SIMULATION OF ROUGH SEAS IN A WATER .SION FACILITY: PART I - I A IKI EV. UATION OF VARI US (

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INTRODUCTION. Accidental water immersion is a serious problem that threatens all sailors. When immersed in cold water, the loss of body heat will be exacerbated by rough seas. To examine this effect, the U.S. Coast Guard (USCG) conducted unique field evaluations in which the thermal protection of various operational protective garments was evaluated when worn in cold water (11°C) under calm and rough sea conditions (1,2). Testing was conducted in the Columbia River near Cape Disappointment, WA. These studies demonstrated that with loosely-fitted, wet-suit concept garments, the rough seas caused significant flushing of cold water through the garment's seals, resulting in body cooling rates 1.5 to 2.0 times those measured in calm seas. Field evaluations such as those performed by the USCG are time-consuming, expensive and can only be conducted at specific times of the year when the required environmental conditions are expected. It is more desirable to simulate a rough seas environment in the laboratory, where controlled human and thermal manikin studies can be conducted. This study evaluated various methods for simulating rough seas in a small pool chamber. part I describes the simulations and the results on the thermal manikin (TM). Part 11 describes the human evaluations, both in a field setting and in the laboratory.

METHODS. Eight techniques were evaluated on our aluminum TM in a temperature-controlled water tank measuring 4.6x2.7x2.1 m (lxwxd). For all evaluations, the TM was dressed in an aviator's anti-exposure ensemble. Water and air temperatures were maintained at 15.5°C; wind speed was 0.3m/s. The methodologies included:

M1) Diffuse Compressed Air - An air line (2-cm id) released controlled volumes (1.4, 2.8, 4.2, 5.7 liters per second (l/s)) of compressed air from the bottom of the pool. As the air rose, it expanded and created water agitation over a wide area. At the highest flow rate, the observed water agitation took the form of waves, 0.3 to 0.4 m in height.

M2) Concentrated Compressed Air - An air line pipe (10-cm id: 122 cm length) was positioned either 30 or 60 cm below the water surface and controlled volumes (1.4, 2.8, 4.2, 5.7 l/s) of air were released from a compressed air line secured to the bottom of the pipe. The observed water agitation took the form of a wave that peaked at 0.8 m and dissipated to 0.2 m at the sides of the pool.

M3) Pump Current - A single 3.7 kilowatt (KW) water pump delivered metered volumes of water (up to 28.4 l/s) from a 10 cm id pipe, 13 cm below the water surface and 60 cm from the TM. At 28.4 l/s, the observed wave agitation was in the form of wavelets and water current.

M4) Pump Spray - A single 3.7 KW water pump delivered metered volumes of water (Up to 28.4 l/s) from a 10-cm id pipe, 1.4 m above the pool surface and at a 65° angle toward the surface. As the pumped water hit the pool surface, a surface current was generated with little or no wave action in the form of wavelets.

M5) Pump Current and Spray (M3 and M4 combined) - Two 37 KW pumps were utilized to pump and spray up to 56.8 l/s of water. Water agitation took the form of random wavelets less than 0.1 meter in height.

M6) T-Wave Maker - A digitally timed, pneumatically-driven T-bar was utilized to create standing wave(s). Depending upon the rate of the T-bar movement, the observed water agitation took the form of one to three standing waves that measured .17 to .30 meters in height

M7) Vertical Displacement - The TM was periodically (1-4 times/minute) pulled out of the water. The resulting water turbulence was very small, with only very small disruptions of the water surface.

M8) M1 and M7 combined - A constant vertical displacement of 4 times per minute was combined with releasing volumes of compressed air (1.4, 2.8, 4.2, 5.7 l/s) from the bottom of the pool. The observed water agitation was in the form of waves 0.3 to 0.4 meters in height.

RESULTS. In *calm* water, immersed clo was 0.29. Test results follow.

Air Flow (l/s) =		1.4	2.8	4.2	5.7
M1) Diffuse		0.15	0.09	0.08	0.08
M2) Concentrated, 60 cm		0.25	0.22	0.20	0.17
Concentrated, 30 cm		--	--	--	0.12
Water Flow (l/s) =	9.5	18.9	28.4	37.3	56.8
M3) Current	0.19	0.12	0.07	--	--
M4) Spray	0.22	0.10	0.07	--	--
M5) Current & Spray	--	0.14	--	0.09	0.08
Mode of Operation =		Level 1	Level 2	Level 3	Level 4
M6) T-wave maker		0.09	0.08	0.07	0.05
Displacement (per minute) =		1	2	3	4
M7) Vertical Displacement		0.22	0.19	0.17	0.16
Air Flow (l/s) =		L4	2.8	4.2	5.7
M8) Combination M1 & M7 (4x/min displacement)		0.16	0.16	0.16	0.16

CONCLUSIONS. The lowest clo value was obtained using the T-wave maker, with *two* standing waves, each 28 cm in height. However, *this* technique proved stressful for the pool itself, and therefore could not be utilized on a daily basis. The second lowest clo values were obtained using M1, M3, M4, and M5 For continued use, we recommend M1 (Diffuse Compressed Air) because: 1) it was the easiest technique to set up and maintain, 2) results were easily repeatable on the TM, and *3)* the method did not create undue stress on the pool.

REFERENCES

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