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An Analysis of Work Environments and Operations in Hot and Humid Areas

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NOTES

An Analysis of Work Environments and Operations in Hot and Humid Areas

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Crews on tankers traveling and hauling cargo on the lower reaches of the Mississippi River during the hot and humid (H&H) summer season face various occupational safety and ergonomics problems. Evaluation of medical data reveals that a large number of the crewmembers experience job related injuries, diseases, disorders, and exhaustion as a result of adverse environmental conditions (National Institute for Occupational Safety and Health [NIOSH], 1993). The accidents and injuries that occurred were characterized and then analysis was used to recommend constructive remedies and solutions. The results were also used to design and develop better work environments on the tankers and in the general industry. In H&H conditions, the body's chemical reactions constantly change in order to maintain the best possible reaction to changing environments. This chemical reaction increases blood flow to the skin through sweating. Body metabolism stabilizes body temperature through muscular work and convection, evaporation and radiation remove heat.

occupational safety ergonomics workplace design

1. STRESS AND DISORDER FACTORS

In this study, it became evident that six environmental factors adversely impact the amount of stress an employee faces in a hot and humid (H&H) work environment: temperature, humidity, radiant heat, work load, clothing, and air velocity. Other factors that may significantly influence the degree of stress are personal characteristics such as age,

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weight, physical fitness, medical condition, and acclimation to the environment (Ohlsson, Attewall, Johanson, Ahlm, & Skerfving, 1994).

2. PHYSICAL WORK CAPACITY

In this study, physical work capacity (PWC) was measured through assessment of aerobic capacity by the Åstrand-Ryhming sub-maximal step up test and energy expenditure by the indirect time and motion study method. The tests revealed that PWC of the crewmembers also depended on age, body build, gender, duration, frequency of tasks, and their acclimation periods (Getty, 1994).

Analysis of the results indicated that increases in accidents and injuries in these conditions were primarily due to traffic and congestion, poor ergonomics and safety (E&S) design and lack of attention to maintenance and operations, insufficient and inaccurate E&S data, and lack of resources and technical capabilities to address their E&S problems. Figure 1 categorizes types of injuries on tankers by fractures and concussions.

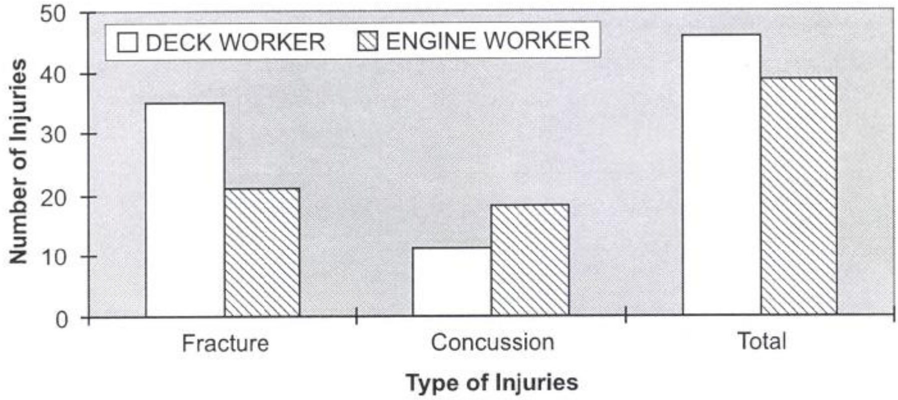

Figure 1. Injuries by fracture and concussion.

3. ACCIDENT STATISTICS

In this analysis, measurement of physiological responses included oxygen intake (V_{O2max}) and energy expenditure of the crews working on actual tasks at different time intervals. Besides oxygen intake (V_{O2max}), other

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measurements were obtained such as pulse (heart) rate; rectal (core) temperature; skin temperature; and perspiration rate (loss of body weight) before, during, and after work. Table 1 is a presentation of the number of injuries during one year of the study. As Table 1 indicates, most injuries happened during the warm and humid months of May, June, and August.

TABLE 1. Monthly Injury Reports for 1994

Month	Cases	%	Deck	%	Engine	%
January	10	6.5	6	6.5	4	6.6
February	8	5.2	5	5.4	3	11.5
March	7	4.6	4	4.3	3	4.9
April	8	5.2	5	5.4	3	14.8
May	19	12.4	10	10.9	9	8.2
June	17	11.1	12	13.0	5	4.9
July	29	19.0	18	19.6	11	18.0
August	18	11.8	11	12.0	7	4.9
September	7	4.6	4	4.3	3	6.6
October	8	5.2	4	4.3	4	4.9
November	8	5.2	5	5.4	3	6.6
December	14	9.2	8	8.7	6	9.8
TOTAL	153		92			61.0

Other secondary, but pertinent to PWC, factors were economics and the sociocultural backgrounds of the tanker crews. Our analysis indicated that the elevation of the body's vital signs is primarily dependent on thermostatic effects of the central nervous system and thermoregulation of the individual's core temperature. The E&S efforts of this study were to obtain a clear understanding of the PWC of the ship crews and to determine the dominant factors impacting the variables considered (e.g., age, gender, body build, nutritional status, environmental temperature, and work activities).

In 1995, a descriptive study of accident data from tankers of all sizes over a period of one year (1993 to 1994) was carried out, using medical reports sent to the author in the Bell Laboratories. It became evident that out of 256 documented accidents, only 123 cases occurred on board, whereas the remaining 133 were traffic accidents during regular operations. We further divided the cases into two categories, deck and engine. Table 2 is a presentation of the accidents on the decks and in

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the engine rooms. This table shows that more accidents happened on the decks than in the engine rooms. Table 3 categorizes accidents by their causes and job classifications. As Table 3 indicates, slippery decks were highest causes of injuries on the decks, whereas burns were the cause of the highest number of accidents in the engine rooms.

TABLE 2. Injuries by Parts of the Body

Part of the Body	Cases	Deck	%	Engine	%
Head	31	13	14.1	18	29.5
Upper extremities	28	17	18.5	11	18.0
Lower extremities	37	29	31.5	8	13.1
Body	27	18	19.6	9	14.8
Eye	16	9	9.8	7	11.5
Other	14	6	6.5	8	13.1
TOTAL	153	92		61	

TABLE 3. Injuries by Cause and Job Classification

Causes	Total Cases	Deck Cases	%	Engine Cases	%
Hitting by lines	21	16	17.4	5	8.2
Burns	31	18	19.6	13	21.3
Dull objects	7	4	4.3	3	4.9
Sharp objects	8	5	6.5	3	3.3
Sandwich	18	12	13.0	6	9.8
Slippery	27	16	17.4	11	18.0
Electric shock	8	5	5.4	3	4.9
Drowning	18	11	12.0	7	11.5
Noxious gas	15	4	4.3	11	18.0
TOTAL	153	92		61	

4. CONCLUSIONS

Presence of H&H impacts employees' vital body signs and increases core temperature, heart rate, and energy expenditure—three critical indicators of heat stress. Blood flow to the skin increases, resulting in diminished flow to the muscles, and work capacity is impaired. In cases of heavy workloads, these body reactions can increase rapidly. Employees working in H&H conditions are encouraged to pace themselves to keep their vital body signs within acceptable levels. A rough estimate in designing an H&H work environment is to plan the amount of rest at regular intervals so that 1 °C (1.8 °F) in ambient temperature above 25 °C (77 °F) is equivalent to a 1% addition in the percent maximum effort for the task.

Project results indicate that temperatures ranging from 19 to 26 °C (66 to 79 °F) are recommended as upper control limits for sedentary or light work in tropical conditions, based on an 8-hr workday. For more than 8 hrs of work per day, we recommend temperatures between 20 and 25 °C (68 and 78 °F; Forget, 1992).

Discomfort of an employee directly relates to the level of humidity that an employee is experiencing. If all other factors stay normal, an increase in humidity from 50 to 90% at 26 °C (79 °F) may decrease the comfort level by a factor of 4 for a person performing light work. In the summer months, humidity below 70% is recommended. Comfort level is increased through lower humidity and is achieved by installing humidifiers at various key positions close to employee work areas.

Airflow can significantly increase employee comfort level even in H&H environments. But air velocity alone is not sufficient to compensate for other critical factors. Workload is another factor that impacts performance and heat stress. The heavier the workload, the more heat stress and injuries. Overall, 175 to 350 W (150 to 300 kcal per hour) presented an average workload in the tankers. All other factors being equal, employees performing tasks with heavier workloads can work a shorter time to maintain their productivity before reaching their threshold limits or unsafe levels.

Heat surfaces were another source of discomfort among employees. They included such areas as windows, walls, chairs, and floors that may generate heat faster than body parts of the employees. Heat-increase surfaces add to the existing body heat and increase the core temperature. If hands, legs, feet, arms, and other parts of the body are exposed to hot surface injuries, burns and accidents may follow (Rogan & O'Neill, 1993).

REFERENCES

Forget, G. (1992). Occupational health and development: An overview of the situation. *IDRC Reports: Perils in the Workplace, 20*(1), 4–7.

Getty, R.L. (1994). Physical demands of work is the common reference for an integrated ergonomics program. In *Proceedings of the 38th Human Factors and Ergonomics*

Downloaded by [185.55.64.226] at 10:27 14 March 2015

Society Annual Meeting (pp. 683–687). Santa Monica, CA, USA: Human Factors Society.

National Institute for Occupational Safety and Health (NIOSH) (1993). *Health hazard evaluation report* (DHHS/NIOSH Publications). Cincinnati, OH, USA: National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services.

Ohlsson, K., Attewall, R.G., Johanson, B., Ahlm, A., & Skerfving, S. (1994). Assessment of neck/upper extremity disorders by questionnaire and clinical examination. *Ergonomics, 37*, 891–897.

Rogan, A., & O'Neill, D. (1993). Ergonomics aspects of crop production in tropical developing countries: A literature review. *Applied Ergonomics, 24*(6), 371–386.

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