

AN INVESTIGATION OF THE THERMAL AND ENVIRONMENTAL CONDITIONS IN THE HOLDS OF SHIPS CARRYING CEMENT

An occupational health survey

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Summary: Following a fatal case of heat stroke, the Occupational Health Unit undertook the investigation of the thermal and environmental conditions in the holds of ships arriving in Malta to unload hot cement. Fifteen ships were surveyed over a period of three months.

The state of dustiness in the holds was not judged to be prejudicial to the health of stevedores working therein, whereas the thermal environment on several occasions, particularly in the month of October, was deemed to impose such a physiological strain on them that it warranted the reduction of their hours of exposure. Of the four heat stress indices chosen, the corrective effective temperature and the predicted four-hour sweat rate emerged as the most suitable indicators of the composite stress. The P4SR correlated best with the severity of the thermal hold conditions obtaining at any particular phase of the investigation. The thermal limits were set at a CET of 75°F. and a P4SR of 3.

This survey helped to effect changes in the legislation regulating the working arrangements of stevedores.

In the afternoon of July 28, 1965, a stevedore who was unloading cement sacks from the hold of a ship berthed at Marsa died suddenly on the job. His death was attributed by the Court medical experts (one of whom was the writer A.G.) as due to heat stroke. This unfortunate incident caused great uneasiness amongst the ste-

vedores and heralded a period of industrial unrest which culminated in a national port strike (October 9-12, 1967). The present investigation was carried out against this background and was requested by the Minister of Labour, Employment and Welfare and the Port Labour Joint Council. Its purpose was two-fold:

- (1) to investigate the thermal and environmental conditions prevailing in the holds of ships off-loading cement; and
- (2) on the basis of these findings, to determine whether the stevedores' claim for an extension of the summer manning scale into the winter months was justified on occupational health grounds.

In view of the urgency of the situation, we were required to submit our report by the first week of January, 1968; that is, the period of investigation, and therefore our conclusions, had to be restricted to the months of October, November and December, 1967.

Up to the time of the survey, gangs engaged in the unloading of cement were normally made up of seven men all of whom worked inside the hold. This was the "winter manning scale". In the warmer months of the year, the seven men in the hold were increased to twelve who worked in groups of six in alternate shifts of one-hourly spells. This was the "summer manning scale" and in effect it halved the daily working load of the stevedores inside the hold. The winter scale was in operation

between October and June, both months inclusive, but if at any time during this period the surface temperature of the cement sacks ("sack temperature") exceeded 110°F., the summer manning scale was introduced — Port Labour (Determinations) Order, 1966. The stevedores' claim therefore, meant the adoption of the 12-men shift scale throughout the year, irrespective of the sack temperature.

From October 1967 up to the 4th January, 1968, fifteen ships carrying cement were investigated, an outside average of five ships per month. As the period under investigation, short as it was, could have been a lean one for cement ships and thus unrepresentative of the actual movements during a whole year, we correlated this finding with the information submitted by the Port Manager of ships arriving in Malta in 1966 and 1967. We found that the rate of ten ships per month was a more correct statistical average. Again, we ascertained that a ship normally took 1.7 days to unload its cargo and that the official hours of work in the port were from 0700 to 1200 hours and from 1300 to 1700 hours, namely, an exposure of nine hours per working day. Conceivably, therefore, any one stevedore could be exposed to the environment under study for a maximum of 1801 hours per annum. This figure is unrealistic and is biased in favour of the worker because:

- (a) it assumes that every stevedore has been working on every ship arriving in Malta whereas we know that different gangs of men are involved in cargo handling operations;
- (b) two or more ships may be concurrently unloading their cement on the same day.

But in an investigation of this kind, it is only natural that the worst possible conditions are underlined and, for the purpose of this survey, the measure of exposure of stevedores in the hold was set at 1801 hours per annum.

From our past experience and knowledge of the work-situation in the holds of ships carrying cement, we had decided early on in our investigation that the most

pertinent fields of study which could sway our conclusions either way related to:

- (A) the state of dustiness in the hold; and
- (B) the thermal environment in the hold.

Throughout the survey, we never had any reason to regret this approach and, in retrospect, we feel certain that no other occupational factor is of greater, or equal, significance.

Cement dust in the hold

Exposure to cement dust is not an occupation reckoned to lead to lung injury (Hunter, 1964). Intensive studies have been carried out by Gardner *et al.* (1939) who examined clinically and radiologically 2,278 cement workers; notwithstanding the high concentration of dust in certain sections of the industry surveyed, no case of disability was met with and radiographic abnormalities were of the slightest. In a follow-up of Gardner's study after an interval of 20 years, Sander (1958) confirmed that exposure to finished cement dust did not result in any recognisable X-ray changes, even after upwards of 30 years of exposure. Inhalation of finished cement dust, moreover, does not predispose to tuberculosis or emphysema (Johnstone and Miller, 1960).

Cement dust, therefore, is not a "fibrogenic" dust as silica, for example, is and there is no evidence that it produces the classical dust disease of the lungs. All acknowledged authorities consider it as a nuisance dust which is irritating to the skin, the upper respiratory passages and the eyes. It is in this context that the duration of exposure to cement dust by stevedores assumes a particular relevance. The Maximum Allowable Concentration of cement dust is the same as that of ordinary dust and is set at the high level of 1766 particles per cubic centimetres of air (U.K. Ministry of Labour). This figure relates to average concentrations for a normal working day over an indefinite period so that a person may, with safety and without undue detriment to his health, work regularly in such dusty atmosphere

throughout the year. This would entail an exposure of 2080 hours per annum (a conservative estimate) as opposed to the stevedore's rate of 1801 hours per annum (a generous estimate).

Whereas the thermal environment may change from ship to ship, depending on the type of vessel, the climatic conditions of the moment, the tonnage and manner of stowage of the cargo and the sack temperature, the state of dustiness in the hold may not be so variable and is mainly attributable to the rate of activity of the men involved in unloading the cement bags. This output, dictated in large measure by the men's terms of payment, i.e. at piece-rates, corresponds fairly well for each gang and it can be postulated, therefore, that the level of dustiness in the holds of different ships may not be liable to such wide fluctuations as in the case of the thermal environment.

Conclusion

Taking into consideration all these factors and particularly the fact that spells of exposure were punctuated by periods free from cement dust, we did not feel justified, on the basis of this one aspect of our investigation, to recommend the adoption of the summer manning scale in winter.

Thermal environment in the hold

The factors which contribute to the adverse thermal environment in the hold of a ship carrying cement include:—

- (a) the temperature of the cement which is delivered hot from the calciners and often remains hot on arrival in Malta: at times the sack temperature reaches 130° F. or more and renders the sacks important sources of radiation;
- (b) the type of vessel, often small, wooden-hulled vessels: wood is a notoriously bad conductor of heat;

- (c) the holds themselves: veritable heat traps where the circulation of the air is deficient;
- (d) the method of emptying the hold: the stevedores do not 'skim off' the cargo but, in order to avoid bending and lifting, they 'cut down' to the bottom of the hold where they work standing upright inside an ill-ventilated, sack-walled space in the cargo;
- (e) the general climatic conditions, in particular the hot humid day when the vapour pressure of the environment is such as to interfere seriously with the cooling effect of sweating.

The human factors, moreover, have to be considered — the stevedore's fitness, his acclimatization and energy expenditure. Environmental changes, such as sudden increases in temperature, impose a physiological strain which is reduced by acclimatization. The work of the stevedore is classified as 'moderate' in that the sacks are merely moved sideways from the top of the stack and then lowered down, and not lifted up, into the crane sling. But the output which the stevedores set themselves is high because they are paid at piece rates, the rate of unloading normally ranging between 250 to 270 tons per working day.

In this survey, three assumptions have been made:—

- (a) that measures to ensure the shipment of cement (ex works) at a reasonably low temperature or the ventilation during the voyage of the cement cargo by the provision of vertical and longitudinal shafts in the stacking are beyond the importers' and Port Manager's control;
- (b) that the wider issue of redeployment of the available port workers is not our concern, as indeed it is not; and
- (c) that the stevedores working in the hold are physically fit and fully acclimatized to carry out their allotted tasks.

Materials and methods

In view of the particular significance we attached to this line of the investigation, the thermal environment in the holds of every ship which arrived in Malta during the period under study was assessed by a team from the Occupational Health Unit. The names of the ships have been changed to ensure anonymity and are shown, together with the relative findings, in the Table.

At every assessment, the thermal variables measured were the following:—
dry-bulb temperature (whirling hygrometer);
wet-bulb temperature (whirling hygrometer);
globe-temperature;
air velocity (Katathermometer);
relative humidity;
(sack temperature).

In choosing the types of indices of thermal stress most appropriate for the purpose of this survey, we were guided by the following considerations:—

- (a) the energy-expenditure of the stevedore in the hold;
- (b) the special thermal conditions in the hold;
- (c) the 'sweating' factor in such an environment; and
- (d) the radiation component of the hot cement.

In the light of these considerations, we selected four scales of warmth or heat stress indices to summate the effects of the thermal variables, namely:—

- wet-bulb temperature;
- corrected effective temperature (CET);
- wet - bulb - globe - temperature index (WBGT);
- predicted four-hour sweat rate (P4SR).

The assessment of the thermal environment is essentially the measurement of all the factors concerned, whether they are attributes of the environment, such as air temperature and humidity, or attributes of those exposed, such as their clothing, rate of working and length of exposure. There is no single, all-embracing index which is valid in all the possible complexi-

ties of work rate, air temperature, air movement, humidity, radiant temperature and clothing. Each index has its limitations but, taken in combination and used within their particular sphere of application, thermal stress indices provide an adequate measure of the severity of an environment.

1. Wet-bulb temperature

This index takes into consideration two factors, the temperature and the humidity of the air; the effect of air movement and radiation is disregarded. Its great drawback to us was that it ignored the radiation component of the cement sacks; the air velocities registered in the holds were never significant. Nonetheless it provides a fair indication of the evaporative heat exchange through sweating, and was included for this purpose. It was not relied on as a measure of the total heat stress. Haldane (1905) has recommended a maximum wet-bulb temperature of 78° F. for clothed men (not especially acclimatized) doing moderate work in still air.

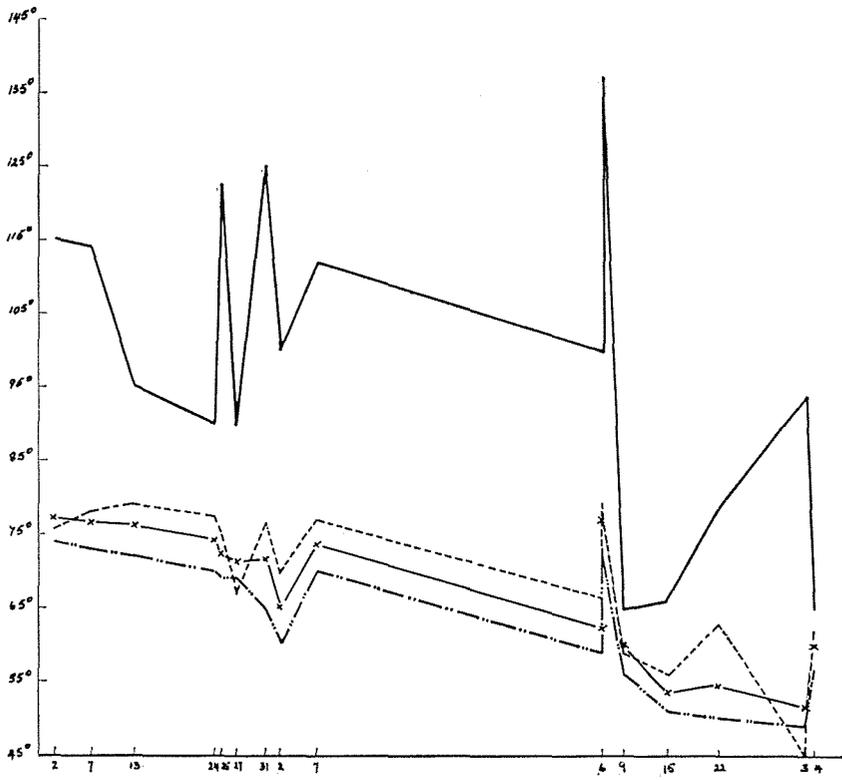
2. Corrected effective temperature (CET)

The CET (normal scale) provides, in a single numerical value, a measure of the combined effect of the temperature, humidity and speed of the air in the hold and the radiant heat from the hot cement. It makes, moreover, an allowance for the effect of clothing worn by the stevedores. Without reference to the rate of work of the men exposed, however, CET values are virtually meaningless since they relate only to the climatic stress and do not take into account the metabolic heat production (Leithead and Lind, 1964). Environmental limits in CET values have tended to be set at 86° F. for sedentary and light work (197 kcal./hr.), 82.4° F. for moderate work (325 kcal./hr.) and 79.7° F. for heavy work (454 kcal./hr.) (W.H.O. Report, 1969). The average weight of a stevedore has been estimated at 12 stones (75.6 kg.). On the other hand, Dr. C.G. Warner (personal communication), cognisant of the stevedores' rate of work in the holds, has stated that such a working environment at a CET

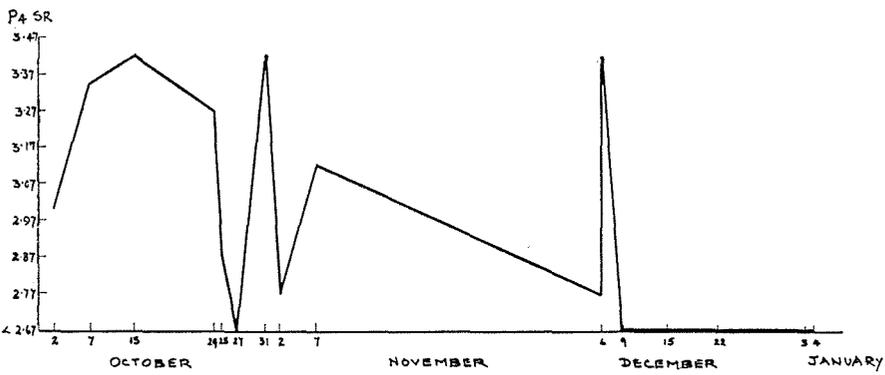
THERMAL FINDINGS IN HOLDS OF CEMENT SHIPS

TEMPERATURE
IN FAHR.

OCTOBER 1967 - JANUARY 1968



_____ SACK TEMPERATURE - - - - - CET
 x - - - - x W BGT - · - · - WET-BULB TEMPERATURE



_____ P4 SR VALUES

OCTOBER NOVEMBER DECEMBER JANUARY
 DAYS AND MONTHS

TABLE

<i>Name * of ship</i>	<i>Date of Test</i>	<i>Wet-bulb temperature</i>	<i>CET</i>	<i>WBGT</i>	<i>Sack temperature</i>	<i>P4 SR</i>
"John"	2/X/67	74°F	75.5°F	77.4°F	115°F	3
"Paul"	7/X/67	73°F	78°F	76.9°F	114°F	3.34
"Paul"	13/X/67	72°F	79°F	76.3°F	95°F	3.42
"Mark"	24/X/67	70°F	77.5°F	74.1°F	90°F	3.27
"Nina"	25/X/67	69°F	75°F	72.4°F	122.5°F	2.87
"John"	27/X/67	69°F	67°F	71.4°F	90°F	2.67
"Peter"	31/X/67	65°F	76.5°F	71.5°F	125°F	3.42
"Paul"	2/XI/67	60°F	69.5°F	65°F	100°F	2.77
"Teddy"	7/XI/67	70°F	77°F	73.8°F	112°F	3.12
"Tony"	6/XII/67	59°F	66.5°F	62.4°F	100°F	2.77
"May"	6/XII/67	72°F	79.5°F	77.3°F	137.5°F	3.42
"Doris"	9/XII/67	56°F	59°F	60.1°F	65°F	< 2.67
"Mark"	15/XII/67	51°F	56°F	53.7°F	66°F	< 2.67
"Fred"	22/XII/67	50°F	63°F	54.7°F	79°F	< 2.67
"John"	3/I/68	49°F	45°F	51.6°F	94°F	< 2.67
"Paul"	4/I/68	57°F	62°F	60.2°F	65°F	< 2.67

* The names of the ships are fictitious.

Thermal findings in holds of cement ships

below 70° F. is entirely acceptable; between 70 to 74° F. CET it becomes uncomfortable and over 75° F. CET it begins to look worrying.

3. *Wet-bulb-globe-temperature index (WBGT)*

The WBGT embraces, in a single value, the effects of radiation from the sun and the environment, air temperature, humidity and air velocity. It is, to our knowledge, the only index specially designed to measure the exposure to high levels of heat stress out of doors where to the burden of high air temperatures is added the solar heat load. WBGT values between 85° to 88° F. have been considered, in another setting, as the climatic range when heat illness is likely to occur (Minard *et al.*, 1957). We realized, however, as the survey progressed, that the WBGT index was not a happy choice because of the absence of direct sunlight in the hold. Eventually we had to disregard it.

4. *Predicted four-hour sweat rate (P4SR)*

The P4SR takes into consideration not only the environmental factors of the temperature, humidity and movement of the air, and the temperature of the surroundings, but also the rate of energy expenditure and the clothing worn in the environment. Such an index can obviously be applied best in conditions under which sweating occurs and has been designed with fit, acclimatized men in mind. It is favoured for use in moderate to high heat stress, particularly in situations that remain fairly stable throughout a period of about 4 hours. We reckoned that the one-hour break divided the working day of stevedores into two such situations, and the P4SR was recorded without fail over both morning and afternoon work-periods. The limiting value for P4SR has been judged to be about 4.5 (McArdle *et al.*, 1947). Above this level an increasing number of workers would find the conditions beyond their endurance. A P4SR of 2.5 is, therefore, more easily supportable and reasonable for sustained activity (Warner, 1965).

Work rate

The work data have already been described. From a time-and-motion study of the stevedore's activities in the hold, his energy expenditure was reckoned at 360 kcal./hour. This figure is midway in the range given by Christensen (1953) and quoted by Passmore and Durnin (1955) for men doing moderate work (300 to 450 kcal./hr.) and corresponds closely with the upper limit ascribed to moderate work by Hatch (1967) for an 11-stone (70 kg.) man who is walking about, with moderate lifting or pushing (353 kcal./hr.). It, moreover, stands comparison with the 325 kcal./hr. (W.H.O. Report, 1969) referred to in our discussion on CET limiting values and with the 300 kcal./hr. adopted by Wyndham *et al.* (1967) for moderate work in hot conditions. Nevertheless, the rate of 360 kcal./hr. still remains a generous estimation of the energy expenditure of the stevedores, but it was purposely weighted to take into account their motivation for high speed work and to avoid any margin of bias against them.

Discussion of thermal findings

This investigation has been an attempt to determine the intensity of heat stress imposed on stevedores unloading hot cement at fairly constant rates but in a wide range of thermal hold conditions, and at the same time to state at which month or months in the period under study the stress was such as to have necessitated the halving of the exposure-hours in order to reduce the heat load. Our primary task, therefore, was to establish the upper limits of heat stress which would be applicable to the hold environment.

The epidemiological approach would have been the most realistic, but it could not be used partly because the incidence of heat collapse or of any other form of heat illness (Wyndham, 1965) was not available and partly because the period of investigation was not long enough as to lend itself to statistical analysis. We decided to place reliance on maxima of thermal stress validated in a work-situation as

near to ours as possible and to judge their objectivity in the light of our own experience in the survey.

On the basis of the limiting values generally recommended for the indices we had chosen, we established a critical climatic level above which the environmental conditions would be considered such as to justify the introduction of the shift system. This thermal yardstick was set at a CET of 75°F. and a P4SR of 3; the sack temperature was retained at 110° F. Below these upper limits, i.e. within the prescriptive zone, seven acclimatized and fit stevedores in the hold could unload hot cement for 9 hours a day, at the measured pace and work-load (360 kcal./hr.), in tolerable conditions in which their bodily thermal equilibrium would be maintained without undue strain on the thermoregulatory or other physiological mechanism.

In October, six ships were surveyed. Two had 'climates' just below the upper limit of the prescriptive zone, one of which ("Nina") had a sack temperature of 122.5° F., whilst the other four had 'hotter than prescriptive' climates. The Table shows clearly that only the last week of October offered fairly tolerable thermal conditions to the men in the holds and it started what turned out to be a progressive improvement in the heat stress picture over the remaining period of our investigation. It may be pointed out here that, under the port regulations existing at that time, four of the ships (sack temperature over 110° F.) would have been manned at the summer scale.

In November, only two ships were visited and the thermal environment in one of them ("Teddy") came very near the conditions prevailing in October. Obviously, no definite pattern could emerge and it would be as unwise to incriminate November on the strength of the findings in this one ship as it would be bold to align this month with December in view of the easily tolerable conditions obtaining in the hold of the "Paul" (2/XI/67). Again, it is perhaps quite indicative that the shift system would have been applied to the "Teddy" in accordance with then existing port arrange-

ments (sack temperature 112° F.).

The thermal conditions in four of the five ships inspected during the month of December were satisfactory. The one exception was the wooden-hulled "May" where the thermal environment in the hold was found to correspond with that prevailing in the ships investigated during October. It is worth noting in this connection that readings obtained from the "Tony", which was inspected on the same afternoon as the "May", were quite satisfactory; one important factor which contributed to the exceptional thermal findings on the "May" was the temperature of the sacks which averaged 137.5° F.

Two ships, i.e. "John" and "Paul", were visited in the first week of January, 1968 and the Table shows that the same favourable trend in the thermal environment registered in December 1967 had been maintained.

The Chart shows a definite pattern indicating a gradual amelioration of the thermal hold conditions from the last week of October onwards, assuming a downward curve with two isolated peaks in November and December in the case of the "Teddy" and the "May". The P4SR emerged as a realistic index and correlated best with the severity of conditions obtaining at any particular phase of our investigation. This is not surprising as it expresses the heat stress of any combination of dry and wet bulb temperatures, globe temperature, air movement, level of clothing worn and rate of work. The CET scale has also proved its reliability in an investigation of this kind where the rate of work is practically constant from day to day. Perhaps a greater revelation was the fact that the sack temperature followed fairly closely the thermal environment with the exception of the "Mark" (24/X/67) and the "Nina"; the readings on the "Paul" (13/X/67) need not vitiate this finding as the ship had lain idle for several days due to the general strike in the port.

Conclusion

Following this survey, we were in a position to report that:—

- (1) the summer manning scale should be extended into October;
- (2) the findings in November were equivocal and thus no definite submission in respect of this month could be made other than that the sack temperature would have proved a realistic criterion of the thermal conditions in the holds;
- (3) there was no justification on occupational health grounds to adopt the shift system in December, provided always that the sack temperature did not exceed 110° F.

Subsequent to our report, the Port Labour (Determinations) Order, 1966 was amended accordingly.

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