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ASBESTOS DUST CONCENTRATIONS IN SHIP REPAIRING: A PRACTICAL APPROACH TO IMPROVING ASBESTOS HYGIENE IN NAVAL DOCKYARDS

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Abstract—A survey of the asbestos fibre concentrations associated with work involving asbestos insulating materials has been undertaken in Devonport Dockyard. The results show that application and removal of asbestos materials both create high dust concentrations, and measures to reduce the health hazards associated with such processes are described. The results of sampling after the introduction of preventive measures are briefly presented and these results indicate that the precautions are effective in reducing the asbestos dust concentrations in shipyard insulation processes.

There have been few published reports on asbestos dust concentrations occurring in the shipbuilding and shiprepairing industry despite the increasing interest in the health hazards associated with asbestos. The present paper is part of an extensive study of the hazards associated with asbestos in Devonport Dockyard (HARRIES, 1970).

THE USE OF ASBESTOS IN NAVAL DOCKYARDS

Amosite, chrysotile and crocidolite asbestos have been used in insulating materials for Naval ships since about 1880. Large amounts of high efficiency insulants have been required to keep pace with progressive ship design, and airborne asbestos dust has been liberated whenever these materials have been applied or removed. From 1940 to 1963 environmental insulation was applied mainly in the form of asbestos sprayed onto deckheads and bulkheads. Most of the asbestos for this purpose was crocidolite, but some amosite was also used. Pipes and machinery have been insulated with moulded sections containing from 15–90 per cent amosite asbestos. These fragile sections were covered with a protective layer of chrysotile asbestos cloth. During refit periods large amounts of sprayed environmental insulation, and often all machinery insulation were ripped out to facilitate modernisation and repair of the ships. There are many other uses of asbestos, and some of these will be described later.

Because the full extent of the hazard associated with asbestos was not appreciated, adequate preventive measures were not introduced into Naval Dockyards until 1967. Variable amounts of asbestos debris were left scattered about the ships for most of the refit periods (sometimes up to 3 yr), because there was no defined procedure for clearing it away. As a result very large numbers of men have been exposed to asbestos dust by working with or near other men who were applying or removing asbestos materials, or because they were themselves disturbing asbestos debris and creating their own local dust clouds.

Energetic measures have now been taken by the Ministry of Defence (Navy) to reduce the hazards associated with asbestos in Naval Dockyards and these have been described by HARRIES (1968, 1970), and by the MINISTRY OF DEFENCE (NAVY) (1970). This report describes the dust concentrations associated with the use of asbestos materials, and the improvements that have been brought about by the recent preventive methods.

METHODS

Dust sampling survey

Sampling was planned in an attempt to give some idea of dust concentrations likely to have been present in the ships over the last 25 yr. The revision of design specifications, as well as substitution to reduce the dust hazard, made it necessary to take the bulk of these samples in ships containing the old materials in order to give some idea of past conditions. The opportunity to do this occurred in an aircraft carrier and a cruiser in 1967. The samples during other processes, especially the application of insulation, have been taken in destroyers and frigates, as well as in the larger vessels so as to give an idea of present working conditions.

Sampling methods

The membrane filter method of sampling and evaluation described by HOLMES (1965) was used for this survey. Millipore type GA 20 and 25 mm membrane filters, pore size 0·45 μm were used in Gelman sampling heads, and air was drawn through them by using Hunt personal samplers (HUNT and ELLISON, 1963), Austen–Dymax diaphragm pumps, or Dräger hand pumps. The Hunt samplers run at a flow rate of 11·3 ml/min, and the Austen–Dymax pumps at 200 ml/min. Both were calibrated with a suitable Rotameter flow meter. The Hunt samplers were worn by men to give an estimate of personal exposure, or were placed alongside long-running gravimetric samplers to provide an estimate of the fibre content of the dust; sampling lasted over a working shift. Austen–Dymax pumps were used to take shorter samples. A comparison between the results of gravimetric sampling and fibre counting is the subject of a separate report.

Many samples were taken with Dräger hand pumps to obtain 200–2000 ml samples. The disadvantages of small, quick samples are recognised, but it is considered that these are valuable as a method of indicating the fluctuation in the local dust concentrations of various processes. The samples were taken in the general environment as well as in the breathing zone of the workers. Small samples are also useful in showing the change in dust concentrations at varying distances or the rate of change after work has stopped. These methods now form the basis of dust monitoring to be used in Naval Dockyards.

The method of fixing the samples, clearing the membrane and the counting technique has been fully described by HOLMES (1965). The samples were counted under phase contrast microscopy at ×400 magnification. Fibres were counted 5–100 μm in length with an aspect ratio of 3 : 1 or over.

RESULTS OF SAMPLING

Sprayed asbestos insulation

No results for spraying are available from the present study because the process ceased in 1963. Records of dust sampling during spraying in 1951 show asbestos fibre counts of 173–322 fibres/cm³ (fibres 2–10 μm length only) and 3121–5957 particles/cm³ of other dusts (particles 0·5–5 μm dia.). This was obviously a most hazardous operation.

The results shown in Table 1 are the concentrations found during the removal of

TABLE 1. ASBESTOS DUST CONCENTRATIONS DURING REMOVAL OF SPRAYED CROCIDOLITE ASBESTOS

	Sample location				
	Aircraft hangar	Adjacent areas	Small compartments	Adjacent areas	Sweeping and bagging debris
Mean concentration, fibres/cm³	334·0	56·5	219·9	82·6	353·0
Range	117–484	19–131	35–384	43–177	213–493
Number of samples	5	4	15	4	2

sprayed crocidolite asbestos from the deckheads and bulkheads of an aircraft carrier. Sampling periods were for 1–2 hr of the working shift as the samples were too dense to count if the sampler was run for the whole shift. Very high concentrations (> 200 fibres/cm³) occurred at the stripping areas, slightly lower concentrations (mean > 50 fibres/cm³) were recorded for rooms and passageways adjacent to the stripping zone. Sweeping and bagging debris created mean concentrations of 353 fibres/cm³, but small samples taken with the Dräger hand pump in the breathing zones of men bagging crocidolite debris showed concentrations of 1000–2000 fibres/cm³.

The widespread dispersion of dust throughout the ship is seen from the results in Table 2. Long running samples showed the dust concentration at the top of a ladder running up from the stripping area to the deck above to be 109 fibres/cm³ and at the top of the next ladder two decks above the stripping area the concentration was

TABLE 2. ASBESTOS DUST CONCENTRATION ASSOCIATED WITH REMOVAL OF SPRAYED CROCIDOLITE ASBESTOS

	Sample location					
	7 Deck stripping area	Hatchway 6 deck leading from 7 deck	Hatchway 5 deck leading from 6 deck	Passageway to shower	Removing suits after shower	Workmen's dining room
Concentration, fibres/cm³	311	109	30	25	16	0·05

Long-running Hunt samplers were used.

30 fibres/cm^3. This shows the importance of sealing off large parts of the ship when this work is being done and allowing access only to those men wearing adequate respiratory protection.

Special facilities for washing, changing and eating were available on the ship for these men. The results in Table 2 show that although showering when wearing special impervious overalls did not fully remove the fine dust, after the men had removed the contaminated clothing and entered their dining room the dust levels they were exposed to were below 0·1 fibre/cm^3.

Removal of pipe and machinery insulation

Long running samples were taken with Hunt samplers during the removal of pipe lagging in engine rooms and boiler rooms of aircraft carriers, cruisers and frigates. The materials removed included pipe sections of 90 per cent amosite asbestos, sections of calcium silicate and 15 per cent asbestos, asbestos cloth and cement. Samples were also taken in small compartments, the brick stowage space for example, to show the effect of removing large amounts of insulation in a small confined space. General atmosphere samples were taken at convenient points in the compartment near gravimetric samplers, and breathing zone samples were taken as near as possible to the men's faces. The results in Table 3 show higher mean general sample levels in

TABLE 3. ASBESTOS DUST CONCENTRATIONS DURING REMOVAL OF PIPE AND MACHINERY LAGGING

Location	General atmosphere			Breathing zone		
	No of samples	Mean, fibres/cm^3	Range	No of samples	Mean, fibres/cm^3	Range
Boiler rooms	153	171	0·04–1062	20	97	25–220
Engine rooms	45	88	0·16–3021	25	91	2–490
Brick stowage space	13	257	9–592	—	—	—

boiler rooms (171 fibres/cm^3) than engine rooms (88 fibres/cm^3) but similar breathing zone levels in boiler rooms and engine rooms (91–97 fibres/cm^3). This is because there is more insulating material in a boiler room than in an engine room, and because work proceeds on at least two levels in boiler rooms so that a lot of debris falls 3–4 m to the deck and creates more dust in the general atmosphere. The very high dust levels in the brick stowage space (mean 259 fibres/cm^3) are the result of a lot of insulation being removed in a small space.

Application of pipe lagging

Dust concentrations recorded during the application of pipe insulating materials are shown in Table 4. The materials being applied included pipe sections of calcium silicate and 15 per cent asbestos, asbestos rope, asbestos cloth and asbestos cement. The dust concentrations were much lower than for the stripping procedures. As in the stripping operations, and for the same reasons, higher values for general and

TABLE 4. ASBESTOS DUST CONCENTRATIONS DURING THE APPLICATION OF PIPE AND MACHINERY LAGGING

Location	General atmosphere			Breathing zone		
	No of samples	Mean, fibres/cm³	Range	No of samples	Mean, fibres/cm³	Range
Boiler rooms	17	22·4	1–61	14	16·8	0·1–68
Engine rooms	28	2·1	0·1–14	16	7·3	0·04–40
Accumulator room	5	16·5	2·5–46	17	9·6	1 –47

breathing zone samples were found in the boiler rooms and the small accumulator room than in the engine rooms.

The results shown in Table 5 indicate that considerable dust concentrations (30–68 fibres/cm³) were created by sawing calcium silicate sections, or by removing them from their boxes. Fitting the sections to pipes created high local concentrations (43 fibres/cm³), but low general concentrations (4·1 fibres/cm³). Clearing calcium silicate debris (134–155 fibres/cm³), "blowing down" the debris from inaccessible ledges with an air hose (480 fibres/cm³) and sweeping amosite debris (564 fibres/cm³) created very high dust concentrations; previously men doing this type of work would not have been protected. Mixing asbestos cement in buckets and removing the dry material from a bag created high general concentrations (167/199 fibres/cm³) and even higher breathing zone levels (217–256 fibres/cm³).

Wrapping amosite asbestos rope around small bore pipes gave dust concentrations over 100 fibres/cm³. Ripping untreated asbestos cloth is a vigorous procedure and produced general dust concentrations of 33 fibres/cm³ and breathing zone levels of 7 fibres/cm³. When the cloth had been contaminated with asbestos debris the mean breathing zone levels in ripping the cloth rose to 20 fibres/cm³. Ripping asbestos cloth treated with a dust suppressant by the manufacturers produced dust concentrations which were all less than 1 fibre/cm³.

Removal of asbestos sheets used for acoustic insulation

This friable material used to soundproof certain compartments of the ship was applied and removed by joiners. The dust concentrations are shown in Table 6. The general atmosphere concentrations were high because the debris was thrown down on to the deck creating intense local dust clouds and the samplers were 1 m above deck level. The mean breathing zone concentrations were lower (130 fibres/cm³) since the samplers were carried by the men working up at the deckhead on staging.

Other processes using asbestos materials

Relatively low dust levels (mean 2·43 fibres/cm³) were seen in sawing perforated asbestos cement sheets (Table 7); these levels were reduced (mean 0·1 fibre/cm³) when the sheets were guillotined instead of being cut with a handsaw. Asbestos materials fitted into galley equipment produced mean dust levels of 1·8 fibres/cm³, but higher dust levels (mean 20·8 fibres/cm³) were found when men fitted calcium silicate slabs into boiler casings. The use of asbestos cloth for maintaining heat in metal to be

Table 5. Asbestos dust concentrations in miscellaneous processes associated with pipe lagging

Progress	General atmosphere			Breathing zone		
	No of samples	Mean, fibres/cm³	Range	No of samples	Mean, fibres/cm³	Range
Sawing calcium silicate sections	7	68	0·7– 158	11	55	7 –152
Removing calcium silicate sections from box	7	30	2 – 78	10	52	16 –136
Fitting calcium silicate section to pipe	9	4·1	0 – 23	20	43	1 –129
Cleaning calcium silicate debris	9	134	32 – 372	7	155	90 –277
Fitting amosite rope	4	118	1 – 280	13	112	5 –340
Removing asbestos 'plastic mix' from container	7	199	48 – 328	13	217	48 –470
Mixing asbestos 'plastic mix' with water in bucket	3	167	53 – 377·4	12	256	24 –579
Ripping cloth (untreated)	2	33	23 – 43	5	7	0·3– 16·5
Ripping cloth (contaminated)	—	—	—	12	20	5·5– 43
Ripping cloth (treated)	12	>1	>1	12	>1	>1
Stitching cloth	—	—	—	12	3·4	0 – 10
Fitting cloth over lagged pipes	—	—	—	7	22	0·3– 43
"Blowing down" asbestos debris	7	489	140 – 932	—	—	—
Sweeping and bagging amosite debris	10	564	76·3–1191	—	—	—

TABLE 6. ASBESTOS DUST CONCENTRATION DURING REMOVAL OF FIBROUS ASBESTOS ACOUSTIC PANELS

No. of samples	General atmosphere		Breathing zone	
	Mean, fibres/cm³	Range	Mean, fibres/cm³	Range
6	413·5	30–684	131	48–271

welded produced mean dust concentrations of 8·7 fibres/cm³. Brushing welding slag off asbestos cloth which had been used to protect equipment during welding and burning was accompanied by mean concentration of 76·6 fibres/cm³. Repeated sampling during the pre-heat welding technique when dust suppressed asbestos cloth was used showed counts below 1 fibre/cm³.

Asbestos mattress shop

A new purpose built mattress shop was erected during the course of the survey and the results in Table 8 show that there is little difference between it and the old shop. The high counts in each shop were associated with sweeping up amosite asbestos fibre around the filling booths.

TABLE 7. ASBESTOS DUST CONCENTRATIONS IN OTHER MISCELLANEOUS PROCESSES

Process	No. of samples	Mean fibres/cm³	Range
Sawing and fitting perforated asbestos board	9	2·4	0 – 10
Guillotining perforated asbestos board	8	0·1	0·04– 0·5
Fitting asbestos board in ship's galley	6	1·8	0 – 11
Use of asbestos cloth for pre-heating welding technique	9	8·7	0 – 30
Asbestos cloth used to protect equipment from welding slag	18	76·6	0 –660
Fitting calcium silicate slabs in boiler casing	18	20·8	1·1 – 7·3

TABLE 8. ASBESTOS DUST CONCENTRATIONS IN ASBESTOS MATTRESS SHOPS

Location	General atmosphere			Breathing zone		
	No of samples	Mean, fibres/cm³	Range	No of samples	Mean fibres/cm³	Range
Old shop	12	12·7	0–126	15	1·5	0– 7
New shop	11	16·3	2– 83	25	3·7	0–17

PRECAUTIONS TO REDUCE ASBESTOS HAZARDS

During this survey the Ministry of Defence (Navy) took steps to reduce the hazards associated with asbestos. These steps included a review of the use of asbestos, and where possible the introduction of substitute materials. The current uses of asbestos and the progress in finding substitute materials are summarized below.

Thermal insulation in machinery spaces

Calcium-silicate sections and plastics. Now supplied asbestos-free and recognizable by its yellow or pink colour. All calcium-silicate should be cut off-ship so far as is practicable. (Calcium-silicate containing up to 14 per cent asbestos is coloured white).

Amosite-asbestos sections and plastics. No longer used, replaced by calcium-silicate. A large number of existing ships are insulated with amosite; de-lagging operations will involve the full implementation of Naval Asbestos Regulations.

Self-setting asbestos finishing cement for high-temperature insulation

An asbestos-free substitute is now specified.

Asbestos cloth. Glass-cloth is now specified. Dust emitted from this cloth is an irritant but not a health hazard. Work is continuing to make this cloth less objectionable to handle.

Asbestos rope and twine. This has been deleted from specifications. Glass is now specified.

Asbestos mattresses. Mattresses of rocksil fibre covered with glass-cloth are now approved and in supply.

Local protection against fire

Asbestos millboard. This is now very little used and has been deleted from specifications.

Asbestos cloth. This is more frequently used, and a dust-suppressed cloth is now specified. No prospect is seen of finding a substitute fire-resistant material. Main applications are hangar fire-curtains, curtains in magazines, and protection in welding and burning operations. Magazines will be separately compartmented in new construction and at long refits of existing ships. Glass-cloth is not acceptable for these usages.

Fire protection in magazines where jet efflux presents a potential hazard

Resin-bonded asbestos fibre. No substitute material suitable for this purpose. Material is supplied by manufacturer to exact sizes required. There is therefore no health hazard in shipyard application.

Thermal insulation of hull structure

Sprayed limpet asbestos. Deleted from specifications. Mineral fibre marine board, which is asbestos-free, is now specified. Any ships still insulated with sprayed limpet asbestos will require full implementation of Naval Asbestos Regulations for de-lagging operations.

Blue-block asbestos or amosite board. Deleted from specifications. Mineral fibre marine board, which is asbestos-free, is now specified.

Asbestos fibre and cloth for pipe covering. Deleted from specifications. Replaced by polyurethane or mineral fibre preformed sections with canvas covering, which are all asbestos-free.

Acoustic insulation of hull structure

Asbestos fibre board. Deleted from specifications. Existing stocks are being kept for small repairs only. Replaced by mineral fibre resin bonded slab, which is asbestos-free.

Amosite asbestos. Deleted from specifications. Replaced by mineral fibre marine board.

Limpet asbestos board. Deleted from specifications. Replaced by perforated PVC sheet.

High-temperature jointing and packing materials

Asbestos fibre and compressed asbestos fibre. No substitute heat-resistant material is available. No health hazard in forms used in shipyard applications.

Bearing materials and brake-linings

Asbestos reinforced plastics. No substitute wear-resistant material is available. No health hazard except if these materials are ground or worked (no known requirement for this).

Bathroom and galley deck-coverings

Neoprene terrazzo. Asbestos-free neoprene terrazzo is now available. Dockyards and overseers have been informed that this is the only acceptable material.

Partition bulkheads

Compressed asbestos sandwiched between metal, plywood, plastic sheets, etc. Deleted from specifications, which now state that materials containing asbestos are not to be used. Steel, aluminium or plywood will generally be used, pending investigations into alternative asbestos-free materials.

Covers to cushions and mattresses in submarines

Asbestos cloth (not dust-suppressed). Deleted from specification. Fire-retardant foam mattresses now approved.

Code of practice

The precautions to be observed by all Dockyard employees working with asbestos were published as a Code of Practice and have been strictly enforced. They were formulated after careful study of working methods and were based largely on the experience gained from this environmental study.

These precautions are:

To isolate asbestos work, and to restrict entry to those properly protected.

To reduce the amount of dust created by asbestos work by improving work methods and the materials themselves.

To protect all workers whether they work directly with asbestos or not. Protection is based on the degree of risk, and workers are sub-divided into (a) Registered Asbestos Workers, those who work directly with asbestos, (b) Neighbourhood Workers, those not directly involved with asbestos, but employed near or with asbestos workers, (c) Management Visitors, those who pay short supervisory visits to places where asbestos work is proceeding.

To keep a register of all men directly employed on asbestos work. To ensure that Registered Asbestos Workers have regular medical supervision. These include sprayed asbestos strippers, laggers, asbestos storemen, and nominated boilermakers, joiners, shipwrights, sailmakers, plumbers, smiths and labourer cleaners.

To provide protective clothing adequate for the degree of risk involved.

To provide changing and washing arrangements.

To carry out regular dust sampling whenever asbestos is handled to ensure that the proper precautions are taken.

The regulations are summarized in Table 9 which shows that the protective measures are related to the degree of risk involved in various processes.

IMPROVEMENTS IN WORKING METHODS WHICH HAVE REDUCED ASBESTOS EXPOSURE

Removal of sprayed asbestos and pipe and machinery insulation will continue to be very hazardous as long as asbestos is present. There seems to be no practical way to wet the material without causing other disadvantages associated with removing and clearing away the debris. Efforts have therefore been concentrated on isolating the work and allowing access only to those men who are properly protected. Large areas of the ship surrounding the work point need to be closed to unprotected workers because the dust easily spreads from one compartment or deck to another. Protection of the worker includes impervious overalls, an air-fed respirator, or at least a positive pressure power respirator, and adequate changing and washing facilities.

Because very high concentrations of dust are to be expected when these materials are removed, dust sampling should be concentrated on the surrounding parts of the ship while the work proceeds to ensure that unprotected men are not at risk. Sampling should also be carried out after all the debris has been removed and after cleaning with industrial vacuum cleaners has taken place. It is important to continue sampling after other men have started working in the cleaned compartments so as to ensure that the cleaning has been efficient, and that no residues of asbestos remains to be made airborne again by the air-driven tools so widely used in ship repair work.

This sampling is done routinely in Naval Dockyards, and workmen are not allowed to work unprotected in compartments in which the asbestos fibre count is more than

TABLE 9. PRECAUTIONS FOR ASBESTOS WORK IN NAVAL DOCKYARDS

Type of work	Notices to be displayed	Protection: Registered asbestos worker	Protection: Neighbourhood worker	Protection: Management visitor
Sprayed limpet asbestos	Sprayed limpet asbestos work ENTRY PROHIBITED	Fully protected with impervious suit, gloves, boots. Issued 'underclothing'. Air-fed hood. Shower at end of forenoon and afternoon.	Not allowed entry (if vital, as for registered asbestos worker).	Visit to be of less than half hour (if longer, as for registered asbestos worker). Impervious suit, gloves, boots, skull-cap. Approved respirator.
Major delagging	Asbestos delagging NO ENTRY	Fully protected with nylon overall, gloves, boots, skull-cap. Issued 'underclothing'. Air-fed hood or approved respirator. Shower on completion of day or night shift.	As for sprayed limpet asbestos.	Visit to be of less than half hour (if longer, as for registered asbestos worker). Nylon overall, skull-cap. Approved respirator.
Major lagging/ cutting of asbestos materials	Asbestos lagging NO ENTRY	As for major delagging.	As for sprayed limpet asbestos.	As for major delagging.
Minor lagging/ delagging	Asbestos work in progress	Nylon overall, skull-cap. Issued 'underclothing'. Approved respirator. Shower on completion of day or night shift.	No restriction on entry. Respirators available on loan	No restriction on entry. Respirators available on loan.
Lagging shop (covered by own regulations)	Asbestos shop NO UNAUTHORIZED ENTRY	As for minor lagging/ delagging.	Respirators available on loan.	No restrictions on entry. Respirators available on loan.
Asbestos stores	Asbestos store NO UNAUTHORIZED ENTRY	As for minor lagging/ delagging.	Respirators available on loan.	No restriction on entry. Respirators available on loan.

2 fibres/cm^3. Similar sampling strategy is employed for the application of pipe insulation, and great emphasis is laid on efficient cleaning of debris both during and after work has finished. Compartments which are shown to produce dust concentrations of over 2 fibres/cm^3 are cleaned again until satisfactory sampling results are obtained. For a 6-month period (May–October 1969) 343 samples in engine rooms showed less than 1 fibre/cm^3, while 17 samples showed a mean of 2·9 fibres/cm^3. In boiler rooms there were 273 samples less than 1 fibre/cm^3, and 9 (mean 2·7 fibres/cm^3) more than 1 fibre/cm^3. In smaller compartments there were 327 samples less than 1 fibre/cm^3 and 25 samples with mean concentration 31·8 fibres/cm^3. These figures suggest that it is possible to reduce the asbestos dust concentrations to very low levels if energetic cleaning methods are employed, although these results also reflect the reduction in the amount of asbestos that is now being used in Naval ships.

Most of the existing insulation in ships, and some of the new materials still contain asbestos, and there will still be the problem of men working in compartments in which the insulation is incomplete and liable to be damaged. Until the protective layer of glass fibre cloth has been applied over the insulating sections, they are vulnerable to damage by tools, other equipment, or merely by men crawling over them to reach other work. Measurements have been made of asbestos dust concentrations created by men working in a boiler room in which the lagging had not been completed. Long running samples over the working shift showed general atmosphere concentrations of less than 2 fibres/cm^3. The values for breathing zone long period samples were between 2–5 fibres/cm^3, but some short samples taken when men were crawling over partly insulated pipes showed dust concentrations of 6–144 fibres/cm^3. Men are therefore required to wear dust respirators when they are working on or close to pipes on which the friable insulating material is still exposed.

Table 6 shows that asbestos is no longer used for acoustic insulation so that joiners will no longer be exposed to the dust except when they remove existing material. They will wear air-fed respirators to do this work. Welders and burners will still use asbestos cloth to protect equipment from molten metal, but by using dust-suppressed cloth, and by disposing of it instead of chipping off slag, they will no longer create high dust concentrations. Sampling has shown that levels of less than 1 fibre/cm^3 are produced if the cloth is used in this manner. The same applies to the use of dust-suppressed cloth for pre-heat welding techniques; welders are now instructed in the correct use of dust-suppressed asbestos cloth.

Asbestos mattresses are no longer used for insulation, so that the provision of dust extracting units in the mattress shop is no longer required. Mattresses are now made of glass fibre cloth filled with mineral rock wool. The problems of skin and mucous membrane irritation associated with the use of glass fibre cloth has been overcome by improvements in the weave of the cloth.

DISCUSSION

This survey has shown that very high concentrations of amosite, crocidolite, and chrysotile asbestos dust have existed for variable periods of time in ships being refitted in Naval Dockyards. High concentrations of asbestos dust have spread to parts of the ship in which unsuspecting men would have worked *without* respiratory protection. The data give some indication of what the dust concentrations in Naval Dockyards are likely to have been over the last 25 yr, and help to explain the prevalence of asbestos disease in Dockyard workers (SHEERS and TEMPLETON, 1968).

The dust concentrations in US Naval shipyards reported by FLEISCHER *et al.* (1946) and by MURPHY and FERRIS (1966) were very high, but these investigators sampled total dust and the proportion of asbestos fibre was small. The processes studied were mainly concerned with the application of pipe lagging. FERRIS (1968) reported dust concentrations of 7–130 mppcf during the removal of amosite asbestos insulation: this dust level is very high but the asbestos content was not stated. BALZER and COOPER (1968) also reported that ripping out insulating material caused high dust concentrations; 8·5 fibres/cm^3 was the mean concentration for this process, and it is not clear in their report where this work was performed. It is likely that higher concentrations occur in the congested spaces aboard ship than in machinery installations ashore.

These reports mention the difficulty of making an accurate assessment of asbestos exposure for insulating workers. This difficulty is due to the variety of materials used, each containing a different amount of asbestos, and due to the intermittent nature of the work. Both of these factors help to produce widely different dust concentrations, not only between different processes, but also during the course of a particular process. Without continuous dust monitoring of every process it will not be possible to establish accurate estimates of time weighted dust exposures for insulating workers.

The BRITISH OCCUPATIONAL HYGIENE SOCIETY (1968) sub-committee report on Hygienic Standards for Chrysotile Asbestos Dust suggests that if exposure to chrysotile asbestos is limited to a time-weighted average concentration of 100 fibre yr/cm^3 then it should be possible to reduce the risk of developing the earliest sign of asbestosis over a working lifetime to less than 1 per cent. That is an exposure of 2 fibres/cm^3 for 50 yr, or 10 fibres/cm^3 for 10 yr. Not enough is known about the effect of high exposures for short periods, so that it would not be acceptable to expose a person to 100 fibres/cm^3 for 1 yr. The report advises that dust concentrations over 10 fibres/cm^3 require the use of an approved dust mask, and that a higher standard of respiratory protection is required for concentrations over 50 fibres/cm^3.

Technical Data Note 13, published as a supplement to the Asbestos Regulations by the DEPARTMENT OF EMPLOYMENT AND PRODUCTIVITY (1970), suggests that 2 fibres/cm^3 for chrysotile and amosite asbestos is the dust concentration manufacturers and users of asbestos should aim to achieve if they are not to provide their workpeople with respiratory protection. For crocidolite asbestos this limit is 0·2 fibre/cm^3 because of the association between this type of asbestos and mesothelial tumours.

From the present survey it is clear that all processes involving work with asbestos insulating materials in Naval Dockyards give rise to asbestos dust concentrations of more than 2 fibres/cm^3. Many processes have dust concentrations of 50 fibres/cm^3 or more.

Despite the improvements which have been made towards reducing the asbestos dust concentrations in ship repairing it is obvious that personal protection for the workers will have to be provided for many years, and that constant vigilance will be required to maintain, and improve, on those standards of asbestos hygiene that have now been achieved.

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The data in this paper are from part of a thesis approved by the University of London for the degree of Doctor of Medicine.

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