero temperatures e.g. in the cold storage application. Although the product has a proven track record it had not been used in the confines of a warship, nor had the materials been subjected to the rigors of MoD fire and toxicity testing.

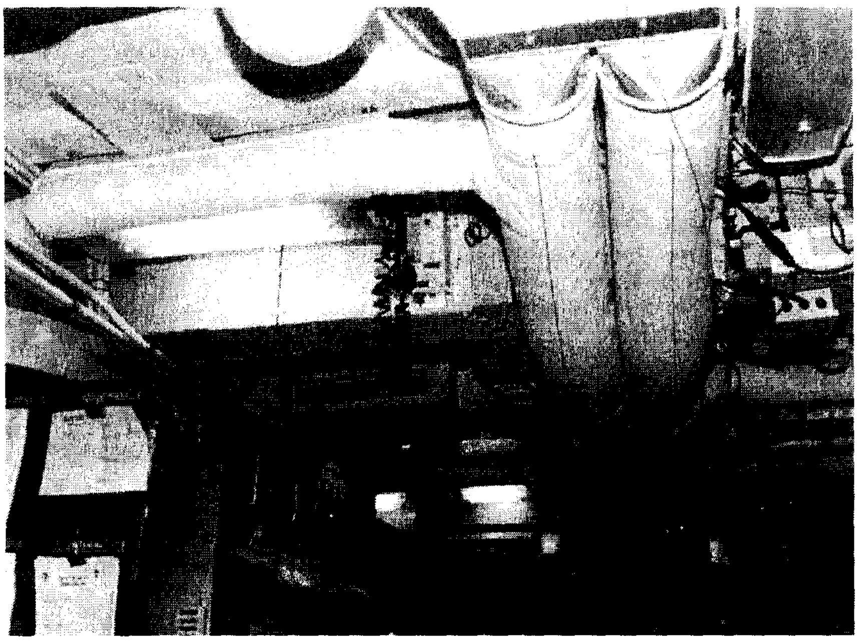


FIG. 1 - TYPICAL TEXTILE UPGRADE INSTALLATION WHERE TRADITIONAL DUCTING COULD NOT BE INSTALLED – HMS FEARLESS OPERATIONS ROOM

MAES5B implemented a programme of work with industry to develop a system suitable for installation in both surface warships and submarines. A system of flexible textile ductwork widely used in the commercial land based application has been adapted for use in naval and other marine applications. The first fit of this unique system was successfully installed on an operational warship of the Royal Navy in 1996 (HMS *Fearless*' Operations Room and MCO (FIGS.1 & 2)).

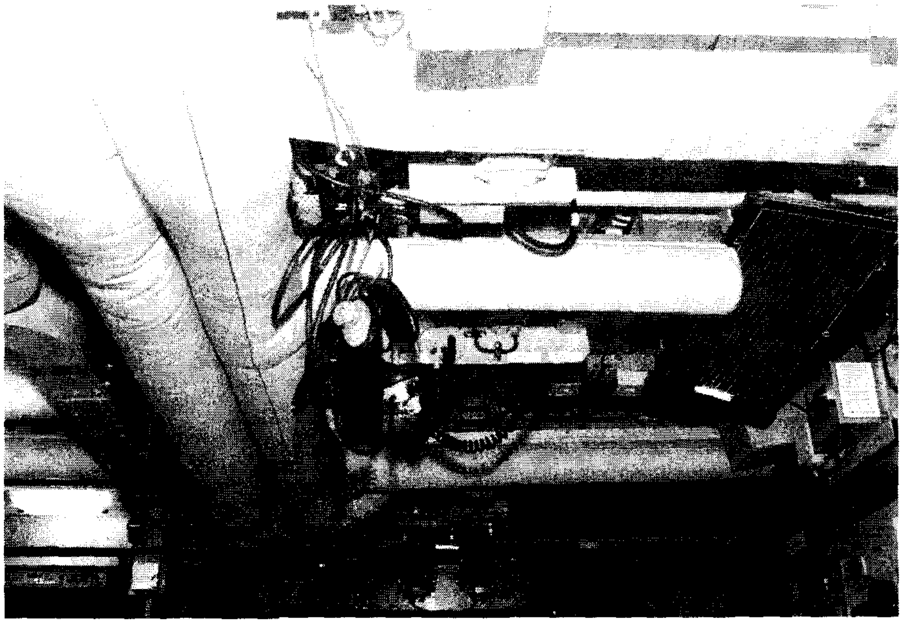


FIG.2 – HMS FEARLESS MCO

Textile ventilation systems designed for the warships application consist of a flexible, loose weave; fire retardant material ducting that replaces or supplements the traditional ductwork in a compartment. It is a highly efficient air distribution system, which still requires the air to be transferred from the fan to the compartment by conventional ducting. The textile is 100% synthetic, manufactured from a flame-retardant material known as Nomex.

Conventional supply ducting will have a number of outlet points either of the directional round eyeball type or louver grills. This arrangement leads to localized hot and cold spots within a compartment. Textile ducting however 'bleeds' over the total surface area giving an even temperature distribution throughout the compartment served.

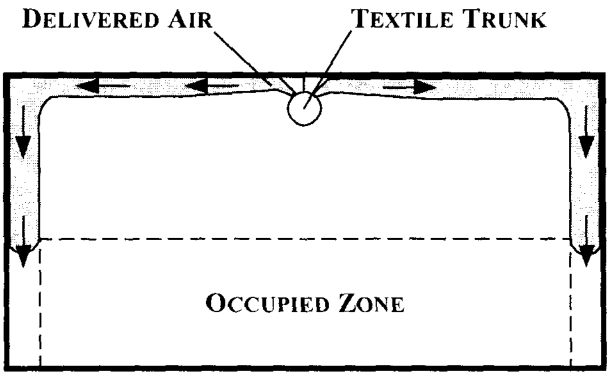
Textile ducting materials including those used for the securing arrangements must pass the fire and toxicity tests for the submarine application. The most commonly used material for textile ducting is a polyester material known as Trevira CS. Fire test results for these materials are provided in Table.1 below.

TABLE.1 – Results of fire tests on fabrics used for textile ducting

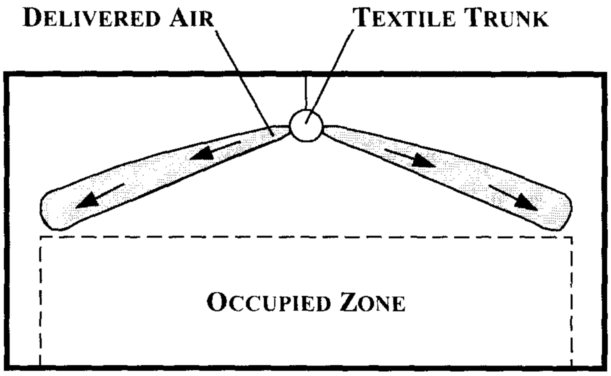
Test	Toxicity index NES 713	Smoke index NES 711	Oxygen index BS 2782:pt 1	Temp index BS 2782:pt	Lassaigne Test
Acceptance criteria	<50	<50	>30	>200°C	
Trevira	9.0	0.5/100g	35.8%	Sample burnt for 15 secs below 230°C	No nitrogen sulphur or halogens detected
Nomex	1.6	2.0/100g	44.5%	>350°C	Nitrogen sulphur or halogens detected

The Trevira material disintegrated on exposure to flame during the NES 711 test and as such was not considered acceptable in large quantities for submarine use. Nomex thread is categorized class 5 in BR 1326A with no restrictions on its use.

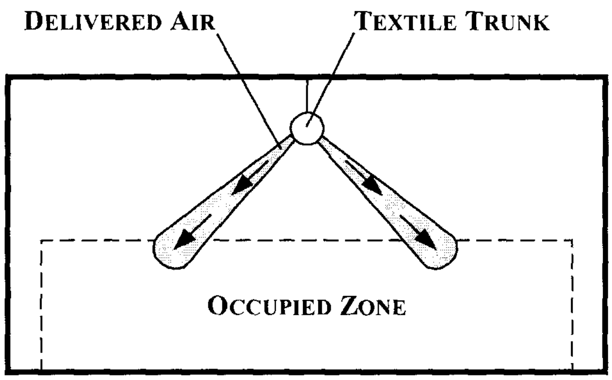
Textile systems normally rely on the air passing through the top section of the textile ducting and moving along the ceiling until the velocity reduces enough to allow the cool air to fall. This design philosophy relies on the distance below the ducting to the deck to be greater than 3 metres so that air mixing can be properly achieved. Equipment fitted to the deckhead of a modern warship combined with the low deckhead height nominally 2.0 meters breaks up the airflow preventing this effect. The flow configuration will be dependent on the relative temperature difference between the delivered air and the temperature in the compartment (FIG.3).



FLOW MODEL 1 – DELIVERY OF COOLED AIR OR HEATED AIR



FLOW MODEL 2: – DELIVERY OF UNDERCOOLED OR SLIGHTLY HEATED AIR



FLOW MODEL 3 – DELIVERY OF HEATED AIR

To be able to design efficient systems for the warship application it became necessary to understand the characteristics of the airflow and derive some basic rules. To better understand the airflow characteristics a number of tests were carried out with various system configurations. It was observed that the system became self-balancing, even when branches were removed or reconfigured. It was also noted that there was no impact on the fan characteristics and consequently the fan unit could not be stalled as a consequence of change. The second observation was that stability in the system was velocity dependent, if the velocity in any given section exceeds 18m/sec then the duct would start to vibrate. It was deduced that the air velocity within the duct determined the flow rate and therefore the dynamic energy was in some way converted to static energy creating a change in air direction and subsequent 'bleed' through the wall. This change from dynamic to static energy can be observed in a straight system with no branches. It can be seen that approximately the first third of the duct is hard (high rate of exchange between dynamic and static) the second third softer (equal dynamic to static) and the final third hard (high static low dynamic). Previously it had been thought that the bleed was dependent purely on the static pressure. Further testing with materials of different weave showed differing levels of developed static pressure. As the result of these trials it became apparent that the coarseness of the cloth weave impacted on the conversion of dynamic to static energy by virtue of friction.

Because air bleeds through the actual material (and warships use ambient air which carries dust particles) it does get dirty and can eventually clog. One of the advantages of textile ducting is that it can be washed in a domestic washing machine, however, to maintain efficiency cleaning intervals need to be in the order of annual planned maintenance. In an effort to extend planned maintenance a section of material with a larger weave was stitched into the length of the duct and has been termed 'the slot'. As the pores in the main duct block up so the static pressure within the duct increases, this increase in pressure forces the air through the larger pores therefore keeping that section relatively clean. The slot can be sized to deliver the required number of air changes when the main duct is dirty. Since the slot is of relatively small surface area it will give a higher velocity and may therefore create a draught, this however, should signal the need for the ducting to be removed and cleaned. The slot can also be incorporated into the textile ducting to deliver air to a specific compartment location or equipment.

An efficient system design for a typical compartment will achieve a flow through the ducting that is able to provide the compartment design airflow at a bleed velocity, which allows the air to mix within the available height. These requirements are met by varying the ratio of duct sizes to volume and therefore the air velocity with the available static air pressure and slot width combined with the porosity provided by the weave of the material or combination of the materials used. If the design and installation is correct then the airflow through the ducting will dissipate at an even velocity providing the required number of air changes with very little air movement being apparent.

Initially, textile ducting was seen as a means to supplement existing compartment systems that could be easily installed and or reconfigured. As the development programme progressed it became clear that this was only one of a number of advantages, which could be delivered through the introduction of textile ducting.

Upgrading or reconfiguring existing systems

This allows ducting configuration changes within a compartment, which could not be easily achieved with conventional ducting.

Safety

Because the ducting is cloth and full of air it poses no threat if it extends below head height. The flexibility of the material, combined with low deckhead height, is no longer a painful reminder of being on board a ship!

Weight Reduction

The total weight of textile ducting including the support system is in the order of 10% of conventionally lagged ducting.

Shock

When subjected to shock textile ducting will collapse and then re-inflate, there is no requirement for structural shock clearances. Textile ducting can be run through top staying if required with no adverse effect to the shock mount characteristics (See FIG.4).

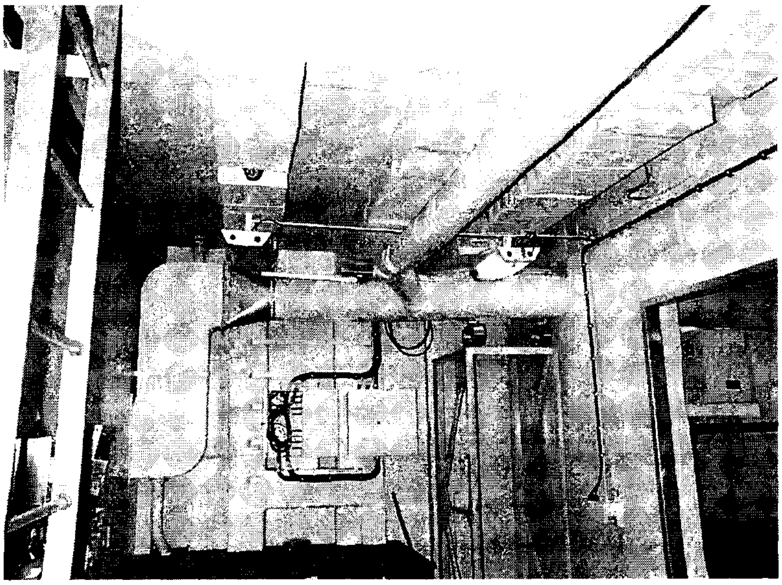


FIG.4 – TEXTILE DUCTING IN CLOSE PROXIMITY TO RESILIENT MOUNTS - CVS

Noise

Textile ducting has two advantages regarding noise; firstly the cloth is a noise absorbent material and secondly since there are no grills fitted, regenerated noise is completely eliminated. Trials have proven that a 5db reduction in ventilation noise can be achieved within compartments fitted with textile ventilation trunking (Fig.5).

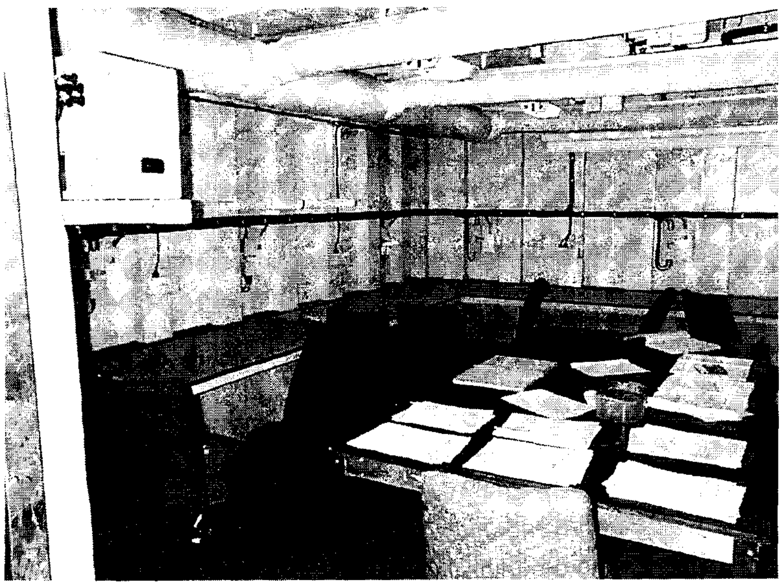


FIG.5 – TYPICAL TEXTILE INSTALLATION IN A QUIET COMPARTMENT – CVS

Maintenance and Cleaning

Unlike cleaning of conventional trunking with its associated bends, splitters and changes of shape, cleaning the textile ducting is simple. Jointed with zippers, sections can be removed and cleaned by washing in a domestic washing machine. A spare system set may be carried on board to replace those sections that are frequently cleaned by ship staff. As a consequence of good husbandry air quality will significantly improve since the trunking provides second line filtration to maintain air quality and therefore compliment crew efficiency.

System balancing

Because the system is self-balancing the only installation testing required is to measure airflow at the point of entry into the compartment. This eliminates most of the balancing and hence orifice plates which need only be fitted where a system passes through the bulkhead into the compartment thus making the system simpler and further reducing installation cost.

Capital Cost

The cost of new textile ducting per unit length is approximately 25% of that for conventional ducting it is therefore cost effective to provide a spare system set to allow for regular cleaning whilst operational.

Installation Cost

Installation costs are approximately 10% of that for conventional ductwork.

Where compartment layouts are required to change and equipment's re-positioned, so can the textile trunking system be reconfigured to ensure that an efficient ventilation system is installed. Such system modifications can be accommodated with little effort.

Refits and Upkeep Periods

The removal and replacement of conventional ducting during refit or repair periods is costly and time consuming. Textile trunking offers a cost effective alternative solution. In particular where the removal during subsequent upkeep periods to access soft patches and shipping routes may be required.

Through life costs

Through life costs in respect of textile systems are very low when compared with the costs associated with the maintenance of conventional ducting. The maintenance costs attributed to the cleaning, painting and re-insulating of conventional trunking are considerable.

Design Considerations

The conditions within ships compartments can be accurately controlled and therefore become part of an automatic control system. Improving the distribution of air also benefits ship personnel and their working efficiency.

Installing textile ducting is one part of a solution to combat excessive heat in compartments and does not entirely solve the problem. When surveying a compartment under consideration for textile ventilation, the total system requirement must be considered. The problem, and therefore the solution, has three elements, they are:

1. To ensure that the correct amount of air is available to provide the required number of air changes necessary to maintain a stable temperature within the compartment.
2. To ensure that air is supplied to the compartment at the correct temperature in order to maintain the required design temperature.
3. To ensure that air can be distributed efficiently within the compartment.

Textile ducting addresses the air distribution element; all three elements must therefore be reviewed simultaneously. Experience has shown that there is a different solution to each application requiring any combination of the three elements. The initial task is to determine the requirements in airflow and temperature. Design data or measurements of actual airflow and supply air temperature can then be established. This will determine if uprated fans or cooling coils are required but in most cases they will invariably prove to be adequate. Finally, a design for the distribution of air by textile ducting can be undertaken.

TABLE 2 – *Cost comparison for the installation of systems in a warship.*

System	Material costs £K	Manufacturing costs £K	Installation costs £K	Approximate Total cost £K	Equivalent man hours
Main propulsion	820	132	594	1546	22000
Cables	1160	1100	465	2725	47000
HP/LP air	860	825	2178	3863	91000
Chilled Water System	2060	660	1947	4667	79000
FW/SW cooling	2939	1023	1947	5909	90000
Hydraulic System	1565	1254	3498	6317	144000
Ventilation System	1549	495	6402	8446	209000

From the table above it can be seen that ventilation is one of the most expensive systems to install in a modern warship. It becomes very apparent that the installation costs are disproportional to material and manufacturing costs. Significant savings can be made on installation by using textile ducting even though at present it can only be used as a distribution system. Research is continuing to find a material suitable for transferring the air from the fan to the compartment, which will further drive down the system cost.

Textile systems are currently in service on a number of RN Ships and Submarines as well as a number of US Navy Surface Platforms Table.3. RN installations have been introduced into service and supported by UK procurement specialists through the Warship Support Agency, MAES IPT.

TABLE 3 – *Installation List*

Ship	Area
T.S. *Hindostan*	Classroom
HMS *Fearless* (LPD)	Operations Room and MCO
HMS *Trafalgar* (SSN)	WT Office and JCO
HMS *Talent* (SSN)	WT Office
HMS *Triumph* (SSN)	WT Office
HMS *Tireless* (SSN)	WT Office
HMS *Torbay* (SSN)	WT Office
HMS *Trenchant* (SSN)	WT Office
HMS *Turbulent* (SSN)	WT Office and JCO
HMS *Splendid* (SSN)	JCO
HMS *Chatham*	CPO's Mess
HMS *Cumberland*	CPO's Mess
HMS *Kent*	Operations Room and Annex
RMAS Newton	Main Hold
US Navy	
USS *Bridge* (LPD)	Operations Room
USS *Roosevelt* (NIMITZ class aircraft carrier)	Primary Flight Control
USS *Truman* (NIMITZ class aircraft carrier)	Primary Flight Control
USS *Iowa* (NIMITZ class aircraft carrier	Primary Flight Control