L.5.1.2.

MICROCLIMATE COOLING SUBSYSTEMS

LIQUID NUTRIENT STORAGE, DELIVERY, RESUPPLY AND THERMOREGULATORY ELEMENTS FOR THE INDIVIDUAL COMBATANT ENCAPSULATED WITHIN THE ADVANCED INDIVIDUAL PROTECTIVE SYSTEM (AIPS)

Background of the Technical Approach

This approach relates generally to delivery and storage systems for liquids and, more particularly, to a system providing for the delivery of drinking liquids inside an integrated individual protective system enabling the wearer to create a closed system for ingestion without exposing the liquid to contamination.

Nuclear, Biological, Chemical (NBC) warfare has, in the past, been demonstrated to be of devastating physical and psychological effect. Chemical agents, such as toxic gases are pervasive, difficult to detect, create immediate and long-lasting disabling effects, and are available in substantial and sophisticated forms to cause a wide range of injury and/or disability from narcosis, discomfort, and disorientation all the way to paralysis and death.

To defend against such combat measures, attempts have been made to create protective clothing and protective masks in order to insulate a combatant from the effects of weapons of mass destruction. Where such clothing and/or masks are effective to shield or filter the particular agent involved, the wearer will be protected so long as the integrity of the protective garb remains intact.

It is characteristic of chemical agents that, once deployed, they may remain effective for a substantial period of time afterward before naturally occurring atmospheric and meteorologic action either disperses, dilutes, or removes them from the environment. As an example, certain chemical substances dispensed in aerosol form may be degraded or altered by the action of direct sunlight, while others, being water soluble, may be "scrubbed" from the atmosphere and/or landscape during rainstorms. Nevertheless, it is an accepted consequences of such forms of warfare that protective clothing, once donned, may have to be worn for an indeterminate amount of time until it is established that the danger to the wearer has abated. Hence, the justification for the development of an Advanced Individual Protective System.

Protection of the wearer is only one aspect of such an advanced system. Another consideration is the ability of the wearer to carry out assigned duties even when prolonged use of such protective clothing is required. This means that such garments must not only enable the wearer to see and to communicate, but, advantageously, must also make some provision for the ingestion of liquids in order to replace those liquids lost by the body through perspiration which may be heightened by the wearing of protective clothing of impermeable or semipermeable characteristics, and by increased or stimulated body reactions resulting from participation in frightening or stressful situations. This must be a necessary function of an integrated suit's microclimate cooling system.

Thus, when the combatant's integrated helmet is properly in place, the wearer must be able to eat or drink normally without breaching the integrity of the helmet's protective features. This poses a critical problem, particularly with respect to body fluids, which must be constantly and continuously replenished to avoid the serious effects of dehydration.

Water Supply

The following is an excerpt from U.S. Army FM 3-4, December 1984.

> "The human body is highly dependent on water to cool itself in a hot environment. Soldiers in MOPP4 may lose more than 1 quart of whater each hour. These losses must be replaced on a continual basis.

An approximate recommended replenishment should be based on work rate and temperature. For example with a moderate-to-heavy work rate and temperatures below 80 degrees Fahrenheit (27 degrees Celsius) 1 quart of water should be consumed every 3 hours. With the same work rate, but temperatures above 80 degrees Fahrenheit (27 degrees Celsius) the water consumption will increase to 1 quart every 2 hours. Otherwise, soldiers will suffer rapid rise in body heat and heart beat, decrease in ability and motivation to work, and eventually heat exhaustion, if water intake is neglected."

Though military and industry studies conclude that liquid cooled garments fashioned into microclimate systems do reduce the need for body fluid replenishment, these devices do not eliminate the need for fluid intake on a continual basis. Army tests in 1980 at Yuma Proving Grounds verify this point in Table 1, on the following page.

Liquified foods may also pass through this tubing system, if required.

Accordingly, the need exists for a liquid delivery system which would substantially overcome the above-identified problems, thereby adding to the security and continued health and well being of one forced to adopt the use of such protective clothing and masks for indeterminate periods of time.

Brief Description of the Proposed Approaches

A. Fluid Intake Suction Tubing (FIST)/FLEX Hydration System

The FIST, a fluid delivery system suitable for use with protective masks and fully integrated protective systems includes a delivery tube sealed, at one end, to the drinking mouthpiece contained within the mask and attached at its other end to a bulb-type siphon pump. A supply tube is attached liquid-tightly at one end to the bulb siphon pump and, at the other end, to a plug member.

A canteen structure is provided with a removable cap having a socket which cooperates with the plug member at the end of the supply tube to form an air-tight positive fit when the plug is inserted into the socket. Means are provided in the canteen construction to enable liquid to be withdrawn from the canteen without requiring venting of the canteen's contents or injection of air into the canteen in order to equalize the air pressure within the canteen with the atmosphere. In one version of such a construction, the canteen structure includes a rigid outer wall and an inner pliable liner within which the liquid is carried, and a selectively openable and closeable valve enabling the air pressure between the inside and the outside of the rigid portion of the canteen structure to be equalized while the liner collapses as liquid is withdrawn therefrom. In another version, the "FLEX" canteen structure is formed with a soft flexible configuration, giving the canteen structure sufficient flexibility to enable the canteen structure to flex during the withdrawal of liquid therefrom without sustaining permanent deformation or damage due to material fatigue. Hence, the name FIST/FLEX hydration system.

Another feature of the proposed approach is a flexible drain tube attached to the interior of the canteen structure cap and extending into the canteen, and having a weighted end distal from the cap whereby the drain tube will automatically drop to the lowermost portion of the canteen, i.e., that portion of the canteen at which the liquid level is at its highest regardless of the position in which the canteen is held.

The supply tube is preferably coiled to present a compact, easily stored construction when not in use, and which may be stretched to connect the mask and the canteen structure, when the canteen structure is carried in a typically belt-worn carrying case. The canteen then need not be removed during the drinking operation. A protective insulating sheath may be used to cover the supply tube as an added measure of protection against freezing, condensation, physical damage, or to coordinate use of the system with selected uniforms or camouflage requirements.

An additional chemical and/or mechanical filter may be inserted to provide an additional measure of protection against contamination of the liquid.

Table 1

XM-1 HEAT STRESS AT YPG

SEPTEMBER 1980

DAY	MOPP/ HATCH	$\bar{T}_a$ o	$\bar{T}_a$ i	$\overline{RH}$ o	$\overline{RH}$ i	$\overline{WBGT}$ o	$\overline{WBGT}$ i	TOLERANCE min	$\bar{T}_{sk}$	$\bar{T}_{re}$	HEART RATE b/min	SWEAT RATE ℓ/hr	COMMENTS
1	I/OPEN	38.7°C	39.1°C	39%	31%	31.9°C	30.5°C	>172	35.4°C	37.6°C	92	0.64	TRAIN #1
2	III/OPEN	28.6	31.4	66	60	25.7	26.8	>163	34.9	37.3	76	0.30	TRAIN #2 (cw under)
3	IV/OPEN	37.6	36.6	29	33	30.0	28.1	>177	36.5	37.8	114	0.99	
4	IV/CLOSED	36.0	38.8	30	57	29.9	35.0	(80)	38.3	38.9	162	2.05	T.C. ERRORS < 60'
5	IV/CLOSED (w/cooling)	36.1	35.7	25	66	27.4	32.5	>208	32.6	38.1	113	0.63	DOUBLE DRILLS
6	IV/CLOSED	34.4	35.3	29	91	28.9	33.4	(124)	38.1	38.5	147	1.69	T.C. ERRORS ~ 60'

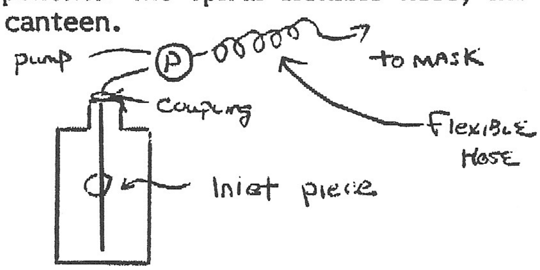
Hand-pumping of the bulb-type siphon pump thus provides a supply of liquid extending in a path from the interior of the canteen structure to the users mouth without being exposed to the atmosphere and, thereby, any chemical agent or contaminant present. The pump may be supplied with a check valve preventing the contents of the supply tube from draining back into the canteen between uses, thus making it unnecessary to "prime" the system each time it is used. A technical report on the Fist System follows.

TECHNICAL FEASIBILITY REPORT
ON
THE WESLEYAN FLUID INTAKE SUCTION TUBING (FIST) HYDRATION SYSTEM

1. OBJECTIVE

The objective of this report is to present the results of an investigation carried out to reveal the technical feasibility of a proposed water drinking attachment, WDA, to be used with conventional canteens under gas contaiminated environments.

The WDA is illustrated schematically in Figure 1. It basically consists of three components: the spiral flexible hose, the pump, and an inlet pipe within the canteen.



By technical feasibility, the compatibility of pump performance and the confirmity of the pumping rate with the requirements are understood.

In what follows, at first, a series of experiments performed to determine the pump performance characteristics will be described and the results of the experiments will be presented. Then, the results of the experiments run to obtain the rate of pumping will be given. Finally, results will be discussed.

2. EXPERIMENTS

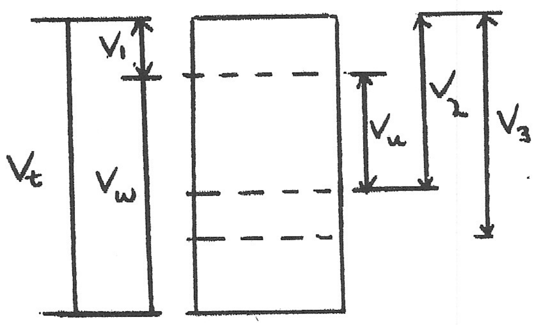
2.1 PERFORMANCE EXPERIMENTS

There are two goals of these experiments. The first goal is to determine the pump characteristics and, thus, the minimum pressure up to which the pump is operable. The second goal is to obtain the percentage of usable volume of the canteen.

Two sets of experiments were run. The first series of experiments were run with an air tightened rigid glass container whereas the regular canteen was used for the second series.

2.1.1 EXPERIMENTS WITH RIGID CONTAINER

At several different initial water levels within the glass container of known volume water is pumped out. The volume at which pumping gets hard and the volume at which pumping becomes virtually impossible are recorded. Then these data are reduced to determine corresponding chamber pressures and to relate the usable volume of water to initial water content as described below.



In Figure 2, the various volumes and their relationships are illustrated.

V_t = total volume

V_1 = volume of initial air pocket within the container at atmospheric pressure.

V_u = usable volume; the volume greater than which becomes very hard to pump out

V_3 = the maximum volume of water that can be pumped out

V_w = initial volume of water

Using the gas law,

$$p\,V = R\,T$$

where

p = pressure

V = volume

R = gas constant for air

T = temperature,

the pressure within the rigid container can be related to atmospheric pressure and to the volume of initial air pocket:

$$p\,V = p_o\,V_1$$

where p_o = atmospheric pressure. For example, at the instant pumping gets hard, the pressure within the rigid container is

$$p_u = \frac{p_o\,V_1}{V_2}$$

where $V_2 = V_1 + V_u$, and

p_u = the pressure below which pumping is very hard.

Similarly, the instant at which pumping gets virtually impossible, the pressure within the glass container becomes

$$p_f = \frac{p_o\,V_1}{V_3}$$

where p_f = the lower limit of operable pressure range.

Results of the experiments are summarized in Table 1.

TABLE 1

V_t	V_w	V_1	V_2	V_u	V_3	Po	Pu	Pf	V_u/V_t (%)	Remarks
130	100	30	67	37	80	14.7	6.58	5.51	28.5	
130	105	25	55	30	65	14.7	6.68	5.65	23.1	
130	95	35	78	43	92	14.7	6.60	5.59	33.1	
130	90	45	99	54	118	14.7	6.68	5.60	41.5	
130	80	55	121	66	--	14.7	6.68	--	50.8	
130	70	60	--	70	--	14.7	--	--	53.8	no hardship
130	50	85	--	50	--	14.7	--	--	38.4	no hardship

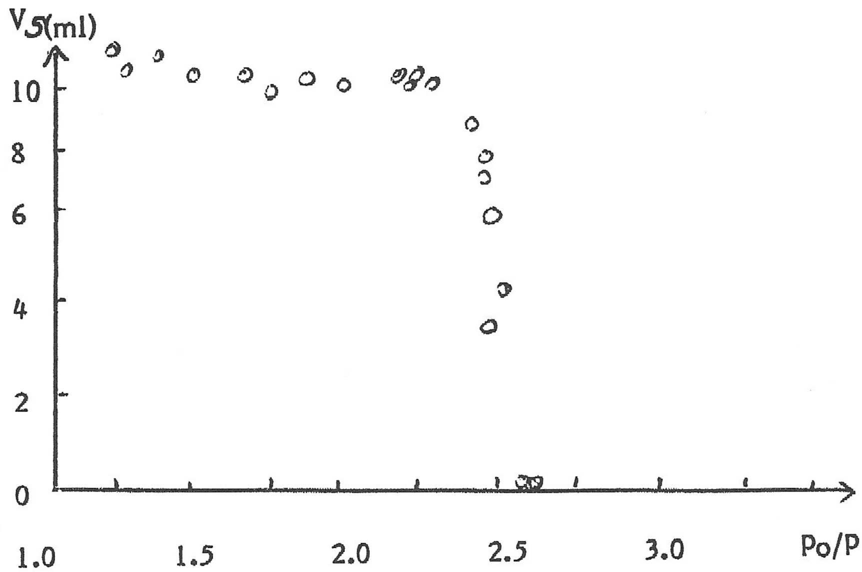
(Note: volumes are in ml and pressures are in psia)

2.1.2 EXPERIMENTS WITH THE PROTOTYPE CANTEEN

Irrespective of the initial volume of air pocket at atmospheric pressure within the canteen, as soon as the Wesleyan FIST begins pumping water, the canteen starts to deform (literally collapses). In other words, the pressure inside the canteen is retained atmospheric or nearly atmospheric at all times. Therefore, the usable volume of water is within the range of 90-95% of the available volume of the canteen.

2.2 RATE EXPERIMENTS

In this set of experiments, it is aimed to obtain a relationship between the pressure within the container and the volume of water pumped out at each squeeze under this pressure. The same set up that is used for the first series of performance experiments is used. The results of the experiments are presented in graphical form, below.



It is also observed that as long as pressure within the container is greater than Pu, a constant rate of approximately 10 ml/squeeze can be pumped 20 to 25 times a minute.

3. **DISCUSSION OF RESULTS**

The study of the results of the first series of performance experiments reveals the fact that after pumping certain volume of water, V_u, the operation of pump becomes very difficult. Continued pumping of water out of the rigid container brings out a state where pumping becomes virtually impossible. The results of the rate experiments, which also confirms these observations, show a sudden decrease in the amount of volume of water that can be pumped out by one squeeze, V_s, when the pressure within the rigid container is about p_u. V_s diminishes very rapidly to zero as the pressure approaches to p.

The usable volume of water depending upon the initial volume of air within the container varies and assumes a maximum value of 54% of total available volume of the container.

This suggests that, if a rigid container, rather than the one in use, is preferred, an additional component to monitor air pressure within the container is recommended. Monitoring of the pressure within the canteen can be realized by means of an air line parallel to the flexible spiral water hose. Yet, inlet of the air line must be designed such that enterance of water should be prevented.

Should the canteen in use be modified with the proposed WDA, there is no need for the chamber pressure monitoring. The elastic wall of the canteen deforms and makes it possible to pump 90-95% of water out. Furthermore, because the chamber pressure is at or about atmospheric at all times, a reliable, constant rate of 10 ml/squeeze is always available. Noting that pump can be squeezed 20 to 25 times a minute, a reliable rate of 200-250 ml/min capacity is made available by the proposed WDA.

However, repeated collapse of the canteen may cause an unpredicted failure under adverse conditions. Should the canteen be used as is with the proposed WDA, a material testing against fatigue is suggested.

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