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SURVIVABILITY OF OCCUPANTS OF TOTALLY ENCLOSED MOTOR PROPELLED SURVIVAL CRAFT

Prepared by RGIT Survival Centre Ltd for the Health and Safety Executive

Offshore Technology Report

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SURVIVABILITY OF OCCUPANTS OF TOTALLY ENCLOSED MOTOR PROPELLED SURVIVAL CRAFT

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Results, including detailed evaluation and, where relevant, recommendations stemming from their research projects are published in the OTH series of reports.

Background information and data arising from these research projects are published in the OTI series of reports.

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SUMMARY

Trials were undertaken from the RGIT Survival Centre Quay to establish survivability for occupants of a totally enclosed motor propelled survival craft (TEMPSC). It was found that under a given set of external conditions the environment within the TEMPSC was related to occupancy level, with full occupancy causing greatest stress. Under winter conditions, and within the time limit of the trial, the internal temperature of the TEMPSC was considerable acceptable. Under summer conditions, however, high internal TEMPSC temperatures were found causing considerable thermal stress and high levels of sweating, particularly in those wearing insulated survival suits. The onset of motion sickness was recorded within the first half hour of the sea trial, with 49% of occupants feeling unwell or worse, while 29% vomited. Motion sickness was thought to be exacerbated primarily by the heat, by observation of others vomiting, and by fumes.

Major recommendations are that the occupancy level of TEMPSC should be reduced and that the problem of dehydration be addressed by supplying fluids tot he occupants. The design of TEMPSC should be reconsidered with particular regard to the degree of ventilation.

Without the above measures, severe debilitation of TEMPSC survivors is likely to occur within 12-24 hours.

1. INTRODUCTION

Numerous studies have been undertaken to evaluate rescue and recovery from TEMPSC (11,12). This phase of survival has been shown to be not without problems and transfer in all but calm conditions is very difficult. The time available to the rescuers may be related to the condition of the survivors and clearly if weather conditions permit, an early rescue and transfer are to be preferred. The question arises however, as to the time scale of events in terms of deterioration of the TEMPSC occupants and whether rescue and transfer can be delayed until weather conditions improve. During the enquiry into the Ocean Ranger disaster (13) considerable attention was focused on the transfer from TEMPSC phase since it was at that point when major fatalities occurred. The question was asked whether or not the survivors should have stayed "shut down" in the TEMPSC, waited for the conditions to abate and have transferred in weather conditions more conducive to rescue. Therefore, estimates of time scale of events, prevention or reduction in debilitating motion sickness, amelioration of the internal environmental threats and maintenance of crew and coxswains' efficiency are important.

Considerable effort has been focused on the development of the totally enclosed lifeboat concept both for offshore applications and for marine use in general. A universal implementation of totally enclosed motor propelled survival craft (TEMPSC) has occurred in the British and other North Sea sectors. Most attention has been directed towards the ability of these craft during an evacuation, to proceed through both flame and toxic atmospheres with the occupants emerging relatively unscathed.

Approval testing of TEMPSC requires the craft to be engulfed in a kerosene fire and the temperature to be measured inside the craft. Although the temperature has to be measured the actual temperature inside the craft is not specified in the testing requirements. In the shut-down mode, ie hatches closed and with the on-board air supply activated, some 10-15 minutes should be available during which time a positive air pressure is maintained within the craft. Given the relatively shallow freeboard between the hatches and the waterline, even in moderate weather, it is recommended that all hatches should be kept closed to prevent swamping and subsequent capsize.

In the event of having to maintain the integrity of the sealed craft the effects upon the occupants and the environment within the craft has received minimal attention. Since it is possible that some 40-50 persons may be forced to abandon in an 8 metre craft the impact of conditions inside may be considerable.

Anecdotal accounts obtained from RGIT training officers during routine training exercises have detailed unpleasant effects such as heat, humidity, stuffiness and sweating within minutes of motoring in the closed-down mode. These effects have been reported in 9 metre craft (50-60 survivor capacity) containing only 10-12 persons in summer conditions. The possibility of physiological problems developing in survivors under such conditions cannot be ignored. Thus a full complement of 50-60 survivors may face severe physiological threats. The problems in physically occupying the space in many TEMPSC, particularly with survivors dressed in survival suits and large bulky inherently buoyant lifejackets, has resulted in many craft being downrated in terms of occupancy.

During the Vinland Incident (3) when over 76 persons evacuated in two 50-man Harding TEMPSC with air and water temperatures of -3°C and +1°C respectively, seasickness was reported as affecting the majority of occupants within 30-60 minutes of launching the TEMPSC. Those that were not initially seasick were eventually overcome by the pervasive atmosphere in the boats and became seasick.

Since the onset of motion sickness (5) is closely related to stuffiness, odour and motion of the craft the effects of increasing temperature and motion may be interactive. Furthermore it would seem that the internal environment of the TEMPSC is conducive to the induction of motion sickness (8). Thermal stress, whilst affecting motion sickness, will lead to sweating and dehydration. When coupled with fluid losses from vomiting, the level of incapacitation and dehydration may be significant. The likelihood of decreasing occupant performance is high and may compromise survival in several ways ie reduction in efficiency, reduction in strength, psychological impact, physical and mental impairment and inability to assist in the rescue phase.

The objective of the study was to quantify the physiological stresses within totally enclosed motor propelled survival craft, with particular attention focused on thermal stress and motion sickness. The results may then be used to establish a survival time for TEMPSC occupants.

2. METHODS

2.1 TEMPSC USED IN STUDY

All trials were undertaken using a Watercraft MK II 42 person capacity TEMPSC. The craft was fully maintained and serviced in accordance with the manufacturer's recommendations prior to conducting each test.

2.2 TEMPSC PREPARATION

The general arrangement of instrumentation is shown in Figure 1.

2.2.1 Temperature measurements

The air temperatures in the craft were measured at six locations using Edale Instruments type EU probes. The temperatures were measured in the forward, midships and aft boat sections at subject head and waist level.

The black bulb globe temperature was measured at the centre of the TEMPSC using a Casella Instruments 6 inch diameter globe thermometer.

2.2.2 Humidity measurement

The relative humidity (% RH) was determined from the dry bulb and wet bulb temperatures obtained from a Casella Instruments sling psychrometer. The humidity was measured at the coxswains position.

2.2.3 Air movement

The air movement was measured using a Prosser air velocity meter and the sensor was placed beside the globe thermometer in the centre of the craft.

2.2.4 Gas analysis

2.2.4.1 Carbon Dioxide

The level of carbon dioxide was measured using chemical detector tubes (Kitigawa/Draegar). The gas samples were taken in the vicinity of the engine cover beside the coxswain.

2.2.4.2 Carbon Monoxide

The level of carbon monoxide was measured using chemical detector tubes (Kitigawa/Draegar). The gas samples were taken in the vicinity of the engine cover beside the coxswain.

2.3 SUBJECTS

Adult subjects were recruited for the trials and wore the following clothing assembly: woollen shirt, long sleeved jumper, denim jeans, socks and either shoes or boots.

Depending on the trial protocol subjects may have worn immersion suits. These items are detailed within the protocol of each trial.

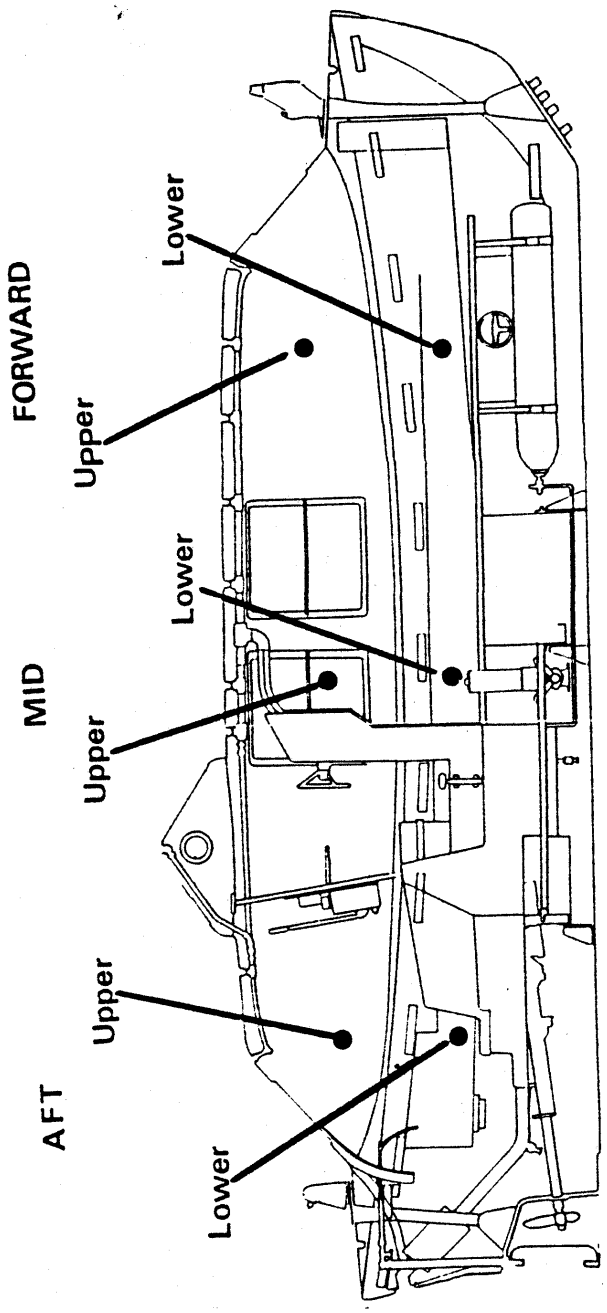


Figure 1
Position of temperature probes during TEMPSC trials

2.3.1 Height and weight

The subjects' height was measured using a wall mounted stadiometer and nude weight to an accuracy of $\pm$10 grams was measured pre and post trial using a Sauter Electronic weighing scale.

2.3.2 Body surface area

The subjects' body surface area was calculated from the DuBois & DuBois nomogram (4) using height and weight.

2.3.3 Sweat rate

The change in body weight with no correction for respiratory/vapour loss was used to estimate sweat rate ($g.m^{-2}.hr^{-1}$) thus:-

$$\frac{1{,}000\ (BW\ pre - BW\ post)}{(BSA)\ t} = Sweat\ Rate$$

Where	BW pre	=	body weight pre-trial (kg)
	BW post	=	body weight post-trial (kg)
	BSA	=	subjects body surface area (m^2)
	t	=	duration of trial (hr)

2.4 EXTERNAL ENVIRONMENTAL MEASUREMENTS

2.4.1 Air Temperature

The ambient air temperature (in the shade) was measured using an Edale Instruments Type EU probe.

2.4.2 Sea Temperature

The ambient sea temperature was measured using an Edale Instruments Type EU probe.

2.4.3 Wind Speed

The wind speed in the vicinity of the craft was measured using a Casella Instruments hand held anemometer.

2.5 TRIAL LOCATION

2.5.1 RGIT Quay maintenance dock

The preliminary trials were undertaken with the TEMPSC positioned with its bow pushing into the riverbank. The procedure adopted is described later.

2.5.2 Aberdeen bay

The final survivability at sea trial was undertaken offshore from the entrance to Aberdeen Harbour. The procedural details are recorded in Section 3.

2.6 TRIAL PROCEDURE

The procedure adopted will be considered for each trial undertaken in the study.

2.7 SIMULATION OF "DEPARTURE FROM PLATFORM"

The trial procedure was essentially designed to simulate the likely sequence of events that would occur during evacuation from an offshore installation. The sequence would typically consist of boarding, engine start, hatches closed, air supply on, lower, release and departure, motoring at full power for 15 minutes. After the movement to a safe location the TEMPSC coxswain would position the craft with the bow 2 points off the weather direction and with power on to give control over the craft.

2.8 SUMMARY OF TRIAL CONDITIONS

A summary of the trials undertaken showing external environmental conditions, occupancy, season and purpose is shown in Table 1.

Table 1
Summary of TEMPSC trials

Trial	Temperature (°C)		Occupancy		Duration (min)	Season	Sea State	Location	Purpose
	Air	Water	No.	Capacity (%)					
1	3-6	2	39	93	60	Winter	Calm	Q	T
2	14-15	14-16	31	74	90	Summer	Calm	Q	T
3	17	12	42	100	60	Summer	Calm	Q	T
4	19-20	18	31	78	11	Summer	Calm	Q	T
5	21-24	18	2	5	60	Summer	Calm	Q	T/E
6	17-18	13	42	100	45	Summer	Beaufort 6-7	B	T/M

Q = RGIT Quay B = Aberdeen Bay T = Thermal E = Engine M = Motion sickness

3. TRIALS AND RESULTS

3.1 TRIAL 1 - CONDITIONS

The trial conditions were as follows:

Air Temperature	:	3.5 - 6.0^{o}C
Water Temperature	:	2.1^{o}C
Occupancy	:	39 persons (93%)
Location	:	RGIT Quay
Time	:	Winter (28/2/90)
Duration	:	60 minutes

3.2 PROCEDURE

3.2.1 Subjects

A total of 39 persons participated in the trial giving an occupancy of 93% (ie 39/42).

3.2.2 Dress

The subjects wore either survival suits (n = 11) and/or standard clothing (n = 28).

3.2.3 Trial Conduct

After body weighing and dressing in the clothing combination, each subject donned a "Duncan" lifejacket. (This particular lifejacket is of the fixed, inherently buoyant type and has a Department of Transport approval). The subjects then boarded the TEMPSC and all craft openings were securely shut. The TEMPSC inner air temperatures were measured prior to boarding. On securing all openings the engine was run at full speed with the propellor turning for 15 minutes, after which the engine rmp were reduced to approximately 50% of maximum. Recordings were made at 5 minute intervals during the first phase and at 10 minute intervals for the remainder of the test.

3.3 TRIAL 1 - RESULTS

3.3.1 Thermal comfort

All subjects reported feeling "thermally comfortable". The subjects reported however, that their lower limbs and particularly their feet were cold.

3.3.2 Body weight changes/sweat rate

Since neither heat stress nor sweating were reported during the trial, post-trial body weighings were not undertaken and thus there are no results for these parameters.

3.3.3 Internal TEMPSC temperatures

The temperature profiles of the forward, midships and aft, upper and mid positions are shown in Figure 2. All sites demonstrated a progressive increase in temperature resulting in an overall average internal temperature of 22.6ºC (Figure 3).

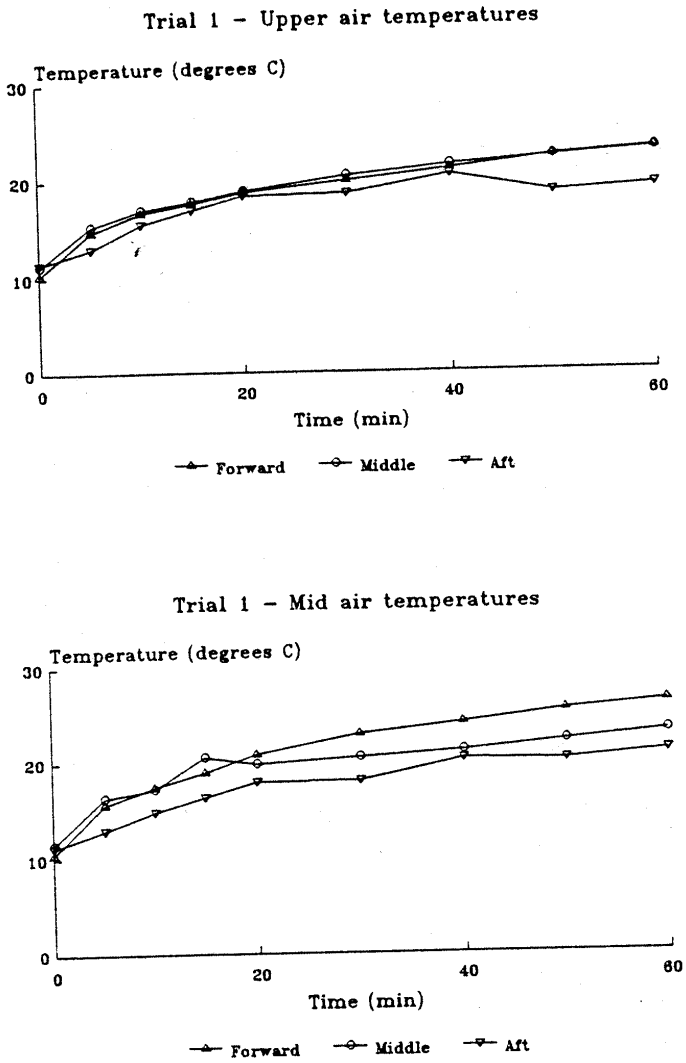


Figure 2
Trial 1 internal TEMPSC temperatures

3.3.4 Internal relative humidity

The effect on the internal relative humidity is illustrated in Figure 3. Relative humidity increased during the first 20 minutes to a level of 80%. The level then decreased to 60-70% (a level judged by the subjects as “comfortable”).

3.3.5 Internal globe temperature

The globe temperatures recorded during the trial are illustrated in Figure 3. Globe temperature indicated a gradual rise as the trial proceeded, to a level of 24ºC after one hour.

3.3.6 Inner craft air movement

The recorded air velocity within the craft was consistently between 0.6 and 0.9 sm^{-1}.

3.3.7 Gas analysis

3.3.7.1 Carbon Dioxide

The level of carbon dioxide was not measured during this trial.

3.3.7.2 Carbon Monoxide

Carbon monoxide was detected after 10 minutes and peaked at 6ppm with full revs of the engine. Reduction in engine revs resulted in a decrease in carbon monoxide level to 3ppm. The results are illustrated in Figure 3.

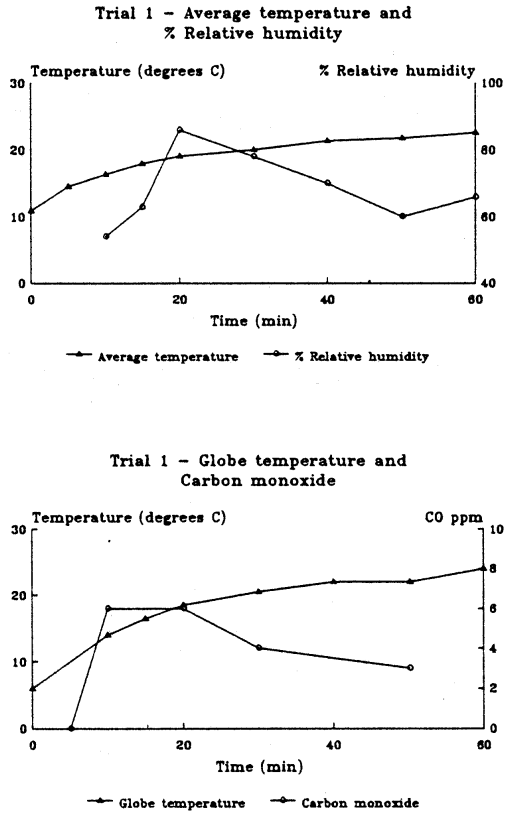


Figure 3
Trial 1 internal atmospheric conditions

3.4 TRIAL 2 - CONDITIONS

The trial conditions were as follows:

Air temperature	:	14.4 - 15.0°C
Water temperature	:	13.8 - 16.0°C
Occupancy	:	31 persons (74%)
Location	:	RGIT Quay
Time	:	Summer (22/8/90)
Duration	:	90 minutes

3.4.1 Subjects

A total of 31 persons participated in the trial giving an occupancy of 74% (ie 31/42). Results were obtained on 29 subjects (4 female and 25 male).

3.4.2 Dress

Subjects were randomly allocated either standard clothing, an insulated survival suit or a non-insulated survival suit. The following table indicates the clothing type and number of subjects:

Clothing	**Number of subjects**
Standard clothing	13
Insulated suit	8
Non-insulated suit	8

3.4.3 Trial Conduct

A similar procedure to that described in 3.2.3 was adopted.

3.5 TRIAL 2 - RESULTS

3.5.1 Thermal comfort

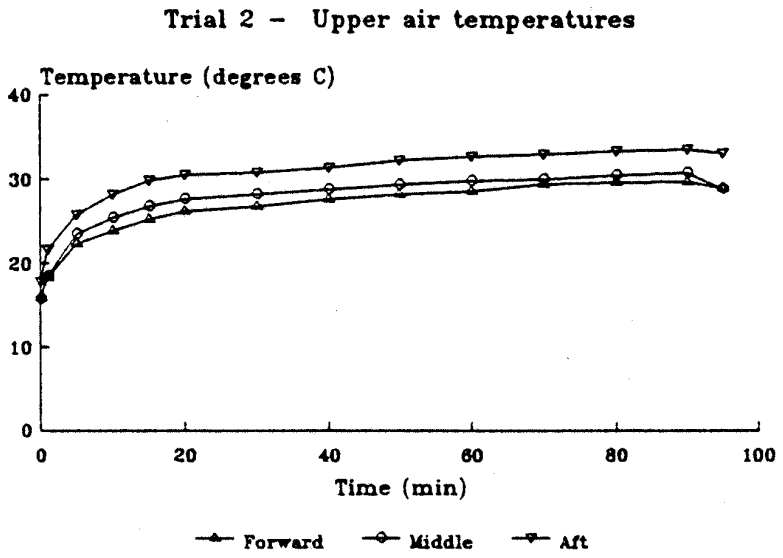
All subjects reported feeling thermally comfortable for the first 10-15 minutes although they reported an obvious rise in temperature in the craft. Most occupants started to sweat after 20 minutes and by 60 minutes most reported feeling thermally uncomfortable and that the environment was humid and oppressive.

3.5.2 Body weight changes/sweat rate

The subject's characteristics and changes in body weight according to the type of clothing worn are given in Appendix 1. Body weight loss was 0.35 ± 0.28kg in standard clothing (n = 13); 0.31 ± 0.18kg in the non-insulated suit (n = 8); and 0.48 ± 0.30kg in the insulated suit (n = 8). (Values are means $\pm$ standard deviation).

3.5.3 Internal TEMPSC temperatures

The temperature profiles of the forward, midships and aft, upper and mid positions are shown in Figure 4. Immediately after closing all hatches the average temperature increased from 16.6ºC to 20.2ºC as shown as Figure 5. Temperatures demonstrated a progressive rise at all sites and an equilibrium temperature as indicated by the 'average' temperature of 31-32ºC was reached after some 90 minutes. The air temperature in the midships and aft regions was warmer than that measured in the forward part of the craft.



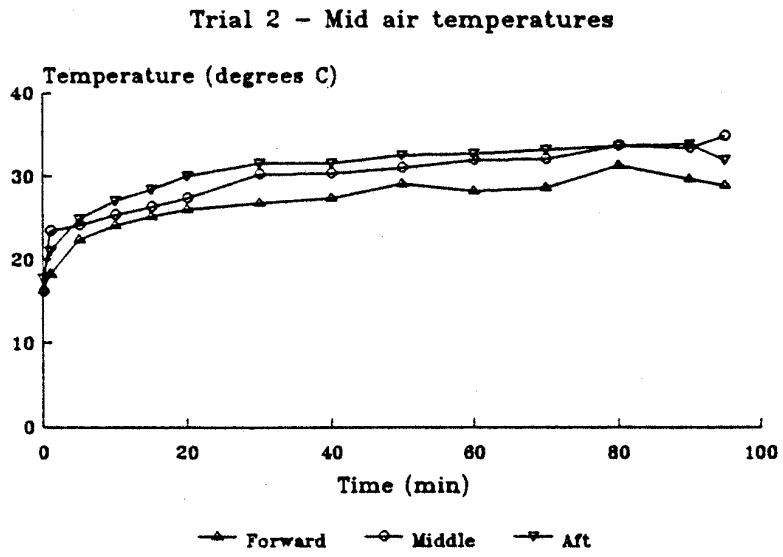


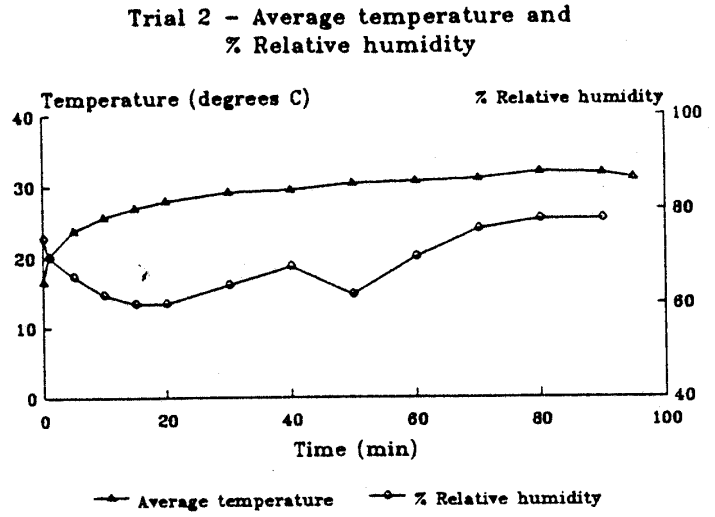
Figure 4
Trial 2 internal TEMPSC temperatures

3.5.4 Internal relative humidity

The effect on the internal relative humidity (% RH) is illustrated in Figure 5. Relative humidity decreased after closing the hatches and then progressively increased after 50 minutes reaching a level of 78% after 90 minutes.

3.5.5 Internal globe temperature

The globe temperature increased from 18.0°C to 30.5°C during the course of 40 minutes. The results are plotted in Figure 5. The result indicated that an equilibrium temperature of 30-31°C was likely.



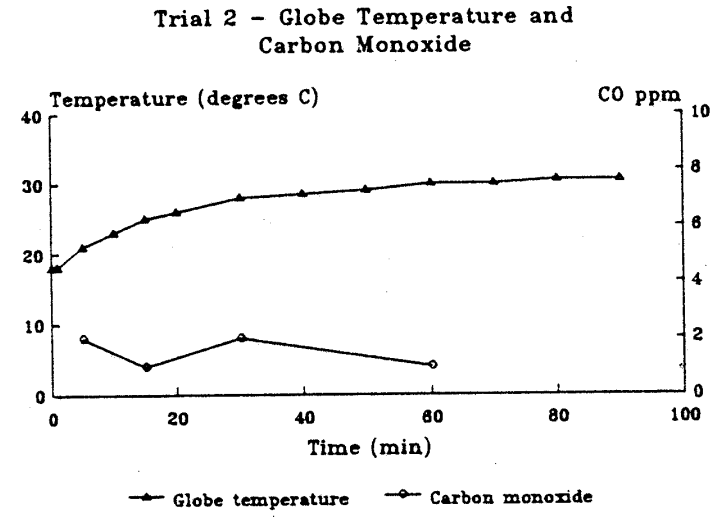


Figure 5
Trial 2 internal atmospheric conditions

3.5.6 Inner craft air movement

The air movement within the TEMPSC was initially recorded at 0.9ms^{-1}, then at 0.7ms^{-1} for the duration of the trial.

3.5.7 Gas analysis

3.5.7.1 Carbon Dioxide

The level of carbon dioxide was not measured during this trial.

3.5.7.2 Carbon Monoxide

Carbon monoxide was measured at 2ppm after 5 minutes. After 60 minutes carbon monoxide was not detected.

3.6 TRIAL 3 - CONDITIONS

The trial conditions were as follows:

Air temperature	:	17ºC
Water temperature	:	12ºC
Occupancy	:	42 persons (100%)
Location	:	RGIT Quay (Summer)
Time	:	Summer (9/9/90)
Duration	:	60 minutes

3.6.1 Subjects

A total of 42 persons participated in the trial giving an occupancy of 100%.

3.6.2 Dress

Subjects were randomly allocated either standard clothing, an insulated survival suit or a non-insulated survival suit. The following table indicates the clothing type and number of subjects:

Clothing	**Number of subjects**
Standard clothing	19
Insulated suit	6
Non-insulated suit	17

3.7 TRIAL 3 - RESULTS

3.7.1 Thermal comfort

The subjects thermal comfort was not recorded during this trial.

3.7.2 Body weight changes/sweat rate

The subject's characteristics and changes in body weight according to the type of clothing worn are summarised in Appendix 1. Body weight loss was 0.25±0.20kg in standard clothing (n = 19); 0.26±0.15kg in the non-insulated suit (n = 17); 0.21±0.01kg in the insulated suit (n = 6). (Values are means ± standard deviation).

3.7.3 Internal TEMPSC temperatures

The temperature profiles of the forward, midships and aft, upper and mid positions are shown in Figure 6. Immediately prior to boarding the average inner temperature was 16-17°C. On completion of boarding all sites demonstrated a rapid rise in temperature. The temperatures measured in forward and midships positions were similar to those recorded aft although the aft lower position close to the engine demonstrated temperatures of 37.0°C. The average temperature is shown in Figure 7. After a period of 60 minutes an equilibrium temperature of the order of 35°C was indicated.

3.7.4 Internal relative humidity

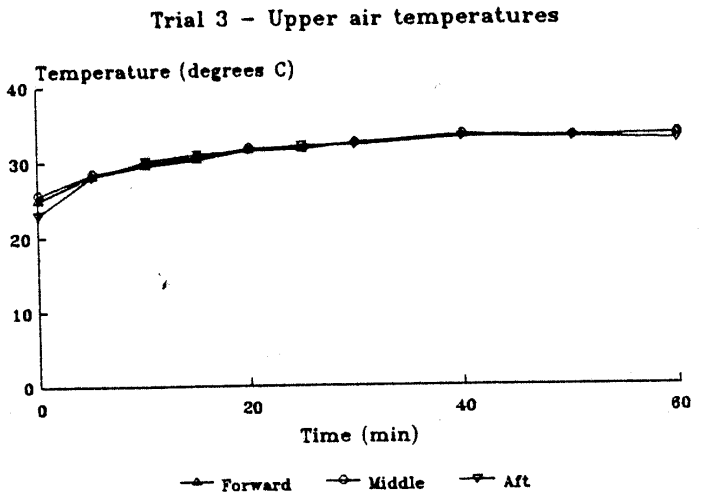
The effect on the internal relative humidity is illustrated in Figure 7. Relative humidity decreased from 86% at the start, to 74% on shut-down of the TEMPSC, then to a level of 60% after 20 minutes. The relative humidity then increased progressively to a level of 74% after 60 minutes.

3.7.5 Internal globe temperature

The globe temperatures recorded during the trial are illustrated in Figure 7. Globe temperature increased progressively from 16.9°C before shut-down to an equilibrium level of 33.2 - 33.4°C.

3.7.6 Inner craft air movement

The air movement was initially recorded at 0.7 - 0.85m.s^{-1} after the first 5 minutes of the trial and remained at that level during the trial.



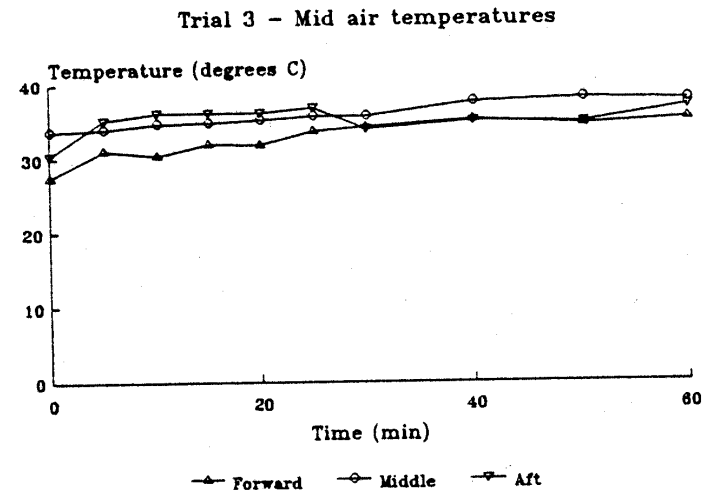


Figure 7
Trial 3 internal atmospheric conditions

3.7.7 Gas analysis

3.7.7.1 Carbon Dioxide

On completion of boarding the level of carbon dioxide was measured as 1.2%. Carbon dioxide concentration increased progressively to 3.5 - 3.6% which was reached after 40 minutes and sustained until the end of the trial after 60 minutes.

3.7.7.2 Carbon Monoxide

Five minutes after completion of boarding, carbon monoxide was measured as 5ppm. The level peaked at 8ppm after 15 minutes and subsequently decreased to 0ppm

after 25 minutes. Carbon monoxide was not detected during the remaining 35 minutes.

3.8 TRIAL 4 - CONDITIONS

The trial conditions were as follows:

Air temperature	:	19 - 20°C
Water temperature	:	17.5°C
Occupancy	:	31 persons (78%)
Location	:	RGIT Quay
Time	:	Summer (29/8/90)
Duration	:	10.5 minutes

3.8.1 Subjects

A total of 31 persons participated in the trial giving an occupancy of 78%.

3.8.2 Dress

The 31 subjects were marshalled together and informed that a simulated evacuation was to take place. The subjects then donned inherently buoyant lifejackets and were escorted to the TEMPSC and directed to their seats. The doors were closed and the trial conducted for a close down period of 8 minutes. The trial was undertaken to assess the possible contribution to the thermal conditions that may result during the first few minutes of an evacuation performed in anger.

3.9 TRIAL 4 - RESULTS

3.9.1 Thermal comfort

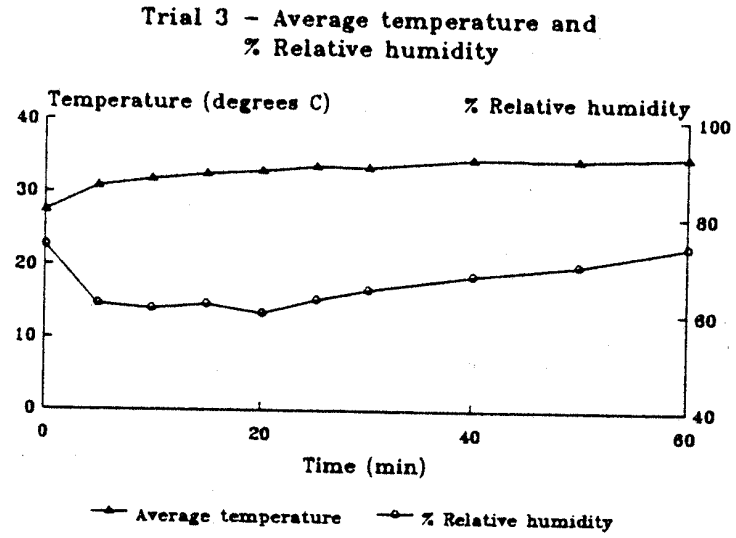
The subjects thermal comfort was not recorded during this trial. No adverse reports of thermal discomfort were offered.

3.9.2 Body weight changes/sweat rate

Due to the short duration of this trial pre and post body weights were not included in the study.

3.9.3 Internal TEMPSC temperatures

Figure 8 shows changes in internal temperature. The average temperature inside the TEMPSC prior to boarding was 22-23°C. On completion of boarding the average temperature had increased to 25°C (see Figure 9). After 8 minutes the average temperature had increased to 28.3°C. The globe temperature increased from 21.5°C to 26.8°C over a period of 8 minutes



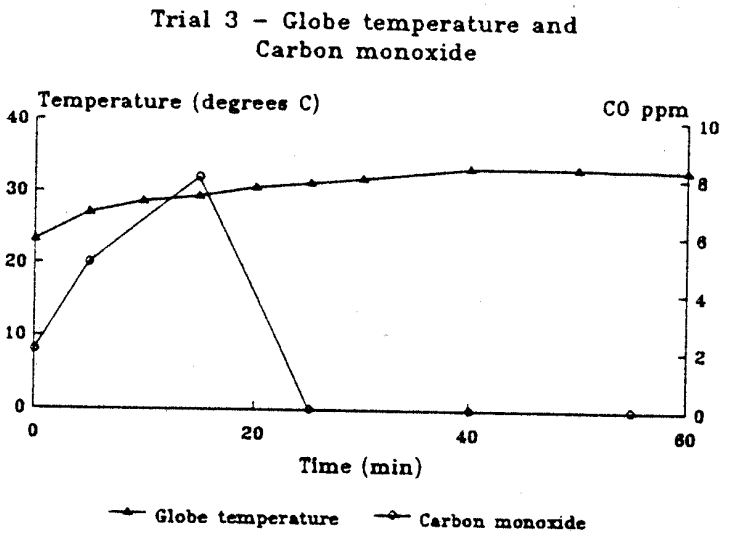


Figure 8
Trial 4 internal TEMPSC temperatures

3.9.4 Internal relative humidity

The effect on the internal relative humidity is illustrated in Figure 9. Relative humidity increased from 66% to a level of 76-78% after 8 minutes.

3.9.5 Inner craft air movement

The air movement within the TEMPSC was consistently measured at 0.7ms^{-1} throughout the trial.

3.10 TRIAL 5 - CONDITIONS

The trial conditions were as follows:

Air temperature	:	21 - 24°C
Water temperature	:	17.5°C
Occupancy	:	2 persons
Location	:	RGIT Quay
Time	:	Summer (27/8/90)
Duration	:	60 minutes

3.10.1 Subjects

A total of 2 persons participated in the trial giving a minimal occupancy of 5%.

3.10.2 Dress

No control was exercised on subject dress since the objective of this trial was to evaluate the thermal conditions arising from the TEMPSC engine system.

3.10.3 Trial Conduct

The 2 subjects (coxswain and crewman) entered the craft and ran the engine at full speed for 15 minutes. After the initial escape phase simulation the engine revs were reduced to 50% maximum (2,000 rpm) and the trial continued for a further 45 minutes.

3.11 TRIAL 5 - RESULTS

3.11.1 Thermal comfort

The subjects' thermal comfort was not recorded during this trial.

3.11.2 Body weight changes/sweat rate

The trial was undertaken to evaluate the thermal input from the engine and environment and so the subjects' body weights were not measured.

3.11.3 Internal TEMPSC temperatures

The upper and mid air temperatures are shown in Figure 10. Immediately prior to starting the engine the air temperature inside the TEMPSC was 22-23°C. After running the engine at full revs for 15 minutes the average temperature was 27.9°C. On completion of the trial the average temperature had increased to 30.3°C. Average values are illustrated in Figure 11. The globe temperature increased from 24°C to 31°C during the one hour trial.

3.11.4 Internal relative humidity

The effect on the internal relative humidity is shown in Figure 11. The relative humidity was constantly measured at 60-70%.

3.11.5 Inner craft air movement

The air movement within the TEMPSC was measured at 0.7ms^{-1} throughout the trial.

3.11.6 Gas analysis

3.11.6.1 Carbon Dioxide

After a period of 5 minutes an internal level of carbon dioxide of 0.4% was recorded. The level of carbon dioxide decreased to 0.15% after 30 minutes and was sustained at that level for the remainder of the trial.

3.11.6.2 Carbon Monoxide

Carbon monoxide was not detected during the trial.

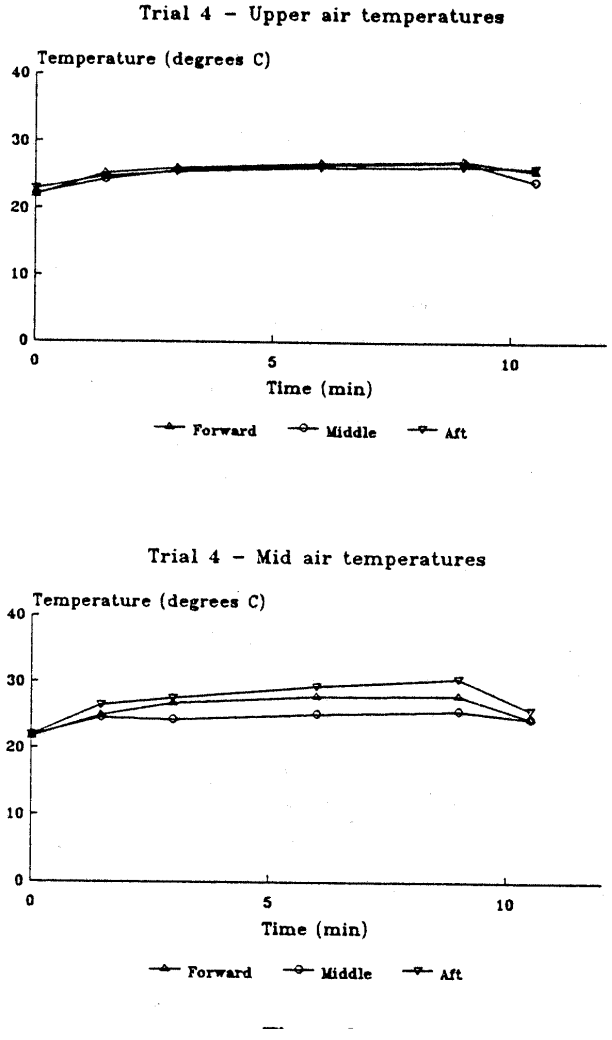


Figure 10
Trial 5 internal TEMPSC temperatures

3.12 TRIAL 6 - CONDITIONS

The trial conditions were as follows:

Air temperature	:	17 - 18°C
Water temperature	:	13°C
Occupancy	:	42 persons
Location	:	Aberdeen Bay
Weather	:	Beaufort Force 6-7
Time	:	Summer (14/9/91)
Duration	:	45 minutes

3.12.1 Subjects

A total of 42 persons (10 female and 32 male) participated in the trial giving an occupancy of 100% (42/42).

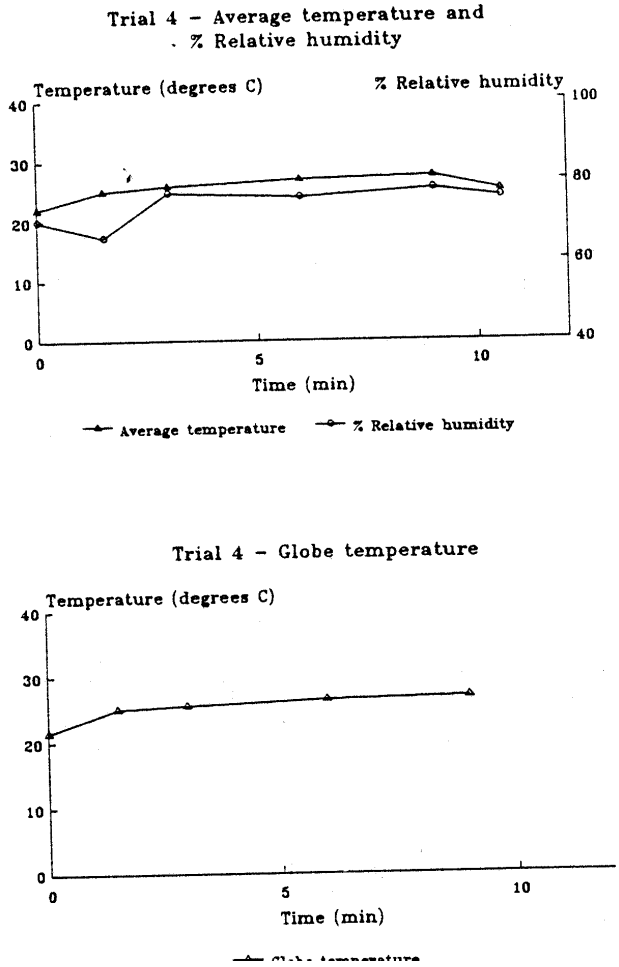


Figure 11
Trial 5 internal atmospheric conditions

3.12.2 Dress

Subjects were randomly allocated either standard clothing, an insulated survival suit or a non-insulated survival suit. Individuals in each type of suit were not grouped but were spaced evenly around the TEMPSC. The following table indicates the clothing type and number of subjects:

Clothing	Number of subjects
Standard clothing	15
Insulated survival suit	12
Non-insulated survival suit	13

Data from 2 subjects was incomplete. Therefore, they have not been included in further analysis.

3.12.3 Trial conduct

This trial was conducted to investigate the effects of taking a fully laden TEMPSC to sea, with the occupants exposed to possible thermal stress as well as motion.

3.12.4 Safety considerations

The following safety contingency was included.

The trial had been approved by the Joint Ethical Committee of Grampian Health Board and the University of Aberdeen. A medical practitioner was present throughout the trial.

The subjects informed consent was obtained after explaining the nature of the trial to them. Their ability to cease involvement in the trial for any reason was explained. The subject information sheet is shown in Appendix 3.

A tender vessel was positioned alongside the TEMPSC to transfer personnel if required. An additional TEMPSC including extra crew was available to assist if transfer/rescue was required.

The Department of Transport was informed and the appropriate exemption obtained. The conditions outlined in this exemption were followed. The exemption is recorded in Appendix 2.

The local headquarters of HM Coastguard were informed of the trial together with the harbour authorities.

3.12.5 Thermal comfort (method)

Thermal comfort was measured using a modified “Bedford” scale (1). Subjects were required to assess their comfort on a 7-point scale, given below:

1 Much too warm

2 Just too warm

3 Comfortably warm

4 Neutral

5 Comfortably cool

6 Just too cool

7 Much too cool

Each subject was asked to select the option which best described his comfort at the given point in time.

Subjects were asked to assess comfort on 3 occasions; a control assessment was made when they were first dressed in the appropriate clothing selected for the trial, while in a room at normal temperature in the range of 15-20^{o}C ("pre-board"); the second assessment was made immediately after the launch of the TEMPSC ("board + 3 minutes") in the closed environment; the third assessment was planned to be made 20 minutes after the launch, when the TEMPSC slowed down and was positioned hove to the waves ("final").

3.13 TRIAL 6 - RESULTS

3.13.1 Thermal comfort

Thirty nine subjects completed the "pre-board" and "board + 3 minutes" thermal comfort assessments; data was not collected from the coxswain and mechanic.

An assessment of thermal comfort was not made after 20 minutes at sea in the TEMPSC due to the impracticality of collecting data when half of the personnel were unwell. However, 19 of the original group of 39 subjects completed a third assessment retrospectively, on return to the Quay. This group represented a random sample of the total group. The 19 subjects were asked to remember how they felt after 20 minutes at sea.

The results of the smaller sample are thus presented separately, following on from the results of the total group.

3.13.1.1 Total Group (n = 39)

The thermal comfort assessment for the total group is shown in Figure 12. After donning the trial clothing the majority of subjects (77%) reported being either "comfortably warm" or "neutral". Immediately after boarding and on closing TEMPSC hatches 74% of subjects felt either "comfortably warm" or "just too warm". After only 3 minutes the trend demonstrated a bias towards subjects reporting conditions being too warm.

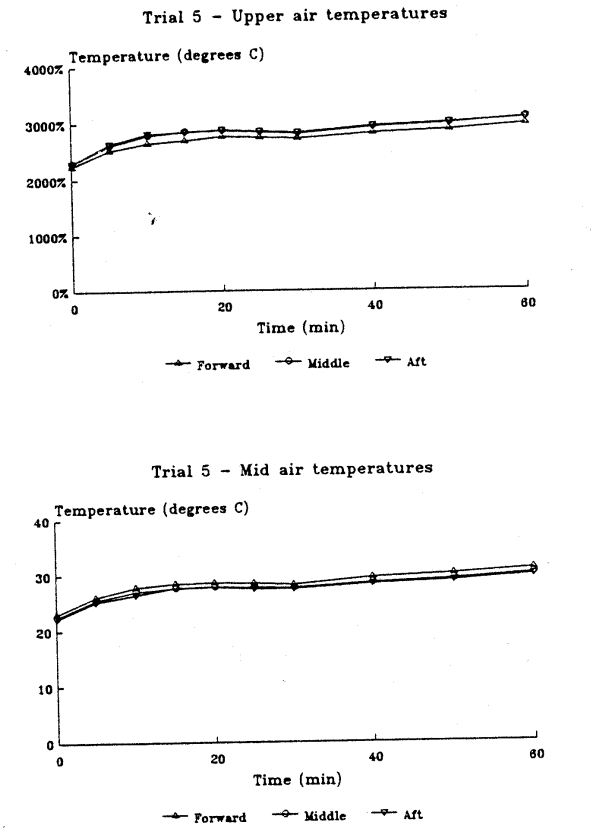


Figure 12
Thermal comfort votes during sea trial 6 (39 subjects)

3.13.1.2 Sample Group (n = 19)

Complete data is available for only 19/39 (40%) of the subjects assessed. The thermal comfort assessment for these subjects is shown in Figure 13. The majority of subjects (16/19) reported feeling comfortably warm, neutral or comfortably cool immediately before entering the TEMPSC. After 3 minutes the majority of subjects (15/19) reported feeling comfortably warm or warmer. The retrospective assessment of thermal comfort showed that 95% (18/19) reported being much too warm during the sea phase.

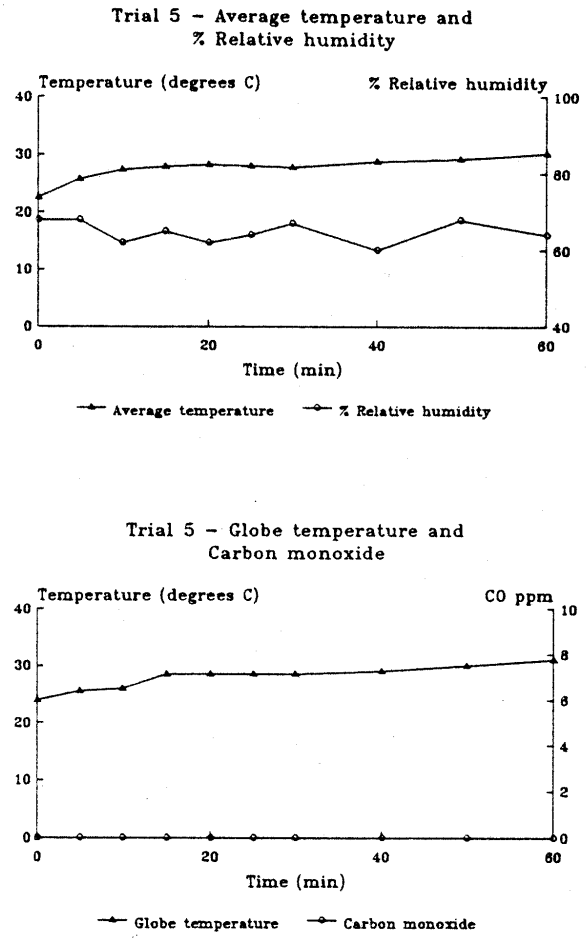


Figure 13
Thermal comfort vote during sea trial 6 (19 subjects)

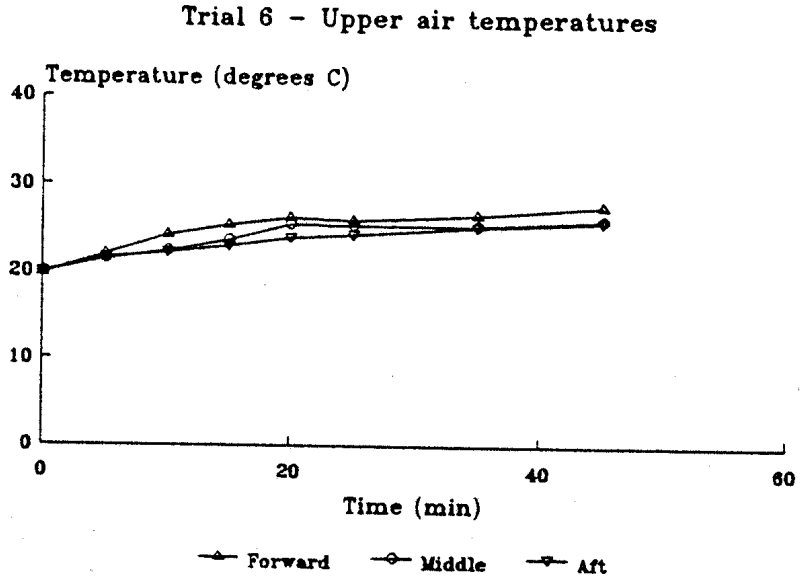
3.13.2 Body weight changes/sweat rate

The subjects' changes in body weight according to the type of clothing worn are summarised in Appendix 1. Body weight loss was 0.26±0.12kg in standard clothing (n = 14); 0.40±0.57kg in the non-insulated suit (n = 13); and 0.82±0.94kg in the insulated suit (n = 12). (Values are means ± standard deviation). The data is based on a sample of 39 subjects where complete data was available. Three subjects reported that they were sweating after donning the clothing. After 3 minutes of being inside the TEMPSC 17 out of 39 subjects reported they were sweating.

3.13.3 Internal TEMPSC temperatures

The temperature profiles of the forward, midships and aft upper and mid positions are shown in Figure 14. The average temperature is shown in Figure 15. Immediately prior to boarding the TEMPSC the average internal temperature was 19.7°C. During boarding over a period of 10 minutes the average temperature increased by 3.5°C to 23.2°C. The next period of motoring at full speed was associated with a further rise in temperature of 2.1°C to 25.4°C. The engine rpm was reduced and a slight decrease in temperature was observed. The final average

temperature measured after 45 minutes was 27.0ºC. Thus over 45 minutes the average temperature had increased by 7.3ºC. An equilibrium temperature was not reached.



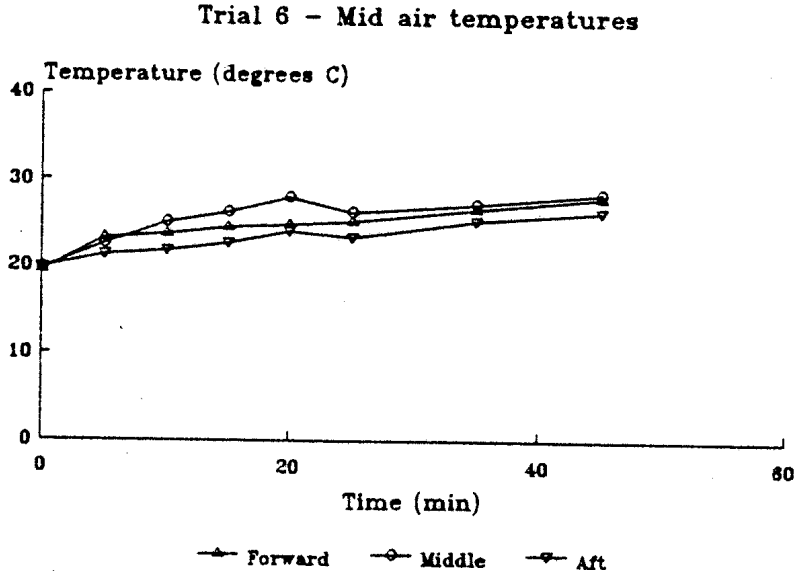


Figure 14
Trial 6 internal TEMPSC temperatures

3.13.4 Internal relative humidity

The effect on the internal relative humidity is illustrated in Figure 15, equilibrating between 70 and 80%.

3.13.5 Internal air temperature

The globe temperatures recorded during the trial are illustrated in Figure 15. Globe temperature increased progressively from 20°C to 26.2°C after 35 minutes.

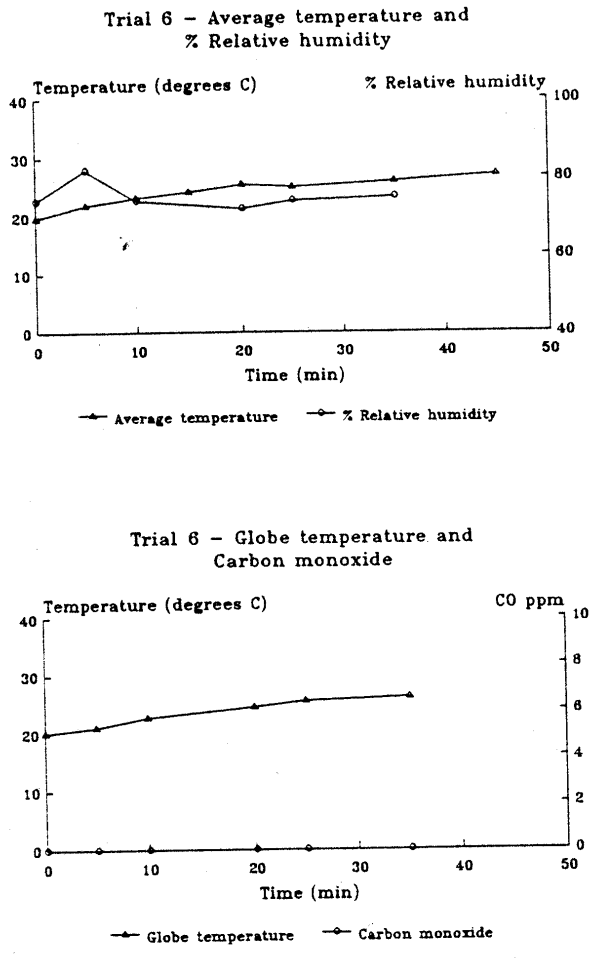


Figure 15
Trial 6 internal atmosphere conditions

3.13.6 Inner craft air movement

The air movement in the craft was consistently recorded at 0.1ms^{-1}.

3.13.7 Gas analysis

3.13.7.1 Carbon Dioxide

Carbon dioxide was measured at a level of 2.5% after 25 minutes.

3.13.7.2 Carbon Monoxide

Carbon monoxide was not detected during the trial.

3.13.8 Motion sickness

Forty one subjects completed a questionnaire at the end of the sea trial. The questionnaire is recorded in Appendix 4 and was based on a questionnaire developed by Lawther and Griffin (9). Each question will be considered:

Question 1 - During this session how did you feel?

Fifty one percent of TEMPSC occupants reported that they felt "all right", 32% reported feeling "unwell", 5% reported being "quite ill" and 12% responded that they felt "dreadful". Overall 49% reported some degree of seasickness.

Question 2 - If you felt unwell, how soon after departure from Platform?

All subjects who felt unwell or ill (ie 49% - 20/41) did so within ½ hour of leaving the platform.

Question 3 - When did you feel unwell?

Thirty percent reported that illness corresponded with transit from the harbour to the exercise site. The majority of those that were ill (52% - 12/23) reported that the exercise was responsible for their illness. Eighteen percent of subjects felt ill during those parts of the exercise when no forward motion of the boat occurred.

Question 4 - Did you vomit?

Twenty nine percent of the occupants (12/41) vomited.

Question 5 - Are you prone to motion sickness?

Seven percent of the subjects reported being susceptible to motion sickness.

Question 6 - Have you taken seasickness tablets?

Although no anti-motion sickness preparations were issued 5% (2/41) of the subjects had taken anti-seasickness tablets on their own volition.

Question 7 - Are you under any medication?

None of the subjects were on any other medication.

Question 8 - Have you during the past 24 hours partaken of:

(i) 2 or more alcoholic drinks

(ii) spicy food.

Seventy six percent of the subjects reported having consumed some alcohol while 24% had eaten spicy food in the past 24 hours.

Question 9 - How old are you?

Seventy six percent of the subjects were 18-30 years, 20% were 31-40 years and 4% were over 40 years of age.

Question 10 - Subject Gender

Seventy six percent of the subjects were male and 24% were female.

Question 11 - Are you a regular sea traveller?

Twelve percent of the subjects reported that they were regular sea travellers. Eight eight percent reported that they were not.

Question 12 - What factors may have caused your illness?

Responses to this question were given by 21 subjects, some gave more than one answer. The following results were obtained:

TEMPSC motion	-	11 responses
Individual's movement	-	1 response
Heat	-	11 responses
Vibration	-	2 responses
Diesel fumes	-	4 responses
Other vomiting	-	9 responses

4. ANALYSIS

4.1 THERMAL CONDITIONS

4.1.1 Trial Conditions

A summary of trial conditions is shown in Table 1. Trials were designed to evaluate the thermal environment within the TEMPSC under summer and winter conditions. Consideration was given to both internal and external elements. The internal elements may be considered as that contribution derived from the prevailing weather conditions.

4.1.2 Temperature

The series of 6 trials conducted over summer and winter conditions encompassed a range of air temperatures between 3.5 and 24.0ºC and sea temperatures of 2.1 to 17.5ºC. Since these trials were undertaken under field conditions control could not be exercised over the exposure conditions. The average temperatures and temperature increases are recorded in Table 2.

Table 2
Average temperature and temperature increase from the start of each TEMPSC trial

	Average temperature (0ºC)			Temperature increase (0ºC)		
Trial	**0 min**	**30 min**	**60 min**	**30 min**	**60 min**	**Season**
1	10.9	20.0	22.6	9.1	11.6	Winter
2	16.6	29.1	30.7	12.5	14.1	Summer
3	27.5	33.5	34.9	6.0	7.4	Summer
4	N/A	N/A	N/A	N/A	N/A	N/A
5	22.6	27.8	30.2	5.2	7.6	Summer
6	19.7	25.5	-	5.8	-	Summer

N/A = Not Applicable

4.1.2.1 Comparison of Trial 1 (Winter) and Trial 3 (Summer)

The average internal air temperatures for Trials 1 and 3 are shown in Figure 16, it can be seen that the initial average internal air temperature in the winter trial was 10.9ºC while an initial temperature of 27.5ºC was recorded in the Summer trial. After 30 and 60 minutes the average temperature had increased in Trial 1 to 20.0ºC and 22.6ºC and in Trial 3 to 33.5ºC and 34.9ºC respectively. Trial duration was identical (60 minutes) and occupancy was comparable (93% vs 100%). The results suggest that at full occupancy, equilibrium temperatures of 21-22ºC and 34-35ºC for winter and summer conditions respectively are likely.

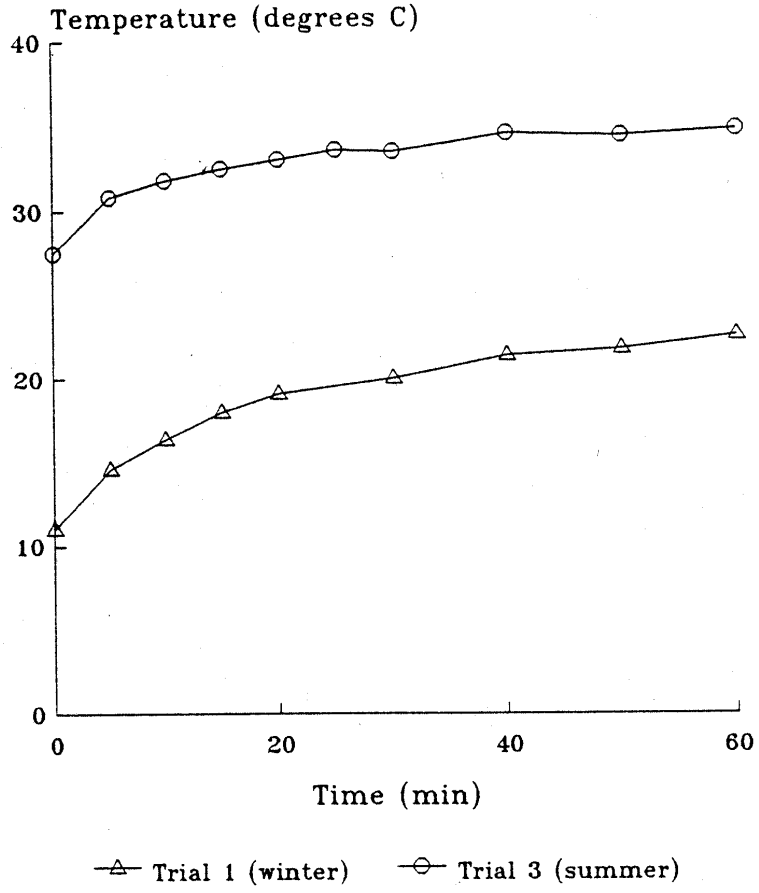


Figure 16
Comparison of average internal temperature
Trial 1 (winter) vs Trial 3 (summer)

4.1.2.2 Comparison of Trial 2 (Summer) and Trial 3 (Summer)

Trial conditions were similar in terms of external air and sea temperatures. The essential difference in the 2 trials related to the occupancy levels of 74% (Trial 2) and 100% (Trial 3). The average internal air temperatures are shown in Figure 17. Initial temperatures were 16.6°C and 27.5°C respectively. After 30 and 60 minutes the average temperature had increased to 29.1°C and 30.7°C in Trial 2 and to 33.5°C and 34.9°C respectively in Trial 3. Thus an equilibrium temperature of the order of 31-32°C was achieved for Trial 2 and 34-35°C for Trial 3. The increase in TEMPSC occupancy therefore, resulted in a higher equilibrium air temperature.

4.1.2.3 Comparison of Trial 3 (Summer) and Trial 5 (Summer)

This is a comparison of 100% occupancy (Trial 3) with only 5% occupancy (Trial 5). However, it should be noted that the ambient external air temperature was higher during Trial 5 (2-24°C) than during Trial 3 (16-17°C). At an occupancy of 100% the average internal temperature equilibrated at 34-35°C. Figure 18 shows that with an occupancy of only 5% (Trial 5) the average internal temperature increased from an initial value of 22.6°C, to 27.8°C after 30 minutes and 30.2°C

after 60 minutes. Thus, low occupancy resulted in lower internal temperatures despite a higher ambient external temperature.

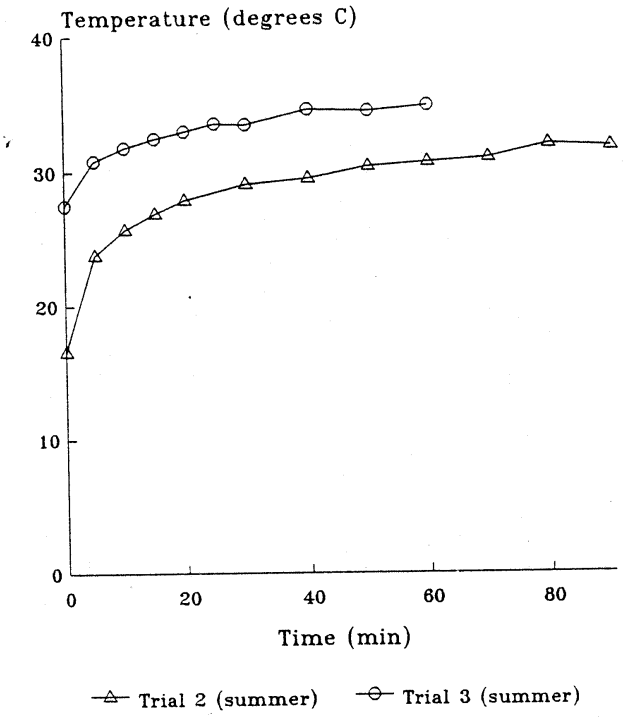


Figure 17
Comparison of averae internal temperature
Trial 2 (summer) vs Trial 3 (summer)

4.1.3 Relative humidity

4.1.3.1 Comparison of Trial 1 (Winter) and Trial 3 (Summer)

Relative humidity levels are recorded in Table 3. During the winter trial, humidity increased from 54% after 10 minutes to 78% after 30 minutes. During the summer trial relative humidity decreased from 74% to 65% over a similar time interval. In the winter trial relative humidity then decreased to 66% after 60 minutes, while an increase to 74% was observed in the summer trial.

Table 3
Relative humidity measured during TEMPSC trials

Relative Humidity (%)				
Trial	**0min**	**30min**	**60min**	**90min**
1		78	66	-
2	74		70	78
3	74	65	74	-
4*	70	-	-	-
5	68	67	64	-
6	74	74	-	-

** Trial duration 10.5 minutes*

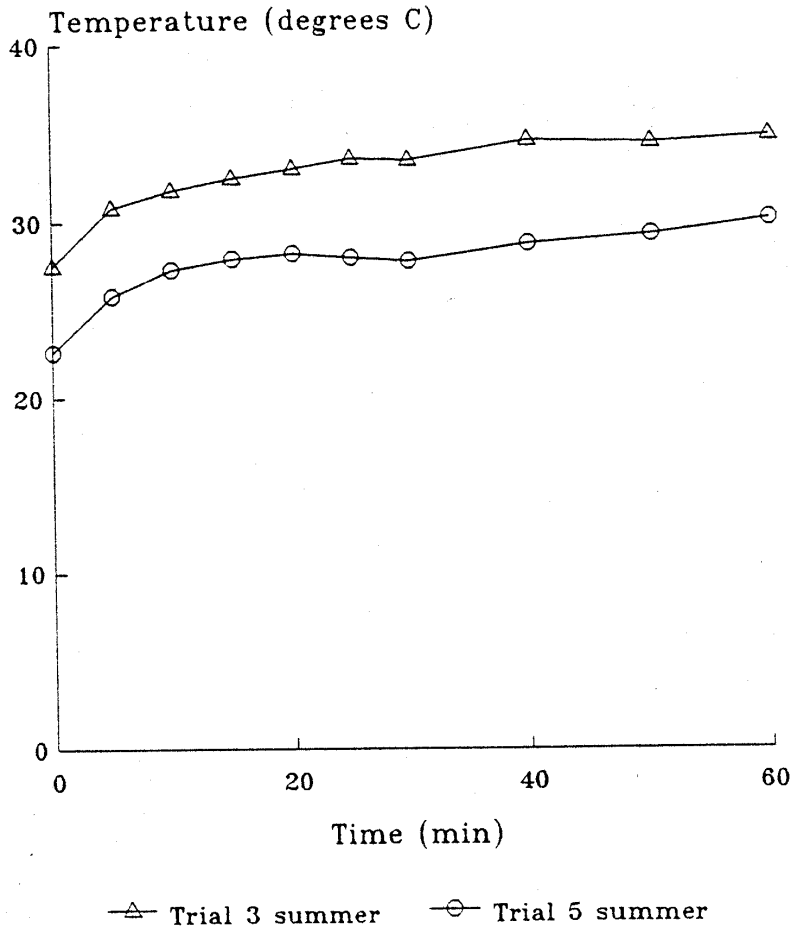


Figure 18
Comparison of average internal temperature
Trial 3 (summer) vs Trial 5 (summer)

4.1.3.2 Comparison of Trial 2 (Summer) and Trial 3 (Summer)

Values of relative humidity in these 2 trials were very similar during the first 60 minutes of the trials, despite the difference in occupancy (74% occupancy in Trial 2 and 100% occupancy in Trial 3). In Trial 2, humidity then increased again to 78% after 90 minutes. A similar pattern would have been expected if Trial 2 had continued for 90 minutes or more.

4.1.3.3 Comparison of Trial 3 (Summer) and Trial 5 (Summer)

Table 3 shows that the pattern of change of relative humidity varied depending upon the level of occupancy. At 100% occupancy in Trial 3 humidity was rising after one hour and is likely to have continued to rise up to values in the order of 80% if comparison is made with Trial 2. However, in Trial 5, at an occupancy of only 2 persons (5%) the lowest initial relative humidity value of 68% was recorded. Values then decreased during the trial, to a level of 64% after 60 minutes. A significant contribution to humidity was therefore attributable to the subjects.

4.1.4 Air movement

Table 4 shows that air movement measured at the centre of the TEMPSC was consistently less than 1.0m.s^{-1} in all trials. It is estimated that the engine of the TEMPSC draws air from inside the craft at a rate of approximately 6000 1.min^{-1}. This corresponds to approximately 7 air changes within the craft per hour.

Table 4
Air movement in TEMPSC trials

	Air movement (ms^{-1})		
Trial	**30 mins**	**60 mins**	**90 mins**
1	0.6	0.9	-
2	0.7	0.75	0.7
3	0.6	0.6	-
4*	0.7	-	-
5	0.7	0.7	-
6	0.1	-	-

** Trial duration 10.5 minutes*

4.1.5 Gas analysis

4.1.5.1 Carbon Dioxide

Carbon monoxide levels are summarised in Table 5.

Table 5
Carbon monoxide levels measured during TEMPSC trials

	Carbon Monoxide (ppm)		
Trial	**30 mins**	**60 mins**	**90 mins**
1	4	3	-
2	2	1	1
3	0	0	-
4*	-	-	-
5	0	0	-
6	-	-	-

** Trial duration 10.5 minutes*

In Trial 1, carbon monoxide increased from a level of 0ppm at the start of the trial to some 6ppm after 10 minutes. On reduction of engine revs the level of carbon monoxide progressively decreased to 3ppm by 60 minutes.

In Trial 2, carbon monoxide was not detected at the start of the trial. The highest recorded level of 2ppm was measured whilst the engine was operating at full revs. After 60 minutes and at reduced engine revs the level of carbon monoxide detected had decreased to 1ppm.

The level of carbon monoxide progressively increased in Trial 3 whilst the engine was at full revs, up to a value of 8ppm at 15 minutes. On reducing the engine revs the level of carbon monoxide decreased to an undetectable level over a 10 minute period.

During Trials 5 and 6 carbon monoxide was not detected, while carbon monoxide was not measured during Trial 4.

4.1.5.2 Carbon Dioxide

carbon dioxide was measured during Trial 3 and Trial 5 (summer conditions - 100% occupancy and 5% occupancy respectively)

In Trial 3, carbon dioxide was detected within minutes of closing the hatches and after 5 minutes a level of 1.2% carbon dioxide had been measured. The level progressively increased during the trial resulting in a final measured level between 3.5 and 3.6%.

In Trial 5, the level of carbon dioxide measured after 5 minutes was 0.4%. The level had reduced to 0.15% after 30 minutes and was maintained at this level for the duration of the trial. Compared to the levels measured during Trial 3 (100% occupancy) the level of 0.15% carbon dioxide attributable to 2 persons, if scaled up to 42 persons indicates a level of carbon dioxide close to that actually measured at full occupancy.

4.2 MOTION SICKNESS TRIAL

4.2.1 Comparison of internal TEMPSC temperature in Trial 3 (summer) and Trial 6 (summer)

These trials were conducted under similar external air and sea water temperatures and at identical occupancy levels. Trial 6 was undertaken at sea with a prevailing wind speed of 25 knots and with considerable wave splash over the canopy. The difference in wind speed may explain the lower average temperature inside the TEMPSC in Trial 6 compared to Trial 3, as shown in Figure 19. Average internal temperature rose during Trial 3, reaching an equilibrium temperature of 34-35ºC. However, during Trial 6 (rough water) an equilibrium internal temperature was not achieved, values still rising when the trial was discontinued.

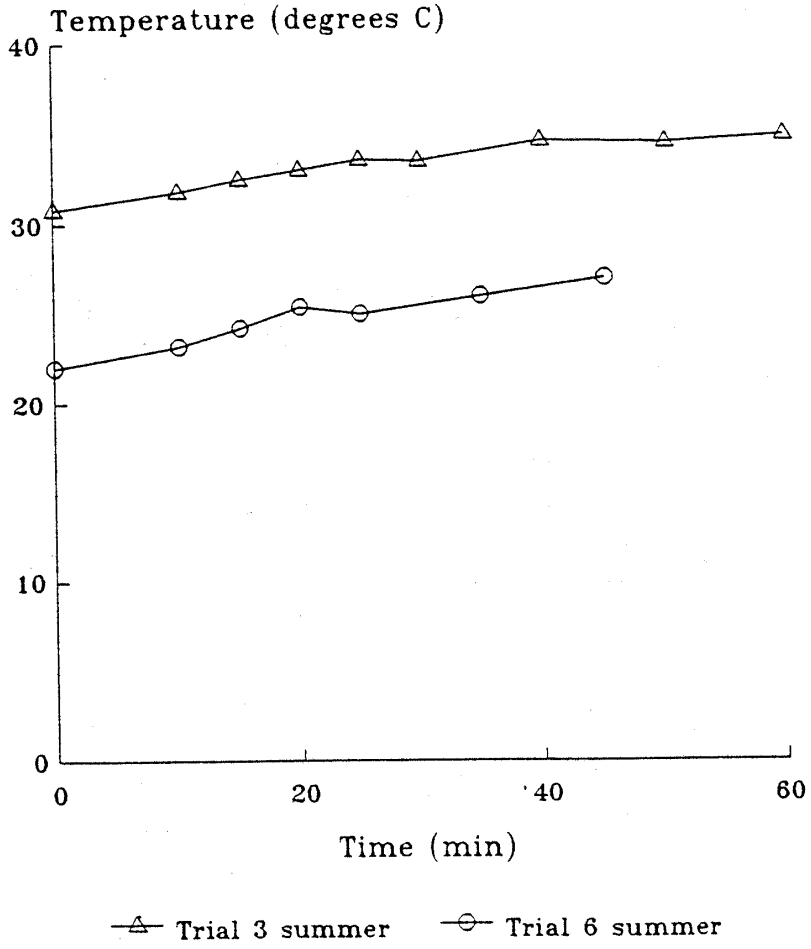


Figure 19
Comparison of average internal temperature
Trial 3 (summer) vs Trial 6 (summer)

4.2.2 Comparison of relative humidity in Trial 3 (summer) and Trial 6 (summer)

Relative humidity values are recorded in Table 3. Values were identical at the start of the trials and remained relatively constant and generally greater than 70%.

4.2.3 Comparison of air movement in Trial 3 (summer) and Trial 6 (summer)

The air movement inside the TEMPSC during the motion sickness trial was considerably less than that recorded during the other summer trial in calm conditions.

4.2.4 Comparison of body weight changes in Trial 3 (summer) and Trial 6 (summer)

Changes in body weight for Trials 3 and 6 are recorded in Appendix 1. At the same level of occupancy the body weight changes wearing each clothing assembly were greater during the summer trial at sea (Trial 6). Mean weight loss in standard clothing was 0.25kg in both trials, while in the insulated suit in Trial 6 mean weight loss was as high as 0.8kg.

4.2.5 Comparison of gas analysis in Trial 3 (summer) and Trial 6 (summer)

The level of carbon dioxide detected in the TEMPSC during the motion sickness trial (2.5%) was slightly less than that detected during the calm water trial (3.5%).

5. DISCUSSION

The trials described in the report have been undertaken to assess both the internal environment of a TEMPSC during evacuation and the possible effects on the occupants. However, a historical data suggests that the greatest risk to life will occur during transfer from a TEMPSC. The prime reason for performing these trials thus arose from the considerable debate concerning the necessity of recovering evacuees from TEMPSC as soon as possible. According to Landolt et al (8): "On the one hand, it was argued resources should be committed to developing techniques to recover TEMPSC occupants as an alternative to prolonged lifeboat confinement. On the other hand, it was argued that any transfer technique at sea is risky and having safely evacuated a drilling unit, evacuees should be left in the TEMPSC until sea conditions are sufficiently moderate to ensure safe recovery of personnel by conventional means". The essential question relates to how long occupants may be left in TEMPSC before their lives may be endangered either in terms of thermal stress, motion sickness or the inability to participate in rescue and recovery. There can be little doubt that seasickness in TEMPSC is a major problem (7, 8). It should be remembered, however, that severe weather conditions in the North Sea are typically prevalent for only 4-5% of the year.

The trials were designed to evaluate the initial conditions likely to arise during TEMPSC evacuation both in terms of the internal environment and motion sickness. Many TEMPSC have already been down-rated in terms of occupancy due to the physical problem of the survivors wearing large bulky survival suits and lifejackets. The initial trials (1-5 inclusive) were undertaken in calm water in both summer and winter to evaluate the effects of occupancy, state of dress and temperature. It was demonstrated that under winter conditions the thermal environment within the TEMPSC was more conducive to thermal comfort, lack of sweating and a comfortable equilibrium temperature. Under summer conditions however, (air temperature 16-17^{o}C; water temperature 12.0^{o}C) the equilibrium internal temperature was very warm (34-35^{o}C). Summer temperatures in excess of 16-17^{o}C are quite likely and given the commensurate likely increase in solar radiation, equilibrium internal temperatures in excess of 34-35^{o}C seem likely. All trials were performed with all hatches closed to simulate operational procedures for craft in rough water.

In recent years the concept of the provision of a survival suit and the wearing of such items during evacuation has been generally adopted. Thus, during the trials the effects upon thermal comfort and sweat rate wearing either standard clothing, a non-insulated survival suit or an insulated neoprene suit were studied. Reviews of TEMPSC evacuations (8) where survival suits have been worn have indicated many negative features such as increased sweating, heat stress, dehydration, poor comfort and ergonomics. The effect of wearing suits during thermal trials and the motion sickness trial was examined. Although the internal TEMPSC conditions were cooler during the rough water summer motion sickness trial (Trial 6) when compared to the complimentary thermal trial in summer conditions in calm water (Trial 3) the subjects body weight losses were significantly greater during the former. Anxiety and fear may thus have contributed to the increased sweat rates even though the exposure conditions were cooler. The lowest sweat rates were observed in those subjects wearing standard working clothing and no survival suit. If given the choice the

subjects reported that they would have been considerably more comfortable without survival suits of any kind.

There was a clear positive relationship between the increasingly unpleasant thermal conditions and the occupancy level. Practicalities however, must prevail regarding the design and "desired" occupancy level. If survival suits are not worn then higher levels of occupancy may be more acceptable. Another important aspect of occupancy level within the craft related to the levels of carbon dioxide detected. The level of 3-4% over a period of one hour was associated with numerous subjective reports of fatigue and headache. Over a prolonged period of survival this must be considered as another complicating factor affecting the long term survivability in a TEMPSC.

In all trials an air movement of less than $1ms^{-1}$ was detected, relating to an estimated 7 air changes per hour. The significant and progressive increases in internal TEMPSC humidity gives an indication of the inadequate air exchange and ventilation. Certainly the pervasive atmosphere of increasing temperature, humidity, carbon dioxide fumes, body odours and noise were all factors reported during the rough water trial (Trial 6) as contributory factors to motion sickness.

The motion sickness trial (number 6) was relatively short (total duration 45 minutes). The majority of occupants were well during the first 15 minutes whereby the TEMPSC was underway at full speed. During the post escape survival phase however, when the TEMPSC slowed down and pointed the bow into the weather the occupants rapidly became motion sick and vomiting was recorded.

The relatively rapid onset of motion sickness (less than 30 minutes) was very similar to that reported by survivors from the Vinland and Rowan Gorilla I incidents (8). Whilst it is not at all clear whether motion sickness actually contributes to death during TEMPSC survivability the physical and mental condition of the occupants is critical. It is essential that the TEMPSC is handled and operated correctly and that at least some of the occupants can assist during rescue and recovery. Capsize and dangerous actions must be avoided.

There is very little information available regarding the effects of seasickness on survival. Llano (10) has indicated that almost all aircrew water survivors during the second World War and Korean War were seasick for varying times in liferafts, on rescue craft and while floating in lifejackets. The incidence of seasickness according to Landolt et al (8) for TEMPSC incidents is reproduced in Table 6. They concluded that "the small size and flat bottom of a TEMPSC almost guarantee that most, if not all, occupants will become seasick shortly after launch unless the sea is exceptionally calm". There can be little doubt that the existing internal conditions likely to prevail during TEMPSC evacuation will present major problems to the occupants. Motion sickness is likely to affect most evacuees within minutes in all but calm conditions and the effects will be exacerbated under summer conditions even though the sea may be less rough. The poor ventilation necessitated by the requirement to maintain the watertight integrity of the TEMPSC will further compound the problem.

The prevention of the motion sickness has not been studied in these trials and for evacuation from offshore structures the requirement to evacuate will, by definition,

give very little time to plan and prepare. Furthermore, the anti motion sickness medication is likely to be positioned within the TEMPSC survival or medical equipment. Thus the evacuees will not have access to any prophylaxis until they enter the TEMPSC. Many medications require considerable time to exert any effects and the success of the oral route of administration must be questioned if many survivors are likely to vomit so soon after evacuation. Other routes of administration require to be evaluated and since the onset of motion sickness seems to be rapid in TEMPSC, attention should be focused on some form of intra muscular or subcutaneous preparation. A rapidly absorbed, fast-acting preparation for administration via the sublingual route may be valuable. A high circulating level is needed.

Table 6
Incident of seasickness during drilling rig evacuation by TEMPSC

	Drilling Rig			
	Alexander L Kielland	**Ocean Ranger**	**Vinland**	**Rowan Gorilla I**
Date of Incident	*27/28 Mar 80*	*15 Feb 82*	*22/23 Feb 84*	*15 Dec 88*
Weather conditions at time of incident	Winds 39 knots Waves 6-10m	Winds 75 knots Waves 13-18m	Winds 25-30 knots Waves 2.4 - 2.8m	Winds 50 knots Waves 12-15m
Weather conditions at time of rescue	Somewhat improved	Similar during attempted	Less than 2m	Winds 30-50 knots Waves 3.7 - 4.6m
Complement of personnel (in TEMPSC)	212 (59)	84 (30 or more)	76 (76)	27 (27)
Number of deaths (in TEMPSC)	123 (0)	84 (all)	1 (1**)	0 (0)
Case of death in TEMPSC	No deaths	Drowning/ Hypothermia	Heart attack	No deaths
Time in TEMPSC	Few hours	1 hour*	8 hours	22 hours
Incidence of seasickness in TEMPSC	Almost 100%	Not known	100%, 90% violently	78%

* Refers to an elapsed time between rig abandonment and unsuccessful rescue attempt by supply vessel, Seaforth Highlander. The TEMPSC was badly damaged, taking on water and capsized during the rescue attempt.

** To be technically correct, this victim was pronounced dead on arrival at the hospital.

Reproduced from Landolt et al (8)

In the motion sickness trial (number 6) the coxswain and crewman were deliberately chosen for their seasickness resistance. Both men rarely experienced seasickness in many years of going to sea either in the case of the former as a fisherman operating a small craft or the latter as a mate on a sailing vessel. Resistance to seasickness would be a clear and desirable attribute for offshore workers. Whilst this is not achievable the possibility of TEMPSC coxswain selection on the basis of lack of susceptibility to seasickness should be considered.

There can be little doubt that seasickness is a serious problem in small craft such as the TEMPSC where the incidence has typically been reported as 75% (49% in 45 minutes in Trial 6). Although there has only been one death reported in a TEMPSC prior to rescue, which cannot be attributed directly to seasickness, other factors may have been involved. The latest trials have certainly demonstrated the complicating factor of thermal stress. Survivors must face the problem of dehydration arising from both vomiting per se and sweating. Given that some individuals demonstrated body weight changes of 1.5 - 2.0kg in only 45 minutes the thermal problems must be addressed. An individual weighing 80kg and losing 2kg per hour (ie 2-5%% of body weight per hour) could be in a very serious state in 5-6 hours. It is likely that the sweat rate would decrease with time (14) associated with elevated core temperature. The possibility for loss of life in a TEMPSC is therefore a real possibility even if the TEMPSC remains intact and ship shape. In addition to considering anti-seasickness preparations the prevention of serious dehydration and fluid replacement must be considered. The nature of the fluid replacement regime in terms of volume, frequency, constituents, osmolality and palatability have been extensively studied for endurance events and effects upon athlete performance (2, 6). Given the potentially high rates of fluid loss and dehydration the requirement for provision of rehydrating substances should be considered.

Since the TEMPSC is in universal use in the North Sea and it seems that TEMPSC will remain the primary means of evacuation, consideration should be given to how the survivability of occupant survivability. The conventional TEMPSC design almost predisposes towards seasickness in terms of the small enclosure with poor visual reference, and a seating arrangement allowing head and body movement.

In addition, the problem of odour, fumes, diesel, carbon monoxide and carbon dioxide has been highlighted. There is a clear requirement therefore to improve the ventilation and number and rate of air changes.

Heat stress has been described earlier and the practical ergonomic consideration together with the thermal penalty of the large insulated neoprene-type survival suit indicates that the continued use of such items during TEMPSC evacuation is not recommended. Improved ventilation may also assist in reducing heat stress. The deluge system, provided it is driven from the engine, may aid in removing heat although this was not studied in the trials undertaken.

The advent of the freefall lifeboat concept, whilst improving initial escape potential may also be worthy of comparative study with conventional TEMPSC in terms of post-escape survivability. The freefall lifeboats currently in use have many features that may benefit the survivor. These features include the provision of a more horizontal seating arrangement, full body restraint, head restraint and increased boat

volume per occupant. All these factors may have a significant bearing on survivability.

6. CONCLUSIONS

The following conclusions are drawn from the trials.

6.1 THERMAL CONDITIONS

The thermal conditions likely to arise within TEMPSC are conducive to thermal discomfort, heat stress, dehydration and poor performance of the occupants. Whilst contributing to heat stress per se subjects reported that the heat exacerbated their motion sickness. The resultant thermal condition was directly related to the occupancy level. The thermal conditions likely to prevail within the TEMPSC during winter conditions whilst being less stressful than those likely to be encountered during summer will still be associated with motion sickness and heat stress.

6.2 TEMPSC DESIGN

The design of conventional TEMPSC widely in use contribute to the poor conditions within the TEMPSC. Factors of particular importance are: 1) seating, 2) body and head movement, 3) seat restraint, 4) poor ventilation, 5) odours and smells, 6) upright posture, 7) lack of visual reference, 8) lack of climatic control/environmental conditioning and 9) overcrowding.

6.3 SURVIVAL SUITS / CLOTHING

The wearing of insulated neoprene style survival suits contributed significantly to heat stress.

6.4 OCCUPANCY

TEMPSC evacuation under summer conditions of full rated occupancy resulted in heat stress and significant thermal and motion sickness problems.

6.5 SURVIVOR MANAGEMENT

A clear requirement has been shown to exist for a rapidly acting, easy absorbed anti-motion sickness preparation. In addition a requirement has been shown for a fluid replacement schedule to be adopted.

6.6 COXSWAIN SELECTION

The 2 RGIT coxswains in the sea trial were not motion sick and did not report significant thermal stress. Resistance to motion sickness is a important TEMPSC coxswain attribute.

6.7 SURVIVAL TIME

Without due consideration to fluid replacement and management of motion sickness, and given the changes in body weight measured in the sea trial, the present study suggests that severe debilitation of TEMPSC survivors is likely to occur within 12-24 hours.

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APPENDIX 1

Subjects' Characteristics and Body Weight Changes; Trials 2, 3 and 6

TRIAL 2

Subject	Clothing	Height (m)	Surface Area (m^2)	Pre-Trial Weight (kg)	Post-Trial Weight (kg)	Change in Body Weight (kg)	Estimated Sweat Rate ($g.m^{-2}hr^{-1}$)
1	1	1.84	2.05	82.0	80.8	1.2	390
2	3	1.81	2.01	80.9	80.7	0.2	66
3	2	1.78	1.98	81.4	80.8	0.6	202
4	2	1.78	1.96	75.5	75.1	0.4	136
5	1	1.63	1.55	53.1	52.9	0.2	86
6	3	1.65	1.67	62.2	62.0	0.2	80
7	1	1.61	1.43	45.0	44.9	0.1	47
8	1	1.71	1.85	74.3	73.9	0.4	144
9	1	1.91	2.08	80.4	80.1	0.3	96
10	2	1.85	2.00	77.4	77.1	0.3	100
11	2	1.80	1.85	67.3	67.1	0.2	72
12	2	1.77	1.88	72.0	71.5	0.5	177
13	2	1.78	1.88	71.2	71.1	0.1	35
14	3	1.84	1.85	64.5	64.3	0.2	72
15	2	1.80	1.85	67.2	66.9	0.3	108
16	3	1.87	2.35	111.1	110.3	0.8	227
17	1	1.82	2.18	97.2	96.8	0.4	122
18	3	1.79	1.80	63.4	62.9	0.5	185
19	1	1.66	1.92	84.4	84.0	0.4	139
20	1	1.74	1.85	72.1	71.8	0.3	108
21	1	1.79	1.80	64.4	64.0	0.4	148
22	1	.71	1.91	79.5	79.2	0.3	105
23	1	1.77	2.31	117.5	117.5	0.0	0
24	3	1.79	1.98	80.0	79.6	0.4	135
25	3	1.92	2.10	82.0	81.5	0.5	159
26	2	1.69	1.71	62.5	62.4	0.1	39
27	3	1.85	1.98	75.3	74.3	1.0	337
28	1	1.82	2.20	99.2	98.9	0.3	91
29	1	1.78	1.82	66.3	66.1	0.2	73

Key to clothing:

1 = Standard Clothing
2 = Non-insulated survival suit
3 = Insulated survival suit

* female subjects

TRIAL 3

Subject	Clothing	Height (m)	Surface Area (m^2)	Pre-Trial Weight (kg)	Post-Trial Weight (kg)	Change in Body Weight (kg)	Estimated Sweat Rate ($g.m^{-2}hr^{-1}$)
1	1	1.85	2.06	82.01	81.25	0.76	369
2 *	1	1.72	1.80	67.89	67.59	0.30	167
3	1	1.79	2.01	81.41	80.73	0.68	338
4	2	1.77	1.95	77.96	77.83	0.13	67
5	1	1.70	1.80	68.64	68.56	0.08	44
6	3	1.77	1.94	76.36	76.00	0.36	186
7	2	1.73	2.04	85.04	84.88	0.16	78
8	3	1.72	1.79	66.95	66.70	0.25	140
9	1	1.83	1.82	70.04	69.88	0.16	88
10	2	1.75	1.90	69.95	69.76	0.19	100
11	1	1.70	1.95	80.24	80.07	0.17	87
12	3	1.75	1.86	75.21	74.95	0.26	140
13	2	1.78	1.98	84.46	84.08	0.38	192
14	2	1.80	1.99	81.46	80.96	0.50	251
15	1	1.84	1.89	70.92	70.85	0.07	37
16	3	1.84	1.99	76.68	76.55	0.13	65
17	3	1.83	2.00	76.74	76.67	0.07	35
18	1	1.76	1.93	77.04	76.92	0.12	62
19	2	1.78	1.80	64.03	63.99	0.04	22
20	1	1.71	1.68	58.43	58.23	0.20	119
21	2	1.77	1.84	67.79	67.69	0.10	54
22	2	1.78	1.96	78.01	77.60	0.41	209[1]
23	1	1.77	1.85	69.34	68.98	0.36	195
24	2	1.72	1.89	75.77	75.30	0.47	249
25	1	1.77	1.81	66.45	66.43	0.02	11
26	1	1.75	1.91	76.62	76.32	0.30	157
27	1	1.70	1.73	63.32	63.20	0.12	69
28	2	1.68	1.68	59.59	59.50	0.09	54
29	1	1.70	1.78	67.89	67.45	0.44	247
30	2	1.67	1.87	78.24	77.80	0.44	235
31	1	1.72	1.94	80.70	80.64	0.06	31
32	2	1.76	1.85	69.50	69.18	0.32	173
33	2	1.77	1.84	67.89	67.64	0.25	136
34	2	1.76	1.97	80.72	80.46	0.26	132
35	2	1.78	1.88	71.37	71.23	0.14	74
36	1	1.92	2.14	84.53	84.29	0.24	112
37	1	1.80	1.86	68.34	68.00	0.34	183
38	1	1.80	1.85	67.14	66.99	0.15	81
39 *	2	1.73	1.87	74.46	74.10	0.36	193
40 *	2	1.71	1.66	56.85	56.61	0.24	145
41 *	1	1.67	1.72	63.71	63.46	0.25	145
42	2	1.60	1.81	77.70	77.40	0.30	166

Key to clothing: 1 = Standard Clothing
2 = Non-insulated survival suit
3 = Insulated survival suit * female subjects

TRIAL 6

Subject	Clothing	Height (m)	Surface Area (m^2)	Pre-Trial Weight (kg)	Post-Trial Weight (kg)	Change in Body Weight (kg)	Estimated Sweat Rate ($g.m^{-2}hr^{-1}$)
1	2	1.72	1.79	65.77	65.60	0.17	127
2	1	1.71	1.67	58.10	57.70	0.40	319
3	2	1.71	1.78	67.12	66.77	0.35	262
4	3	1.79	2.04	86.37	85.00	1.37	895
5	1	1.64	1.71	64.86	64.73	0.13	101
6*	2	1.69	1.78	67.52	67.32	0.20	150
7	3	1.70	1.78	68.47	67.68	0.79	592
8	1	1.68	1.77	67.96	67.65	0.31	234
9	2	1.78	2.02	85.32	85.12	0.20	132
10	3	1.70	1.74	64.00	63.45	0.55	421
11	1	1.92	2.18	89.42	-	-	-
12	1	1.72	1.82	69.04	68.91	0.13	95
13	3	1.80	1.93	74.47	74.08	0.39	269
14	1	1.58	1.49	50.04	49.92	0.12	107
15*	2	1.82	2.08	87.00	86.86	0.14	90
16	3	1.69	1.68	59.20	58.91	0.29	230
17	1	1.60	1.48	47.52	47.41	0.11	99
18*	2	1.58	1.40	43.17	43.08	0.09	86
19*	3	1.70	1.78	67.45	66.89	0.56	419[3]
20	1	1.83	2.04	82.59	82.39	0.20	131
21	2	1.87	2.07	82.27	80.03	2.24	1443
22	1	1.79	1.98	78.63	78.33	0.30	202
23	1	1.64	1.66	61.00	60.74	0.26	209
24*	2	1.64	1.55	51.57	51.43	0.14	120
25*	3	1.70	1.77	67.54	67.39	0.15	113
26*	1	1.70	1.68	58.69	58.56	0.13	103
27*	2	1.77	1.85	69.14	69.04	0.10	72
28	3	1.77	1.86	69.92	66.33	3.59	573
29	1	1.73	1.88	73.92	73.58	0.34	241
30	2	1.76	1.82	66.87	66.40	0.47	344
31	3	1.80	1.93	74.44	73.95	0.49	339
32	1	1.76	1.92	76.29	75.88	0.41	285
33	2	1.84	2.00	77.05	76.60	0.45	300
34	3	1.77	1.86	71.90	71.15	0.75	538
35	1	1.86	2.04	79.61	79.32	0.29	190
36	2	1.91	2.20	89.57	89.13	0.44	267
37	3	1.77	2.02	83.88	83.05	0.83	548
38	1	1.80	2.16	96.63	96.19	0.44	272
39	2	1.69	1.68	59.23	59.02	0.21	167
40	3	1.75	1.78	63.93	63.80	0.13	97

Key to clothing: 1 = Standard Clothing
2 = Non-insulated survival suit
3 = Insulated survival suit * female subjects

APPENDIX 2

DoT Exemption

Department of Transport
Marine Office
Marine House
Blaikies Quay
Aberdeen AB9 2AZ

E X E M P T I O N

RGIT - TEMPSC

(1) The Secretary of State in exercise of his powers under Section 271(1) of the Merchant Shipping Act 1894 as substituted by Section 17 of the Merchant Shipping Act 1964 and under Section 28 of the Merchant Shipping (Safety Convention) Act 1949 respectively hereby exempts the following vessel, viz:-

WATERCRAFT MK II 8 METRE

from the provisions of the said Section 271(1) as so substituted and of the said Section 271(1) as so substituted and of Regulation 9 of the Merchant Shipping (Life-Saving Appliances) Regulations 1986, subject to the conditions set out in Paragraph 2 hereof, for the purpose, and only for the purpose of a Research Study Trip to commence on or about 14th September 1991 and to continue for a period of One Working Day. The geographical limits of the sea trials will be the RGIT Exercise Area off Aberdeen.

(2) This Exemption is subject to the following conditions:

(A) The number of persons onboard during the trial period shall not exceed 42.

(B) The said WATERCRAFT TEMPSC is to be accompanied throughout the trial trip by a 56 person TEMPSC crewed by 3 RGIT Instructors and having a Doctor in attendance.

(C) That the entire seawards operation takes place in daylight and fine weather.

(3) A list of all persons who will be onboard during the trial period shall be retained ashore by RGIT Survival Centre Ltd.

(4) This Exemption shall expire on 30 September 1991.

N D McFARLANE
District Chief Surveyor
EAST OF SCOTLAND
For the Secretary of State for Transport
13 September 1991

APPENDIX 3

Subject Information Sheet

Trial 6

SUBJECT INFORMATION SHEET

SURVIVABILITY OF TOTALLY ENCLOSED MOTORISED SURVIVAL CRAFT OCCUPANTS

The experiment to be undertaken has been designed to advance the level of knowledge relating to personal survival within lifeboats. The trial will attempt to follow standard operating procedure for evacuation; the boat will be filled to capacity and will be run at full throttle for 20 minutes. After this time the boat will 'heave to' to await rescue.

In order to measure sweat loss you will be weighed and measured both before and after the trial. Everyone will wear a lifejacket and various types of survival suits will be randomly allocated. During the time at sea it is possible that some subjects may experience some discomfort due to heat or to the motion of the boat.

It is envisaged that you will be on the boat for no more than 2 hours. Throughout this period there will be a doctor and safety boat alongside. At any time during the study you will be free to leave the lifeboat.

SUSAN COLESHAW
SC/fs

APPENDIX 4

Motion Sickness Questionnaire

Trial 6

During this session, did you feel:

1. All right ❑ **3.** Quite ill ❑

2. Unwell ❑ **4.** Dreadful ❑

If you felt unwell, how soon after departure from Platform:

5. ½ hour or less ❑ **7.** 2 hours ❑

6. 1 hour ❑ **8.** 3 hours ❑

Did this occur:

9. During transits ❑ **10.** During Exercise ❑

11. When stopped ❑

Did you vomit:

12. Yes ❑ **13**. No ❑

Are you prone to Motion Sickness:

14. Yes ❑ **15.** No ❑

Have you taken "Seasickness Tablets"

16. Yes ❑ **17.** No ❑

Are you under any medication:

18. Yes ❑ **19.** No ❑

[If "Yes", Please State] _____ **20.**

Have you during the past 24 hours partaken of
2 or more alcoholic drinks:

21. Yes ❑ **22**. No ❑

Spicy food:

23. Yes ❑ **24.** No ❑

Age: **25.** 18-30 ❑ **26.** 31-40 ❑ **27.** 41-40 ❑ **28.** 51-60 ❑ **29.** 60+❑

30. Male ❑ **31.** Female ❑

Are you a regular Sea-Traveller:

32. Yes ❑ **33.** No ❑

Which of the following do you think may have caused your illness:

34. Boat Motion ❑ **35.** Your Movement inside boat ❑ **36.** Heat ❑

37. Cold ❑ **38.** Vibration ❑ **39.** Apprehension ❑

40. Inactivity ❑ **41.** Cigarette Smoke ❑ **42.** Diesel fumes ❑

43. Others Vomiting ❑