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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

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MAINTENANCE OF AIR OPERATIONS WHILE UNDER ATTACK WITH CHEMICAL AGENTS. Supplement.

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The Effects of Acute & Chronic Low Dose Exposure to Anticholinesterases

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Summary

Acute sublethal and chronic subclinical exposures to toxic anticholinesterases may result in long term neurobehavioral deficits. The deficits most likely to occur include: slowed reaction times, erratic mood swings, sleep disturbances, and impaired visual memory. Individuals who operate high performance equipment and are acutely exposed should be kept off the job until examinations of brain function are normal.

The immediate short term effects of acute anticholinesterase poisoning are well known and are easily recognized by experienced physicians, nurses and emergency technicians.[1] For those of us who are responsible for medical care, reports of long term persistent multiple organ system symptoms following either single non-incapacitating or chronic subclinical doses of anticholinesterases are disturbing and demands more detailed examination.

This paper reviews our present knowledge of persistent deficits in subjects exposed either acutely or chronically to anticholinesterase poisoning and discusses the functional consequences of such deficits.

In 1953, Craig and Freeman[2] reported 53 laboratory and field workers who were accidently exposed to organophosphate anticholinesterases. Acute symptoms included respiratory difficulties (77%); rhinorrhea (58%); visual problems, mainly characterized by dimness of vision and impaired accommodation (58%); nervous system disturbances including sleeplessness, headache, definite mood changes and easily fatigability (51%); and gastrointestinal problems characterized by anorexia, nausea, diarrhea and vomiting (26%). In all of the 45 mild exposures the symptoms described above lasted for at least 48 hours. In many of the patients readily observable deficits lasted for more than two days and in one individual impairment was present for as long as 20 days. Examples of protracted deficits in a patient where impairment lasted for more than two days included: sleep disturbance present for 11 days, diarrhea continuing for 10 days, headache for almost a week and impaired visual accommodation for eight days.

In a later report Craig and Cornblath[3] reported further persistent effects of organophosphate exposures. This report involved 64 volunteers who had an agent applied to the skin of their forearms; local sweating developed in the exposed skin and in some volunteers persisted "for weeks."

With increasing interest in the long term effects of toxic agents in the 1960's Metcalf and Holmes[4] carefully reviewed neurobehavioral sequelae in their 56 cases of previously reported acute organophosphate exposures and subclinical chronic exposures in agricultural and arsenal workers. The exposed population was compared to 22 controls. When these subjects were first examined in 1952 the exposed workers complained of "forgetfulness, difficulty in thinking and visual difficulty." Drowsiness, fatigability and loss of interest in work were found in 45% of the exposed group and in only 5% of the controls. In 1969 the exposed group continued to demonstrate disturbed memory and difficulties in "focusing" their attention. "Soft" neurological findings in the exposed group included "minor incoordination deficits" and "oculomotor inbalance." The EEG's were filled with a preponderance of low-to-medium voltage theta activity and mirrored the more severe EEG slowing seen during acute intoxication. Gerson and Shaw[5] examined the behavior of 16 adults who were chronically exposed to a variety of organophosphates and discovered that depression and schizophrenic symptoms predominated in the group. In a 26 year old male who had been exposed to subclinical parathion and malathion poisoning for four years, nausea, chest pain and muscle fasciculations were persistent post-exposure complications.

Sidell's report of the clinical manifestations of acute accidental soman poisoning and the long term sequelae of the exposure is one of the most dramatic in the literature.[6] His patient had severe cholinergic symptoms including coma; he was vigorously treated and made a rapid recovery except that he remained depressed, withdrawn, subdued, and had restless sleep. Scopalamine transiently but dramatically improved his mental symptoms in the days immediately following his acute illness but became less effective as time went on. Weeks after his poisoning the patient continued to do poorly on visual retention tasks and was slow when asked to do work association tests.

An exhaustive health survey of workers in a pesticide plant in Houston, Texas provides some persuasive arguments for the persistence of long term deficits in chronically exposed pesticide workers. Xintaras et al[7] found impairment of motor dexterity, slowed reaction times, decreased ability to do block design tests and intermittent numbness and tingling in the hands suggestive of neuropathy.

Korsak and Sato[8] have emphasized that when dealing with asymptomatic patients the sensitivity of testing determines the lower range of involvement. In an attempt carefully to evaluate the neurobehavioral sequelae in 59 patients with varying subclinical exposures to dieldrin, aldrin and carbamate insecticides the authors used seven sensitive tests of brain function extracted from the Halstead Test Battery and

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The opinions expressed in this paper are those of the authors' and do not reflect official policy of the U.S. Army or the Deparement of Defense.

supplemented with EEG's subjected to power spectral analyses. They compared those subjects who had "high" chronic subclinical exposures with those who had "low" chronic exposures and found that both the EEG and behavioral tests demonstrated subtle but definite frontal lobe impairment in those who had "high" chronic exposure. Their EEG's showed a preponderance of slower alpha rhythms in the frontal areas. This finding was corroborated by defects in visual search tasks and the relationship of these tasks to left frontal lobe function.

The classic animal experiments on the effects of chronic poisoning with DFP by both Koelle and Gilman[9] and Hunt and Riker[10] further demonstrate how long lasting the effects of organophosphate poisoning can be. In Koelle and Gilman's study 0.5 mgms/kg intramuscularly of DFP three times per week for 12 weeks caused fasciculations which became severe in 17 days. In ten weeks hind leg paralysis appeared. Muscarinic effects (dyspnea and wheezing) appeared in four weeks and disappeared in six. Hunt and Riker produced muscle weakness in 20 cats after daily injections of 1 mgm/kg of DFP. When weakness occurred DFP administration was stopped. Fasciculations lasted for four days after DFP administration and gross weakness lasted for an average of seven days. Even after the animal appeared normal weakness could be illicited with forced exercise. Total recovery in some of the cats was delayed for as long as 147 days.

The data given above which support the occurrence of persistent deficits in subjects who have had acute anticholinesterase poisoning or who have been subjected to subclinical chronic exposures have been challenged by Durham,[11] Clark[12] and particularly by Rodnitzky et al.[13] Rodnitzky et al tested the hypothesis that neurobehavioral abnormalties might be present in mild degree in workers chronically exposed to organophosphate pesticides. Twenty-three workers were tested for abnormalities in memory, signal processing, vigilance, language and proprioceptive feedback performance and were compared to a well matched group of controls. Rodnitzky concluded that higher nervous system functions were relatively resistant to mild chronic organophosphate exposure.

The inconsistencies in the studies described above are most likely due to the differences in patient selection criteria, difference in exposure times and doses, differences in the sensitivities of the neurobehavioral tests and the quality of the clinical observations. Despite Clark's belief that---"the human data is a maze of unexplained inconsistencies---;" nonetheless, in those studies in which the acute exposures are well documented and the clinical observations were carried out under the most controlled conditions (e.g., Sidell's report, Craig and Freeman's observations, and Xintaras' study) deficits occurring well after the acute sublethal exposure are not uncommon and include:

Slow reactions to stimuli

Erratic mood swings

Sleep disturbance

Impaired visual memory

In addition, subtle frontal lobe EEG changes may be present. Without further clinical correlation it is difficult to determine the functional significance of these changes.

The functional significance of the sequelae of either acute sublethal anticholinesterase poisoning or of chronic subclinical exposure should be readily apparent. All those who operate complex equipment will be seriously impaired if their reactions are slow and their integrative visual functions are impaired. Individuals who have been even mildly exposed to organophosphates will have to be kept off critical jobs until it can be definitely determined that their brain function is normal. The modified Halstead-Reitan Battery may be a useful method for testing central nervous system integrity.

References

1. Davis, J. H. et al, "Occurrence, Diagnosis, and Treatment of Organophosphate Pesticide Poisoning in Man," Ann. N.Y. Acad. Sci., 160: 383-392, 1969.

2. Craig, Albert B. and Freeman, Gustave, "Clinical Observations on Workers Accidently Exposed to G-Agents," Chemical Corps Medical Laboratories Research Report 154, January 1953.

3. Craig, Albert B. and Cornblath, Marvin, "Further Clinical Observations on Workers Accidently Exposed to G-Agents," Chemical Corps Medical Laboratories Research Report 234, December 1953.

4. Metcalf, David R. and Holmes, Joseph H., "EEG, Psychological, and Neurological Alternations in Humans with Organophosphorus Exposure," Ann. N.Y. Acad. Sci. 160: 357-365, 1969.

5. Gershon, S. and Shaw, F. H., "Psychiatric Sequelae of Chronic Exposure to Organophosphorous Insecticides," Lancet 1: 1371-1374, 1961.

6. Sidell, Frederick R., "Soman & Sarin: Clinical Manifestations and Treatment of Accidental Poisoning by Organophosphates," Clin. Toxicol. 7(1): 1-17, 1974.

7. Xintaras, C. et al, "Occupational Exposure to Lepthophos and other Chemicals," U.S. Dept. of Health, Education and Welfare. National Institute of Occupational Safety and Health. Publication no. 78-136, 1978.

8. Korsak, R. J. and Sato, M. M., "Effects of Chronic Organophosphate Pesticide Exposure on the Central Nervous System," Clin. Toxicol. 11(1): 83-95, 1977.

9. Koelle, George B. and Gilman, Alfred, "Chronic Toxicity of d:-isopropyl Fluorophosphate (DFP) in Dogs, Monkeys & Rats," J. Pharmac. Exp. Ther. 87: 435-448, 1946.

10. Hunt, Carlton C. and Riker, Walter F., "Effect of Chronic Poisoning with d:-isopropyl Fluorophosphate on Neuromuscular Function in Cat," J. Pharmac. Exp. Ther. 91: 298-305, 1947.

11. Durham, Wm. F. et al, "Organophosphorus Insecticides and Mental Alertness," Archs. Envir. Hlth. 10: 55-66, 1965.

12. Clark, George, "Organophosphate Insecticides and Behavior, A Review," Aerospace Med. 42: 735-740, 1971.

13. Rodnitzky, Robert L. et al, "Occupational Exposure to Organophosphate Pesticides," Archs. Envir. Hlth. 30: 98-103, February 1975.

CONSIDERATION OF PYRIDOSTIGMINE AS A PROPHYLACTIC AGENT FOR AIRCREW

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SUMMARY

The carbamate pyridostigmine shows considerable promise as a first-generation prophylactic for nerve agent poisoning. Although it is unlikely to yield all the benefits desirable, the potential utility of pyridostigmine in conjunction with appropriate therapy warrants detailed study.

GENERAL BACKGROUND

Pyridostigmine is a charged, quarternary carbamate, most commonly available in the bromide form. It has a history of medical use in the routine treatment of myasthenia gravis, for which the initial oral dose is 60 mg, with subsequent administration individualized on the basis of the patient's reactions. Pyridostigmine has lesser side effects than its analogues (e.g., neostigmine) and is therefore the preferred carbamate for both clinical use and potential chemical warfare prophylaxis. Being charged, it does not cross the blood-brain barrier and is therefore said to be unlikely to cause neurotoxic effects.

That the carbamates afford some protection against organophosphate poisoning has been known since 1946 (1). The greatest interest in this class of compounds as nerve agent prophylactics, however, has been due to the finding that, combined with appropriate therapeutic measures, they can provide protection against soman poisoning (2). Poisoning by soman is not responsive to oxime therapy, as is the case with other agents (3). It is most appropriate to consider pyridostigmine a "treatment potentiator"; administered alone it is relatively ineffective, but pyridostigmine pretreatment followed by therapy with atropine and oximes is said to raise the LD_{50} for nerve agents several fold (4).

The advisability of examining pyridostigmine as a nerve agent prophylactic was established by the US Air Force in early 1978. The compound has been under study in other nations, and the US Army Chemical Systems Laboratory is presently preparing protocols for studies with human subjects, following several years of animal trials. Unclassified analyses of USSR research have suggested that within the next few years the USSR probably will examine the prophylactic potential of carbamates such as pyridostigmine, and that such work will result in a new generation of prophylactic-therapeutic mixtures for Soviet ground forces within three to five years.

The appeal of pyridostigmine, or of carbamates in general, as a likely route to nerve agent prophylaxis has not been universal: informal discussions elicit the practical observation that such pretreatment would not reduce the number of personnel rendered ineffective by nerve agent exposure, although it should increase the survival rate. The question as to whether different sizes (or numbers) of tablets would be needed for personnel of varying body weight has been raised, and there is some feeling that any effective drug is likely to result in decrements of performance, making prophylaxis in general an unpalatable approach.

The "ideal" prophylactic. In assessing pyridostigmine as a potential nerve agent prophylactic it appears reasonable to attempt a listing of the characteristics desirable in prophylaxis and a comparison of the compound against those characteristics. The "ideal" prophylactic might be described as follows:

- Suitable for oral administration
- Effective for 12-24 hours after administration of a single dose.
- Protection against moderate agent exposure without any subsequent therapy.
- Compatible with available therapeutic measures.
- No behavioral or psychomotor side effects.
- Prevention or reduction of the miotic effect of sublethal nerve agent exposures.
- No requirement for dose individualization.
- No variation in efficacy and side effects with age in the range of the military population, sex, or with the use of common medications.
- Sufficiently stable to permit storage for rapid distribution and administration at an appropriate stage of alert readiness.
- Effective against all agents that might be employed against friendly forces.
- For US forces, the drug should be approved by the Food and Drug Administration.
- Suitable for use for periods of several weeks with no toxic effects and no change in the level of protection provided.

Pyridostigmine is routinely given orally in current clinical practice, and it appears that a prophylactic dose schedule may require administration no more frequently than every 6-8 hours. It is abundantly stable in tablet form, and it appears at least potentially effective against all the common nerve agents. It is, however, almost completely ineffective without supportive post-exposure therapy, and as an anticholinesterase it seems likely to worsen rather than diminish miotic effects. There appears to have been no detailed study of the impact of pyridostigmine on the ability to accomplish aircrew flying tasks, nor of the impact of age, sex, or medications. Clinical usage suggests that prolonged adminis-

tration is unlikely to result in severly adverse reactions, but there is no data to preclude the possibility of decrements in aircrew performance or changes in efficacy due to phenomena such as enzyme induction. Animal data suggest that individualization of the dose is not critical (4), but the medical community is unlikely to accept that until rigorous trials have been done with human subjects.

Current US Air Force approach. Under present US directives, use of a drug for a new purpose means that it must undergo essentially the same approval process as a newly-developed pharmaceutical. Therefore, even relatively rudimentary laboratory study of pyridostigmine, with no agent challenge, requires approval by the Food and Drug Administration, involving detailed documentation and at least several months for clearance. At present, the USAF School of Aerospace Medicine is monitoring efforts on pyridostigmine by the US Army and other laboratories while assembling the required literature for approval to begin inhouse efforts.

It is felt that laboratory trials must include, in addition to the considerations noted above, examination of interactions of the drug with stresses of the aerospace environment (e.g., acceleration) and detailed study aircrew performance. Ultimately, compatibility of pyridostigmine prophylaxis with TAB, the current US therapeutic, must be examined, and that effort is expected to be done by the US Army.

At present it seems likely that the study of pyridostigmine will be only the first of a series of prophylactic trials. Because oxime prophylaxis may offset any miotic effect of pyridostigmine as well as agent-induced miosis, and the oxime P_2S is already in use in various services, the examination of pyridostigmine-P_2S combinations appears to be a logical follow-on development. Additionally, an array of other oximes are under study, and it is easy to imagine the desirability of testing other mixtures.

While the cost of these pharmacologic studies is considerable, the current need makes time a significant consideration in planning the path of future endeavors. A program of coordinated efforts by several laboratories appears highly desirable.

REFERENCES

1. Koster, R. 1946. Synergisms and antagonisms between physostigmine and di-isopropyl fluorophosphate in cats. J. Pharmacol. Exper. Ther. 88:39-46.

2. Berry, W. K., and D. R. Davies. 1970. The use of carbamates and atropine in the protection of animals against poisoning by 1, 2, 2, trimethylpropyl methylphosphonofluoridate. Biochem. Pharmacol. 19:927-934.

3. Heilbrown, E., and B. Tolagen. 1965. Toxogonin in sarin, soman, and tabun poisoning. Biochem. Pharmacol. 14:73-77.

4. Gordon, J. J., L. Leadbeater, and M. P. Maidment. 1978. The protection of animals against organophosphate poisoning by pretreatment with a carbamate. Toxicol. Appl. Pharmacol. 43:207-216.

THE EFFECT OF LOCALLY APPLIED ORGANOPHOSPHATES ON MIOSIS AND ACETYLCHOLINESTERASE ADAPTATION TO CHRONIC TREATMENT

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SUMMARY

Topical administration of organophosphates to the eye of guinea pigs inhibited acetylcholinesterase of different parts of the eye to a different degree. The differences reflected most likely dilution of the agent caused by diffusion into the eye. The effect of locally applied organophosphates was ascribed to an effect on the iris and ciliary muscle and not on retina. The degree of miosis and recovery of pupillary function after soman treatment correlated better to inhibition of external acetylcholinesterase than total acetylcholinesterase. Chronic treatment with soman reduced the miotic potency of soman and reduced the recovery time of the miosis. This adaptation was dependent on other factors than cholinergic. Local treatment of miosis with topical application of oximes to the eye reduced the miosis and reactivated acetylcholinesterase in cornea and iris. The reactivation was enhanced in the presence of benzalkonium.

INTRODUCTION

Miosis occurs on exposure to nerve agent vapour or it may occur concomitantly with other symptoms from systemic nerve agent poisoning. Since the miosis decreases the ability to see in darkness and to a certain degree affect the colour sight, it will influence military activities and personnel's capabilities in solving military tasks.

There is extensive literature on the effect of these compounds on pupillary diameter and intraocular pressure (Leopold & Krishna 1963, Potts 1965, Leopold & Comroe 1946). However, very few data are available on the actual measurements of acetylcholinesterase (AChE) inhibition in different parts of the eye and a correlation between the degree of inhibition and physiological function. It was therefore of interest to us to study the effect of topically administration of organophosphorus compounds on the inhibition of AChE in the eye and correlate the inhibition to pupillary function.

RESULTS

Topical administration of organophosphates (sarin, diisopropyl phosphorofluoridate DFP) to the eye of guinea pigs inhibited the AChE of different parts of the eye to a different degree. As demonstrated in Fig. 1a, b, there was a marked difference in the inhibition of AChE from cornea, iris and retina. The difference most likely reflects dilution

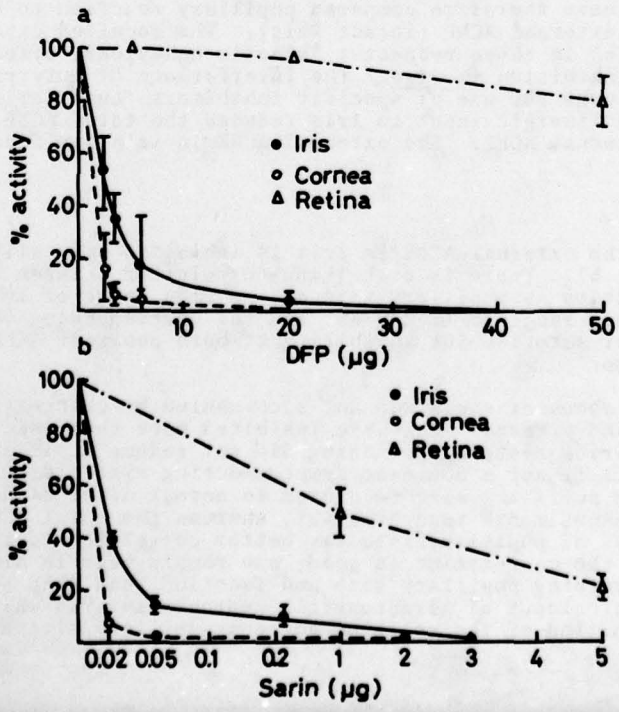

Fig. 1 The inhibition of acetylcholinesterase in cornea, iris and retina by the local application of varying amounts of sarin to the eye. (a) DFP, (b) sarin.

of the agent caused by diffusion into the eye since there is no evidence in the literature that AChE from different sources in the same species differs with respect to inhibition by organophosphates.

The efficiency of local administration of drugs to the surface of the eye is dependent on multiple factors. The small amounts applied are immediately diluted on the eye surface with a variable amount of reflex tear production and partly lost through the lacrimal system. Moreover, the epithelial layer of the cornea represents a significant barrier to the penetration of agents. By comparing the rate of inhibition by DFP and sarin of AChE in vitro with the inhibition found, we can obtain an estimate of the penetration. As a first approximation we can assume that the inhibitor was homogenously distributed over the whole eye (volume 300-500 µl) and inhibited the iris for 30 min. (the time between instillation of the agent and death). The dose of DFP and sarin which would cause 50% inhibition of the iris was found to be 2 µg and 0.02 µg respectively (fig. 1a, b). This corresponds to an overall concentration in the eye of 0.03 M for DFP and 4.5 for sarin. These inhibition rates are, however, 10^4-10^5 lower than those found in in vitro experiments (Andersen et al. 1972). This simple estimation clearly indicates that only a minor part of the agent reaches the AChE in these regions.

The results show that the effect of locally applied cholinesterase inhibitors on the eye must be ascribed to an effect on the iris and ciliary muscle and not due to an effect on the retina. The doses of organophosphates required to inhibit AChE of the iris and ciliary muscle more than 90% was 1/100 less than the intraperitoneal LD_{50} dose (Holmstedt 1963). This surely indicate that systemic effects including central neuronal effects can be disregarded under these particular conditions. This does not support the suggestion by Rubin et al. (1957) who ascribed changes in visual acuity during poisoning by cholinesterase inhibitors to central or retinal effects.

Clinical observations indicate that topically applied organophosphates to the eye affect ciliary function less than pupillary function (Leopold & Comroe 1956, Leopold & Krishna 1963). These observations are in agreement with a single experiment in monkey where topically applied soman inhibited AChE of the iris to 99%, whereas AChE of the ciliary muscle was inhibited to 90% (Lund Karlsen, unpublished). Since the toxic effect of organophosphorus compounds is primarily due to the inhibition of AChE and accumulation of acetylcholine (ACh), it is of great interest to correlate the physiological function of an organ to the degree of inhibition of AChE.

The iris is a structure where it is possible to correlate the activity of AChE to pupillary function and therefore the degree of miosis. These parameters are in our studies measured by means of infrared television recording of the eyes of the experimental animals. Total AChE activity, however, may not be the best parameter to correlate to function since it consists of enzyme activity both from the neuromuscular junction and intracellular structures. Theoretically the physiological function should be correlated to the part of AChE at the intrasynaptic cleft. It has been suggested that assay of AChE in intact tissue reflects such a pool since the uptake of ACh under these conditions is minimal, less than 4% of maximal (Mittag et al. 1970, Harris et al. 1973, Ehrenpreis et al. 1970).

External localized pools of AChE have also been demonstrated by histochemical staining at neuromuscular junction and at autonomic ganglia (Schwarzacker 1960, Barnett & Palade 1959, Koelle & Koelle 1959). We have therefore compared pupillary reaction to both the total AChE (homogenized iris) and external AChE (intact iris). The socalled external AChE was found to differ from total AChE in three respects: kinetic behaviour, effect of denervation and rate of recovery and inhibition in vivo. The interference of butyryl ChE in the two AChE pools was excluded through the use of specific inhibitors (Lund Karlsen & Fonnum 1977). Denervation of the cholinergic input to iris reduced the total AChE activity to 40% but did not affect the external AChE. The external AChE in iris was found to represent about 15% of the total AChE.

Single Application

By topical application of soman the external AChE in iris is inhibited only slightly more than total AChE in iris (fig. 2a, b). There is a striking correlation between inhibition of both pools of AChE and reduction in pupillary size over a wide range of inhibition. In the case of external AChE this range is from 0-80% and the corresponding value for total AChE was 0-60%. Thus, to our surprise 50% inhibition of both pools of AChE gave significant reduction in pupillary size.

Subcutaneous injection of lethal doses of soman was not accompanied by changes in pupillary diameter although both total and external AChE were inhibited more than 90%. Thus, less than 10% of AChE in iris during systemic poisoning did not reduce pupillary size. This clearly explains why miosis is not a dominant symptom during systemic poisoning. After single application of soman, the pupillary size recovered to normal after 24 hours. The external AChE had under the same experiments recovered 40%, whereas the total AChE had only recovered 20%. Thus, the recovery of pupillary size was better correlated to the external than the total AChE. Although the correlation is good, one should bear in mind that other factors may be involved in determining pupillary size and function than AChE activity. For example, there exists a considerable input of noradrenergic neurones to iris which must be taken into account for the determination of the relation between pupillary size and activity of AChE (Ehringer & Falck 1966).

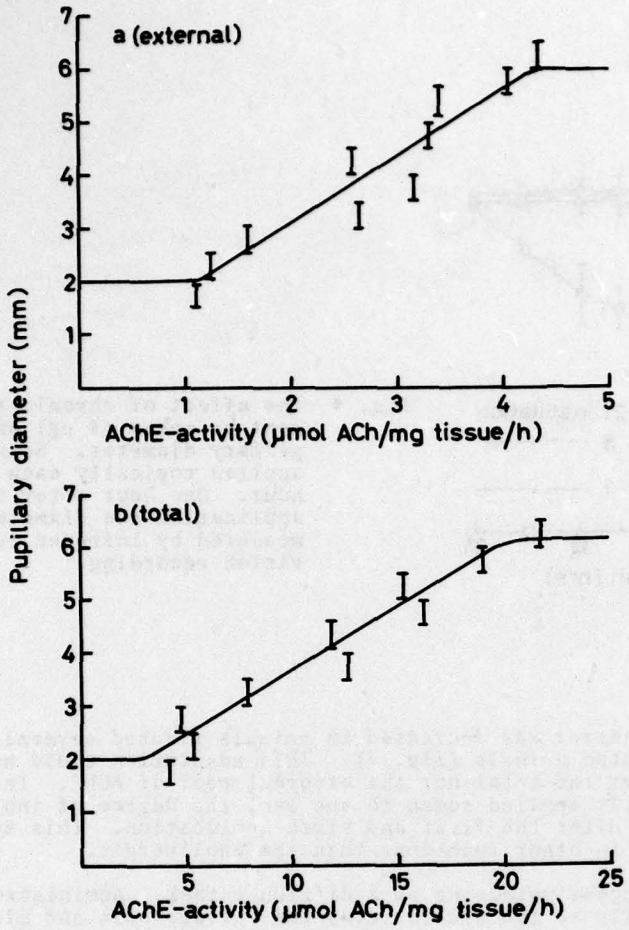

Fig. 2 Correlation of pupillary diameter to inhibition of external AChE in iris (a) and of total AChE in iris (b) after topically application of soman (4 µg) to guinea pig eyes.

Multiple Application

Repeated instillation of organophosphates each 24 hour for a week to the eye reduced the miotic potency of this drug (fig. 3). In addition the time for onset of miosis was delayed.

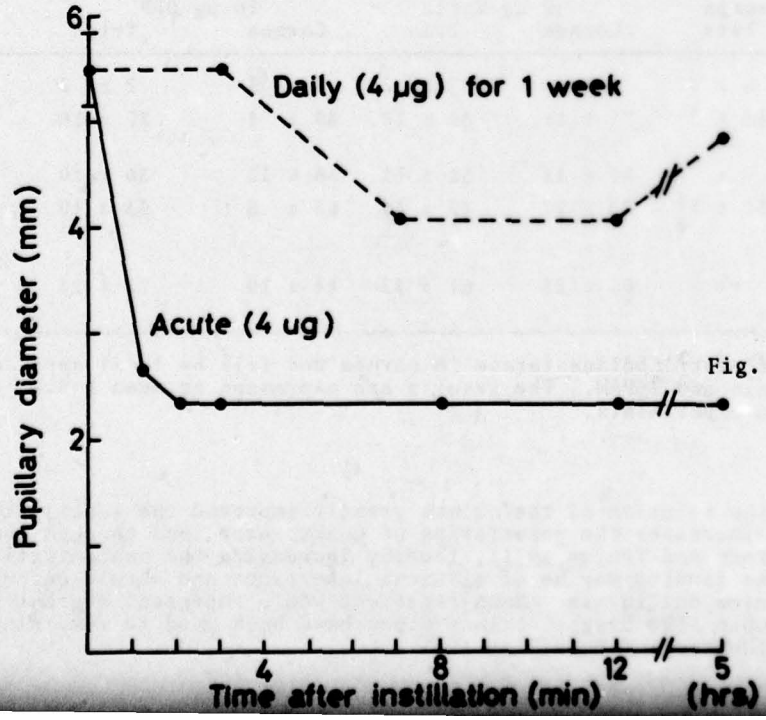

Fig. 3 The effect of repeated instillation of soman (4 µg) each 24 hour in guinea pig eyes on the pupillary diameter and the recovery of the diameter. Pupillary diameter was measured from infrared television recordings of the eye.

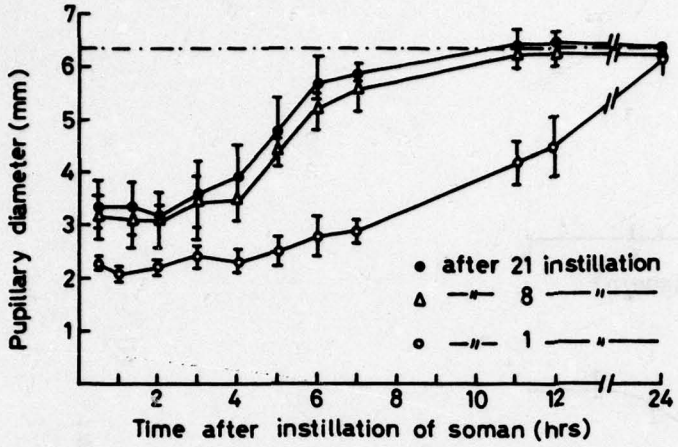

Fig. 4 The effect of chronic treatment by soman (4 µg) on pupillary diameter. Soman was applied topically each 24 hour. One hour after the application the diameter was measured by infrared television recording.

The recovery time of pupillary diameter was decreased in animals treated several times with soman compared to acutely treated animals (fig. 4). This adaptation could not be correlated to the recovery of neither the total nor the external pool of AChE. In animals treated several times with topically applied soman to the eye, the degree of inhibition of both pools of AChE was similar after the first and sixth application. This type of adaptation is therefore to be found in other functions than the cholinergic.

Treatment of miosis due to nerve agent poisoning is a difficult task. Administration of atropin either systemically or locally to the eye relieves the ciliary pain and miosis but causes easily mydriasis and hence does not improve visual acuity. In guinea pig we have studied the effect of topically oxime treatment to overcome organophosphate induced miosis. It was possible to overcome and control some of the unwanted effects accompanying the local application of DFP and sarin. As can be seen from table 1, both toxogonin and pralidoxime were able to reactivate partly the inhibited enzyme of cornea and iris (table 1).

	Per cent acetylcholinesterase activity					
	8 µg paraoxon		2 µg sarin		20 µg DFP	
	Cornea	Iris	Cornea	Iris	Cornea	Iris
Untreated eye	7 ± 3	6 ± 4	0	3 ± 2	5 ± 5	2 ± 2
5% 2-PAM	83 ± 3	56 ± 3	71 ± 11	39 ± 14	39 ± 4	27 ± 10
5% 2-PAM + 0.03% Benzalkonium	-	-	86 ± 11	51 ± 11	56 ± 11	36 ± 10
5% Toxogonin	86 ± 8	57 ± 17	43 ± 17	27 ± 18	66 ± 5	53 ± 10
5% Toxogonin + 0.03% Benzalkonium	-	-	65 ± 25	61 ± 22	84 ± 10	72 ± 13

Table 1. Reactivation of acetylcholinesterase in cornea and iris by local application of toxogonin and 2-PAM. The results are expressed as mean ± S.D. from 5 separate experiments.

Adding 0.03% benzalkonium to the solution of the oximes greatly improved the reactivation of the enzymes. Benzalkonium increases the penetration of quarternary ions through membrane barriers like cornea (Green and Tønjum 1971), thereby increasing the concentration of reactivator in the eye. The finding may be of clinical importance and should encourage similar experiments to be carried out in man. Such treatment would represent a great improvement over the use of atropin like drugs. Oximes alone have been used in reversing miosis in DFP treated humans (Hunter and McCulloch 1961).

At this point the dangers involved in extrapolating data from experimental studies in animals to humans should be emphasized. Although animal models often give important information on basic mechanism, differences may exist which make a direct comparison difficult. One obvious discrepancy between animals and humans is the duration of miosis. In humans miosis begins after 5-10 min after topical application, is maximally developed within 30 min and lasts for 4-7 days (Leopold & Comroe 1946, Scholz 1946). Ciliary spasm develops slower, is maximal within one hour and lasts shorter than miosis. In rabbits and guinea pig a fully developed miosis lasts for 24 hours (Leopold & Krishna 1963, Lund Karlsen & Fonnum 1977). In addition humans do not show any decreased miosis after repeated treatment of the eye with organophosphates (Wahl & Tyner 1965).

REFERENCES

1. Andersen, R.A., Laake, K. and Fonnum, F. Reactions between alkyl phosphates and acetylcholinesterase from different species. Comp Biochem Physiol, 42B, 429-437, 1972.

2. Barnett, R.J. and Palade, G.E. Enzymatic activity in the M Band. J Biophysic Biochem Cytol, 6, 163-9, 1959.

3. Ehinger, B. and Falck, B. Concomitant adrenergic and parasympathetic fibres in the rat iris. Acta physiol scand, 67, 201-7, 1966.

4. Ehrenpreis, S. Mittag, T.W. and Patrick, P. Radiometric assay of cholinesterases in intact tissues in the nanomolar concentration range of acetylcholine. Biochem Pharmacol, 19, 2165-9, 1970.

5. Green, K. and Tönjum, A. Influence of various agents on corneal permeability. Amer J Ophthal, 72, 898-905, 1971.

6. Harris, L.S., Shimmyo, M. and Mittag, T.W. Cholinesterases and contractility of cat irides. Arch Ophthalmol, 89, 49-51, 1973.

7. Holmstedt, B. Handbuch der Experimentellen Pharmakologie. Ed. G.B. Koelle, Springer Verlag, Berlin-Heidelberg-New York, 1963, 15, 449-450.

8. Hunter, W.S. and McCulloch, C. The neutralization of cholinesterase inhibition by various oximes and by atropine. Amer J Ophthal, 52, 841-844, 1961.

9. Koelle, W.A. and Koelle, G.B. The localization of external or functional acetylcholinesterase in the synapses of autonomic ganglia. J Pharm Exp Ther, 126, 1-8, 1959.

10. Leopold, I.H. and Comroe, J.H. Use of di-isopropyl fluorophosphate (DFP) in treatment of glaucoma. Arch Ophth, 36, 1-16, 1946.

11. Leopold, I.H. and Krishna, N. Local use of anticholinesterase agents in ocular therapy. Handbuch der Experimentellen Pharmakologie. Ed. G.B. Koelle, Springer Verlag, Berlin-Heidelberg-New York, 1963, 15, 1051-80.

12. Lund Karlsen, R. and Fonnum, F. Properties of the external acetylcholinesterase in guinea-pig iris. J Neurochem, 29, 151-6, 1977.

13. Mittag, T.W., Harris, L.S., Cohn, K., Galin, M.A. and Ehrenpreis, S. Analysis of cholinesterases of intact cat cornea, ciliary body, lens and retina. Invest Ophthal, 9, 742-8, 1970.

14. Potts, A.M., Modrell, R.W. and Kingsbury, C. Permanent fractionation of the electroretinogram by sodium glutamate. Am J Ophthal, 50, 900-7, 1960.

15. Rubin, L.S., Knop, S. and Goldberg, M.N. Effect of sarin on dark adaption in man; mechanisms of action. J Appl Physiol, 11, 445-9, 1957.

16. Scholz, R.O. Studies on the ocular reactions of rabbits to di-isopropyl fluorophosphate. J Pharmac Exp Ther, 88, 23-6, 1946.

17. Schwarzacher, H.G. Untersuchungen über den Cholinesterasegehalt der Skeletmuskel-Sehnenverbindung. Arch int pharmacodyn, 128, 330-7, 1960.

18. Wahl, J.W. and Tyner, G.S. Echothiophate iodide. Am J Ophthalmol, 59, 586, 1965.

Therapy on Nerve Agent Poisoning

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Nerve agents react with the enzyme cholinesterase on the cholinergic transmission on ganglions and endplates of muscles. Poisonous effects are produced by acetylcholine as muscarine-like and nicotin-like effects. Atropine is the antimuscarinic drug. The problem in the treatment is the dose of atropine necessary for a pharmacological titration against acetylcholine.
In addition to atropine the reactivators are the most important antidotes. Some oximes produced comparatively rapid and complete recovery of the cholinesterase blocked by either sarin or tabun (8). In soman poisoning in vivo 2-PAM was described to have certain antidotal properties in dogs as well as cats when administered intravenously shortly after the soman (5, 9) whereas obidoxime and TMB-4 have no therapeutic effect on soman poisoning (2, 3, 7). In statements of success or failure of antidotal therapy against soman poisoning, several authors pointed to species' differencies in response to anti-cholinesterase agents as well as antidotes (1, 4, 9).

Studying antidotal effects of 35 pyridinium salts HS-3 and HS-6 were described to have a protective effect against soman (10). Investigations into the therapeutic properties of various combinations of the bispyridinium salts HS-3 and HS-6 and the cholinolytics atropine and benactyzine against soman poisoning in unanesthetized male beagles were performed (11).
In all experiments atropine and benactyzine, 2 mg/kg, were given i.m. 6 min after s.c. poisoning with soman. The most effective therapy in soman poisoning was attained when the oximes HS-3 and HS-6 were implied together with the cholinolytics. The dose of 50 mg HS-3/kg and 100 mg HS-6/kg seemed to be too high for the treatment in man, whereas same treatment was not effective in sarin poisoning.
In respect to the therapeutic application of bispyridinium oximes in soman poisoned humans all tested substances were given in combination with the cholinolytics atropine and benactyzine dosed 30 μM/kg (6). All antidotes were injected i.m., 6 min after the s.c. poisoning with soman. The therapeutical efficiency is evaluated in relation to clinical symptoms, serum enzyme activities of cholinesterase, GOT, CPK, and ALD, but the most important parameter was the rate of our survived animals.
After application of 5 LD50 of soman the cholinesterase decreased independently from the oximes used very rapidly to 4-14% and within 1 hr remained beyond 3-6% of the original values. Independent from the oximes used the cholinesterase started to increase after 152 hrs to about 50% of the original values. The surviving rate differed from the oximes used considerably. After poisoning with 5 LD50 of soman, 0% of the dogs survived the therapy with HY-10; 17% survived HS-6, 25% HS-3, 67% HI-6, and 80% HGG-12. With higher dosages of soman all animals died. All oximes were used as hydrochloride salts. The survived dogs showed weakness of the neck muscles during 3 weeks so that they could not lift up their heads. With this method of therapy, literally, all dogs recovered during a period of about four weeks.

Other oximes showed different results. HY-58 was ineffective; with HH-64, HY-44, 50% of the soman poisoned dogs survived the 5 LD50 of soman. HGG-42 and HGG-12 are being studied with different doses in therapeutic use against 5-10 LD50 of soman and sarin as well against Vx 15 LD50 (11).

Results. Enzyme activity, GOT and CPK activity have a maximum level of 4-6 hrs after intoxication. CPK increases about three to eight-fold, GOT up to two-fold of the original value. CPK in two days decreases to the original values and GOT in seven days.
After application of 5 x LD50 of soman cholinesterase activity in serum decreases independently of the oximes used within 30 min under 10% of the original values (Fig. 2). After 2 hrs a slight increase up to 15% begins. On the first and second day cholinesterase activity in serum reaches 30 to 60% of the original values. Three weeks later cholinesterase increases to normal values. Cholinesterase in erythrocytes shows similar behaviour. There is no difference in cholinesterase activity in regard to therapy with 3-5 x LD50 in soman and 15 x LD50 in Vx-poisoning.

Therapeutic properties. Good therapeutic effects show the combinations of HGG-12 and HGG-42. In a dosage of 3 μMol for each antidote survival rate increases, mean survival time is extended and clinical symptoms are distinctly slighter and reduced. HGG-42 given alone shows the best therapeutic effect, but the dosage has to be higher (30 μMol/kg) than given in combination. HGG-12 even in high dosage has less therapeutic effect than HGG-42 or the combination.
In soman and sarin poisoning the used antidotes have good therapeutic effects up to 5-6-fold of LD50, in Vx-poisoning up to 10-15-fold.

Conclusions. Present data demonstrate that from all antidotes tested HGG-12-Cl and HGG-42-J in doses effective for treatment of men show good therapeutic effects in beagles poisoned with soman, sarin, and Vx. Best effect has HGG-42-J in a dose of 30 μMol/kg (= 18.27 mg/kg).
In soman poisoning no reactivation of serum cholinesterase and cholinesterase in erythrocytes was observed. Other mechanisms of therapeutic activity must be discussed.

Fig. 1 Chemical structure of HGG-12 and HGG-42

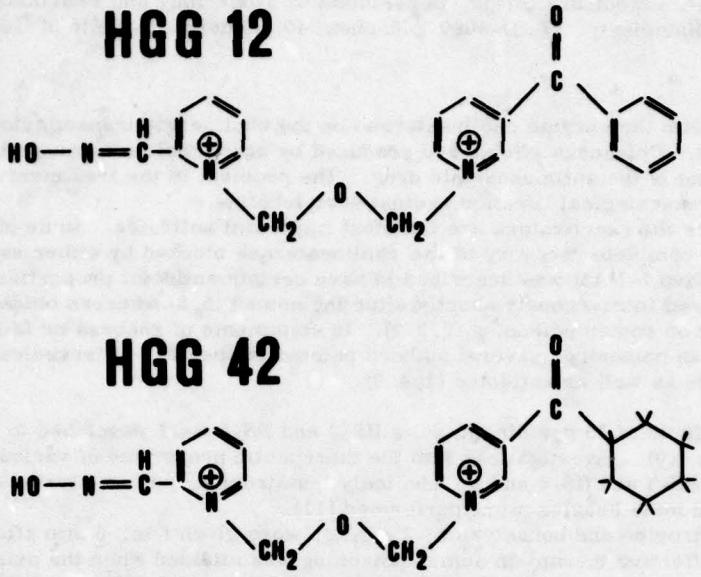
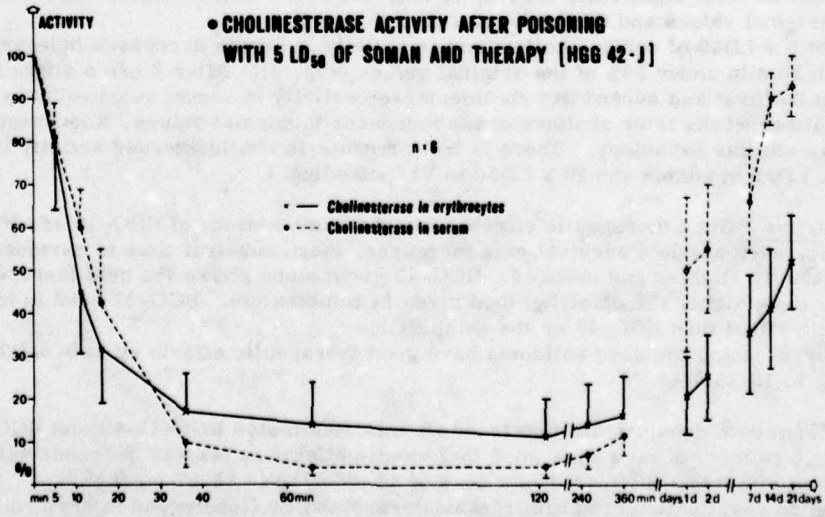


Fig. 2 Cholinesterase activity after poisoning with 5 LD50 of soman and therapy with 30 μMol/kg of HGG-42-J.
x - cholinesterase in erythrocytes
o - cholinesterase in serum



SURVIVAL RATE, SURVIVAL TIME AND CONVULSIONS AFTER POISONING WITH

5 LD_{50} OF SOMAN

Antidotes µMol/kg	number of animals	survived	survival rate %	survival time (min)	convulsions (% of animals)
HGG 12-Cl 3 HGG 42-J 3	8	3	63	3840	25
HGG 12-Cl 15	6	0	0	183	50
HGG 12-Cl 40	6	4	66	1490	17
HGG 42-J 15	5	1	20	450	80
HGG 42-J 30	6	5	83	17280	0
HGG 42-Cl 30	6	0	0	1788	34
HGG 42-J 15 OBIDOXIM 50	6	1	17	471	100
HGG 42-J 30 OBIDOXIM 50	6	3	50	2880	66

Table 1

Combination of HGG-12 and HGG-42, even in low dosage of 3 µMol/kg each, distinctly reduces clinical symptoms after poisoning with 5 LD50 of soman. Survival time and rate increase.
HGG-12-Cl, 40 µMol/kg, shows therapeutic effects. Surviving rate and clinical symptoms are not significant or different from the combination HGG-12 and HGG-42, 3 µMol/kg. HGG-42-J is more effective. In a dose of 15 µMol/kg, therapeutic effects begin and in a dose of 30 µMol/kg high significant effects (99%, Fisher test) in comparison to the therapy with atropine and benactyzine alone are observed. Combination of HGG-42-J with obidoxim has no better therapeutic effects, even a small negative influence of obidoxim is present; this, however, is not significant.

SURVIVAL RATE, SURVIVAL TIME AND CONVULSIONS AFTER POISONING WITH:

5 LD_{50} OF SARIN

Antidotes µMol/kg	number of animals	survived	survival rate %	survival time (min)	convulsions (% of animals)
HGG 12-Cl 3 HGG 42-J 3	4	2	50	48	100
HGG 12-Cl 30	6	1	17	13	100
HGG 42-J 30	6	3	50	30	100
10 LD_{50} VX					
HGG 12-Cl 3 HGG 42-J 3	6	4	66	3323	50
15 LD_{50} VX					
HGG 12-Cl 30	6	2	33	120	100
HGG 42-J 30	6	4	66		100

Table 2

After poisoning with 5 x LD50 of sarin the combination of the two oximes, HGG-12-Cl and HGG-42-J, 3 µMol/kg, has a good antidotal effect. HGG-12-Cl in high dosage of 30 µMol/kg is probably less effective whereas HGG-42-J has the same therapeutic effect as the combination of 3 µMol/kg each.
After poisoning with 10 x LD50 of Vx the combination has little effect. The oximes alone in high dosage, however, have better therapeutic effects. HGG-42-J seems to be better effective than HGG-12-Cl.

References

1) Berry, W.K., Davies, D.R.: The use of carbamates and atropine in the protection of animals against poisoning by 1, 2, 3-trimethylpropylphosphonofluoridate. Biochem. Pharmacol. 19, 927 (1970)

2) Bosković, B., Jović, R.: New possibilities of prophylaxis and treatment of poisoned animals with various kinds of nerve agents (yugosl.) Vojnosanitetski Pregled 26, 179 (1969)

3) Bosković, B., Stern, P.: Protective effect of oximes and cholynolytics in soman poisonings. Arch. Toxikol. 26, 306 (1970)

4) Davies, D.R., Green, A.L., Willey, G.L.: 2-Hydroxyimino-methyl-N-methylpyridinium methanesulfonate and atropine in the treatment of severe organophosphate poisoning. Brit. J. Pharmacol. 14, 5 (1959)

5) Fleisher, J.H., Harris, L.W., Murtha, E.F.: Reactivation by pyridinium aldoxime methochloride (PAM) of inhibited cholinesterase activity in dogs after poisoning with pinacolyl methylphosphonofluoridate (soman). J. Pharmacol. exp. Ther. 156, 345 (1967)

6) Hauser, W., J. Abb, P. Meier, and N. Weger: Therapeutic effects of the bispyridinium salts HGG-12 and HGG-42 and atropine, benactyzine in organophosphate poisoning of dogs. Abstract No. 52, 20th Congress of the European Society of Toxicology, Berlin (West) June, 25-28, 1978

7) Heilbronn, E., Tolagen, B.: Toxogonin in sarin, soman, and tabun poisoning. Biochem. Pharmacol. 14, 73 (1965)

8) Holmstedt, Bo: Pharmacology of organophosphorus cholinesterase inhibitors. Pharm. Rev. 11, 567-688 (1959)

9) Jović, R., Vojvodić, V.: Acute toxicity and therapeutical possibility in experiments of soman poisoning (yugosl.), Vojnosanitetski Pregled 28, 186 (1971)

10) Oldiges, H., Schoene, K.: Pyridinium und Imidazoliniumsalze als Antidote gegenüber Soman und Paraoxonvergiftung bei Mäusen. Arch. Toxikol. 26, 293 (1970)

11) Schenk, J., Löffler, W., and Weger, N.: Therapeutic effects of HS-3, HS-6, benactyzine, and atropine in soman poisoning of dogs. Arch. Toxicol. 36, 71-81 (1976)

Abstract

Therapeutic properties of various combinations of the bispyridinium salts HGG-12 and HGG-42 against soman and sarin poisoning were investigated in male beagles.

Best therapeutic efficiency showed HGG-42 in a dosage of 30 μMol/kg. Also good effects had the combination of both oximes in a low dosage of 3 μMol/kg for each one.

In soman poisoning no significant reactivation of cholinesterase in serum or erythrocytes was observed.

APPROACHES TO CW AGENT AREA DETECTION SYSTEMS FOR AIRFIELDS

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Summary

This paper describes the approaches the United States Air Force (USAF) is pursuing to develop a Chemical Agent Area Detection System for the protection of air bases. Point Detection Techniques which might provide a limited and interim area detection capability are discussed. Included in this discussion, is a brief technical description of the A/E23D-3 Chemical Agent Automatic Alarm and its characteristics. In addition, the USAF requirement for an instrument which will detect toxic chemical agents before they reach the intended target along with the capabilities such a detector must possess are presented in detail. The paper concludes with a discussion of the Air Force's present views on how such a system might operate.

Introduction

The objective of this paper is to discuss various approaches the USAF has considered to solve the problem of detecting Chemical Warfare (CW) agents before they arrive at the intended target. The paper is organized in somewhat of a chronological sequence, i.e. the subject will be treated in the order in which various approaches have been considered. Therefore, we shall first discuss Point Detection techniques which might, with limitations, be applied to remote detection. Following that, we will describe the requirements the Air Force has defined for its Area Detection System (ADS) and some of the techniques which have a potential to satisfy these needs.

Point Detection Techniques

One solution to the problem of detecting CW agents is the development of point detectors. A point detector is any device which will detect CW agent or agents at the location where the detector is placed. By definition, such a device will be of use only if it is placed exactly where the agent is located. A point detector will not be effective if the CW material passes above or to the side of the detector. In addition, most point detectors have the disadvantage of requiring the involvement of humans not only to place the detector, but also to observe its function and read-out.

Perhaps, the earliest chemical point detector was the canary. Miners took canaries into mines in order to have warning when dangerous levels of gases were present. The bird, since it was more sensitive to the presence of mine gases and the absence of oxygen than humans, would die before most miners were affected. Thus personnel were alerted to the danger and, hopefully, had time to leave the area. While this approach may seem primitive, it is not entirely clear that this concept should be totally dismissed in solving today's CW alarm problem.

In more recent times, a number of manually operated Chemical Agent Detector kits such as the US Army's M-15, M18A2 and their replacement, the M256, have been developed. These kits (M18 and M256) will determine the presence or absence of nerve, blister, blood, and choking agents. The M18A2 (and M15) kit is clumsy to use when personnel are wearing protective gear and its use involves careful manipulation of small glass tubes and other components. The M256 kit is much simpler to use. Even personnel wearing protective clothing can rather easily perform all tests. The kit itself is much smaller and more rugged than the M18 and has a longer storage life.

However, these kits do have many significant limitations in their ability to detect CW agents. Some of these are: (1) they cannot be used below 0°C, (2) they detect agent only in vapor form (M8 paper is used to detect liquid agent), (3) they require operation by humans, (4) identification of agent requires 10 minutes or more, (5) each kit (tube) can sample only once, (6) the kits cannot sample continuously; normally they are used only after a suspected attack to confirm the presence or absence of agent.

These kits provide virtually no area detection capability. They cannot reasonably be used to continually monitor a location; they are not automatic; and they have rather severe environmental limitations.

The US Air Force's A/E23D-3 Chemical Agent Automatic Alarm, often called the Ionization Detector (ID), was developed by Honeywell Avionics Corporation and the Air Force to provide a capability to automatically detect and alarm to G and V nerve agents, in vapor and aerosol forms, under virtually all environmental conditions. This detector does not require the presence of humans to function, or to sound an alarm, and can be operated for long periods of time without servicing or calibration, since it uses physical

detection methods instead of chemical. As part of the ID System, an Organizational Test Set (OTS) and an Intermediate Test Set (ITS) were also developed. Pertinent data on the characteristics of the system are shown in Table One, on its sensitivity in Table Two, and on its performance in the presence of possible interferents in Table Three. Production units currently undergoing tests at the US Army Chemical Systems Laboratory (CSL) have operated for over 15,000 hours with no failures. Three hundred fifty production units have been delivered to USAF operational units.

The A/E23D-3, while detecting only nerve agents, offers significant improvements over the handheld and operated kits. The ID can be operated independent of personnel, can directly interface with the USAF Base and Installation Security System (BISS) to provide warning of a CW attack, needs minimum calibration and functional checks, can effectively operate in virtually all weather conditions, needs minimum logistic support, and can be used to continuously monitor for the presence of nerve agents.

The major limitation of the unit is its inability to detect CW agents other than nerve.

Unlike the handheld kits, the A/E23D-3 can provide limited remote detection capability. Units can be placed in normally upwind locations relative to facilities or personnel which would need advance warning of a CW nerve agent attack. These positions could be prewired and ready to accept detectors in times of increased hostility. Units, in the battery mode or connected to suitable mobile power, can be used to track the travel of agent cloud and to quickly verify the absence of vapor contamination either by being carried by personnel or mounted in a vehicle. Like the kits, however, the ID's will only react to what they sample. In order to reduce the risk of agent passing to the side of the detectors, at least five of them would be needed to give a reasonable level of protection to an air base.

Figure 1 is a sketch of possible placements of ID's to offer an area detection capability around an airfield. The USAF is presently seriously considering such use for the A/E23D-3.

Area Detection

Obviously the use of A/E23D-3 detectors even in the remote mode does not provide a true area detection capability to the Air Force. For the purpose of this discussion, we define an area detector as a system which will provide detection and warning of chemical warfare agents at some distance away from the detector itself.

Consequently, the Air Force has a formal requirement for an Area Detection System (ADS) which will have the following capabilities:

1. Detect all known nerve agents no matter what their physical form
2. Detect these agents in the atmosphere at a range of at least 1600 meters
3. Detect these agents in the atmosphere at the sensitivity levels shown:

Concentration (mg/m^3)	Distance from Detector (meters)
1	10-100
10	100-1000
100	< 1000

4. Provide a radial resolution of at least 70 meters.
5. Be single-ended.
6. Perform hemispherical scan and provide ranging information.
7. Not false alarm to common atmospheric interferences.
8. Be air-transportable.
9. Be compatible with the Base and Installation Security System (BISS).
10. Operate from 230/115 VAC, 50/60 HZ power.
11. Be automatic.
12. Be capable of operating in the field for four weeks with no calibration.
13. Have a 98% reliability.
14. Have a mean time to repair of not more than of one hour.

TABLE 1
CHARACTERISTICS OF THE A/E23D-3 SYSTEM

	A/E23D-3 Sensor and Power Supply	A/E23T-5 OTS	A/E23T-4 ITS
SIZE	7 x 7 x 20 in.	7.5 x 4.8 x 6.8 in	24.5 x 19.5 x 16.2 in
WEIGHT	28 lbs	7.5 lbs	78 lbs
POWER	115 VAC, 50-400 HZ 28 VDC BATTERY	28 VDC from A/E23D-3	115 VAC, 60HZ
RELIABILITY	MTBF: 7000 hrs (90% conf) MTBFA: 20,000 hrs (lab)	---	---
MAINTAINABILITY	MTTR: organ, level 0.86 hrs int. level 0.81 hrs	---	---
TEMPERATURE EXTREMES OPERATING	-40°C to 60°C (operating) -28°C to 60°C (start up)	0°C to 49°C	0°C to 49°C
STORAGE	-40°C to 71°C		
ENVIRONMENTAL	MIL-STD-810C	MIL-STD-810C MIL-T-28800B	MIL-STD-810C MIL-T-28800B
EMI	MIL-STD-462	MIL-STD-454	MIL-STD-454

TABLE 2
SENSITIVITY OF THE A/E23D-3

AGENT	AIR FORCE REQUIREMENT		A/E23D-3 PERFORMANCE**	
	CONCENTRATION (mg/m^3)	AVG TIME (sec)	CONCENTRATION (mg/m^3)	AVG TIME (sec)
GA	0.4	120	0.2	5
GB	0.2	120	0.08	10
GD	0.2	120	0.04	2
VX	0.1 (0.2)*	120	0.13	70

* REQUIREMENT RELAXED TO 0.2 mg/m^3 FOR ID EFFORT

**CALIBRATED TO 0.1 mg/m^3 GB

TABLE 3
RESPONSE OF A/E23D-3 TO FIELD INTERFERENCES*

INTERFERENT	DISSEMINATION DISTANCE (m)	DETECTOR RESPONSE	COMMENTS
DIESEL EXHAUST	4.6	nil	engine at idle
	4.6	alarm (7 volt)	direct exhaust
	9.1	alarm (7 volt)	with hose
	15.2	4.5 volt	
JET EXHAUST	91.4	alarm	directly behind engine at idle
	sides of runways, etc	minimum response	during A/C operations
SMOKE			
YELLOW	9.1	4.0 volt	heavy cloud
RED	12.1	5.0 volt	heavy cloud
GREEN	18.3	6.5 volt	heavy cloud
VIOLET	6.1	2.0 volt	heavy cloud
HC	12.1	-3.0 volt	negative
BURNING WOOD	6.1	2.0 volt	
BURNING GRASS	6.1	3.5 volt	
BURNING CLOTH	6.1	2.0 volt	
BURNING RUBBER	6.1	2.0 volt	
BURNING GASOLINE	3.1	2.5 volt	
BURNING DIESEL	3.1	2.0 volt	
DOUSED FIRE (H_2O)	6.1	alarm (6 volt)	
ROCKET PROPELLANT	9.1	0.6 volt	
VAPOR			
HYDRAULIC FLUID	0.9	nil	
LIQUID BLEACH	0.9	nil	
DRY STB POWDER	0.9	nil	
DS-2	0.9	2.5 volt	
GASOLINE	0.9	2.0 volt	
DIESEL FUEL	0.9	nil	
COMP B (1/4 lb)	15.2	nil	exploding
TNT (1/4 lb)	15.2	0.5 volt	exploding
PYRETHRIN	4.6	9.0 volt	insecticide

* RESULTS OF TESTS ON PRE-PRODUCTION UNITS. TESTING ON PRODUCTION UNITS INDICATE NO SIGNIFICANT DIFFERENCES.

In addition, the ADS should also meet the following desired requirements:

1. Detect and discriminate among nerve, mustard, lewisite, and blood agents.
2. Detect agents in the atmosphere at ranges up to 8000 meters.
3. Be capable of operating between -40°C to 55°C and 5 to 100% RH.
4. Have a half-life of eight years, service life of ten years.
5. Withstand storage regimes of -62°C to 71°C and relative humidity of 0-100%.
6. Require calibration once a year.

The primary purpose of the ADS is to provide advance warning of CW agent approaching key base locations. Additionally, in the case of an on-target attack, the ADS will identify possible contamination of mission essential areas (flight-line, crew alert shelters, etc). During the post attack phase, the ADS will determine if airborne contamination has dissipated and, if it has not, determine its location and course.

Many technical approaches are possible to provide the above capabilities. Among those under study or undergoing test are: (1) passive infrared systems which essentially look at the natural radiation being absorbed by objects or material in the 8-12 micron range; (2) active laser systems which look at the absorbance of transmitted radiation which is reflected back to a detector; (3) a combination of both. No matter what approach is used, there are many technical problems, not the least of which is the process used to reject false targets and detect and identify true targets. Figure 2 is a sketch of some of the substances of concern in this regard. Somehow, the ADS must be able to discriminate agent from materials such as dust, smoke, pollutents which will be present in the air over an air base both in peacetime and in war.

The problem is particularly troublesome in a hemispherical scanning detector. Figure 3 shows some of the interfering substances with which a scanning detector might have to deal. Fixed false targets as well as variable false targets (variable with respect to location and IR emittance) will have to be discounted before CW agents can be detected with certainty. Fortunately, the ADS will be a fixed installation. Consequently the response of fixed false targets can be catalogued and the ADS can be programmed to discount them. The response of various non-fixed targets can be catalogued and stored in a data processor for quick comparisons. Other false targets such as fires, sun, atmospheric clouds, etc. can be eliminated by temperature or spatial discriminators. Figure 4 presents a possible decision matrix to eliminate false targets. Note, that in order to proceed through this algorithm, more than one wavelength of radiation must be scanned.

Figures 5, 6, and 7 pictorially present a concept of how the ADS might function.

Conclusion

In this paper we have described briefly the approaches the Air Force is pursuing to develop an Area Detection System for the protection of air bases. We have mentioned some of the existing Point Detection devices, and in particular the A/E23D-3, which can be used to provide an interim and limited area detection capability. We have also discussed, in some detail, the US Air Force requirement for an Area Detector and our present views on how such a system might operate to detect CW agents.

FIGURE 1

A/E 23D-3 CHEMICAL AGENT AUTOMATIC ALARMS FOR AREA DETECTION CAPABILITY

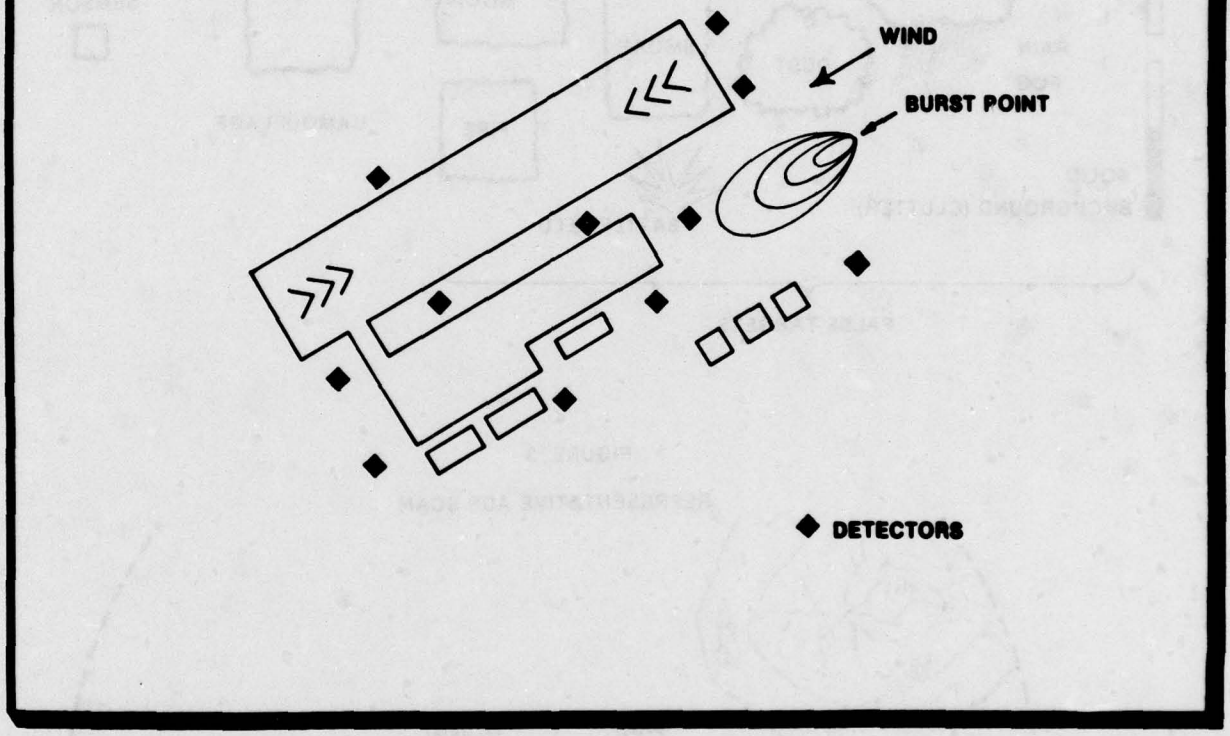


FIGURE 2

POTENTIAL TARGETS OF AN AREA DETECTOR

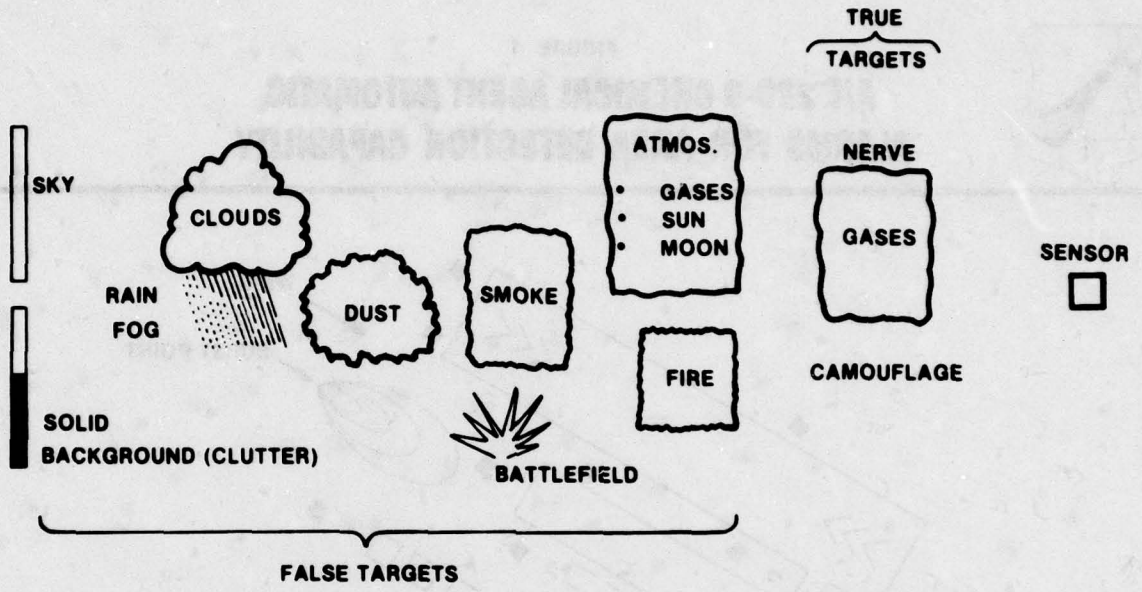


FIGURE 3

REPRESENTATIVE ADS SCAN

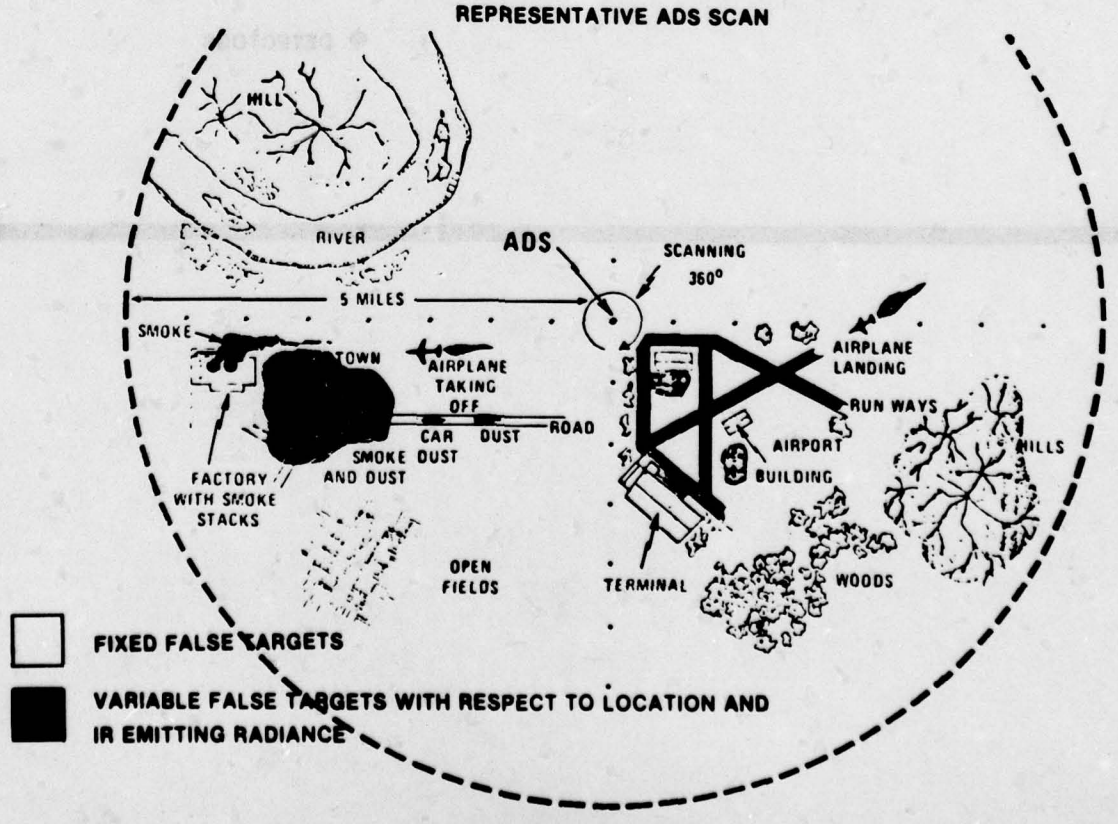


FIGURE 4

POSSIBLE ADS DECISION MATRIX

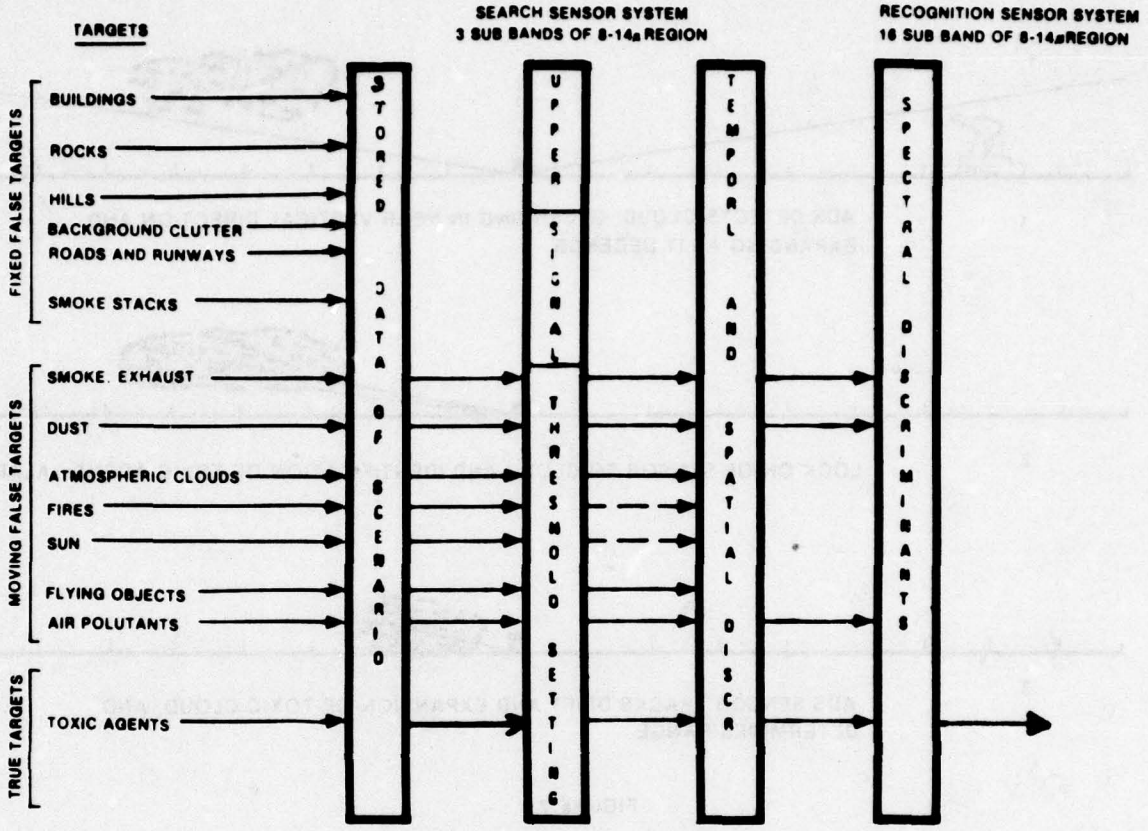
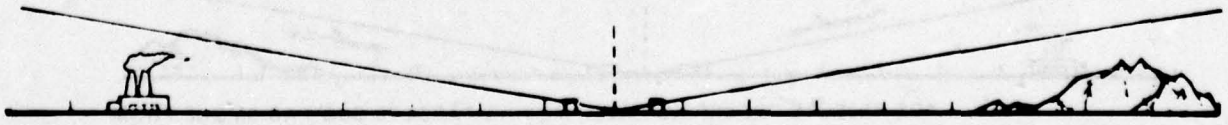


FIGURE 5

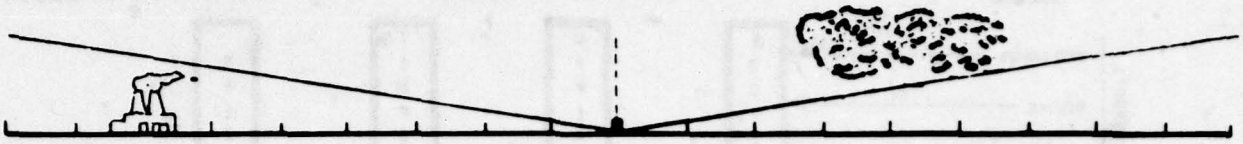
MODES OF ADS OPERATION



- ADS IS INSTALLED AND STARTS OPERATING
- MAPS ALL FALSE FIXED IR EMITTING TARGETS
- STORES DATA

FIGURE 6

TRUE TARGET ACCEPTANCE



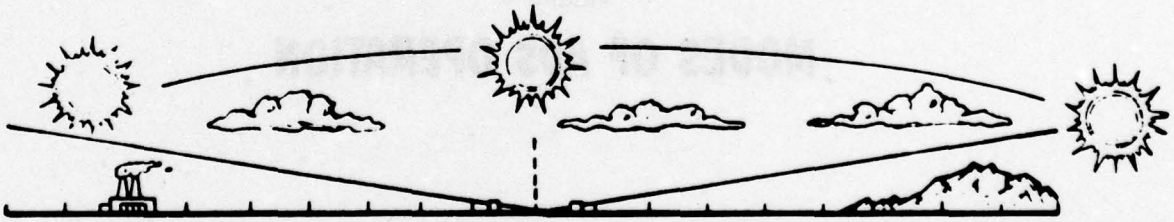
1 ADS DETECTS CLOUD. DECENDING IN NEAR VERTICAL DIRECTION AND EXPANDING AS IT DECENDS

2 LOCK ON OF SENSOR TO CLOUD AND IDENTIFICATION OF TOXIC AGENT: ALARM

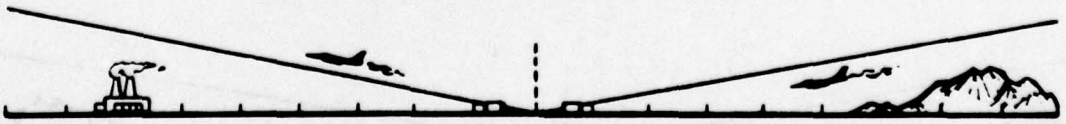
3 ADS SENSOR TRACKS DRIFT AND EXPANSION OF TOXIC CLOUD, AND DETERMINES RANGE

FIGURE 7

FALSE TARGET REJECTION



A
- ADS REJECTS ALL FIXED IR EMITTING TARGETS UPON CONSECUTIVE SCANS
- REJECTS SUN BLINDING FROM RISE TO SET
- REJECTS ATMOSPHERIC CLOUDS BASED ON SIZE



B ADS REJECTS RECURRING FALSE MOVING TARGETS SUCH AS SMOKE FROM SMOKE STACKS AND AIRPLANES (TAKE-OFF AND LANDING) BASED ON STORED LOCATION DATA, SIZE, DRIFT AND SIGNAL AMPLITUDE (HOT EXHAUST FROM AIRPLANES)

C
- ADS DETECTS CLOUD RISING FROM THE GROUND
- LOCK-ON SENSOR
- CLOUD IS IDENTIFIED AS DUST AND FALSE TARGET IS REJECTED

PHILOSOPHY OF PROTECTION OF U.S. AIRCREWS AGAINST CHEMICAL WARFARE AGENTS

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In 1975, the USAF recognized the need to provide protective equipment to aircrews that would allow them to accomplish their operational missions after having been attacked by an enemy using chemical warfare agents. This requirement was deemed to be an urgent one; thus, a two phase program was initiated. Phase one was the development and production of "near term" equipment which would provide the required operational capability with delivery of equipment to the field to begin within two years. Phase two consists of a longer term program to provide more complete protection with a reduced operational burden.

NEAR TERM PROGRAM

Because of the time constraints of the near term program, primary emphasis was placed on using, where possible, equipment already existing or already under development by the Armed Forces of the U.S. or its allies. Candidate equipment items were identified, screened, evaluated for AF use, modified where required, retested, and if successful, placed into production. Several basic assumptions were fundamental to the near term program:

a. It was assumed that aircraft cockpits would be "dirty," that is droplet or liquid contaminated, and that these cockpits could not be effectively decontaminated. This assumption was based on our inability to assure that cockpits would be clean.

b. A protection factor of 10^4 was considered to be the minimum acceptable for aircrew respiratory/eye protection. This protection factor was determined by taking into account the susceptibility of aircrews to ocular effects of nerve agents and by assessing the anticipated operational environments to be encountered.

c. Interoperability and, where desirable, standardization with protective systems of other U.S. Armed Forces and our allies were important considerations. With regard to interoperability, it was recognized that "free standing" equipment requiring no ancillary support equipment, provides a significant step toward interoperability. Standardization of consumables such as replacement filters was a particularly important goal.

d. The final over-riding assumption was that the near term equipment would be, in fact, interim, and that it would be replaced as rapidly as feasible with improved, less burdensome, and perhaps more elegant equipment.

An aircrew protective ensemble, consisting of seven components for use in the cockpit, and two additional for use in transit to the aircraft, was developed against these criteria. All were successfully transitioned into production; and all are currently in use by USAF operational forces. A detailed description of the USAF near term chemical defense ensemble for aircrews will be given in a subsequent paper.

LONGER TERM PROGRAM

The longer term USAF research and development program for chemical defense has a number of objectives, among which are:

a. The provision of a more complete operational capability.

b. The provision of a higher level of personal protection, where feasible and necessary.

c. The unburdening of operational personnel, particularly aircrews, by eliminating some of the discomfort and performance limitations of the near term personal protective equipment.

d. The incorporation of chemical defensive capabilities into "standard" military equipment.

In order to pursue a more complete operational capability, a number of parallel efforts are being conducted. These include a quantitative evaluation of hazards presented by ingestion of chemical agents through aircraft engines and Environmental Control Systems (ECS); evaluation of the inherent protective qualities of aircraft ECS, and their ability to "purge" contaminated cockpits; the development of Area Detection and Warning Systems; a better understanding of contamination control principles and the development of decontamination systems. Overlaying these and providing a cohesive substructure is an integrated systems analysis of Air Force

operations in a chemical environment and the parametric opportunities for their improvement. Our efforts in Area Detection and Warning will be described in more detail in a later paper.

The over-riding goal in the area of personal protection is to provide as much protection as is required at the least possible burden to the human operator. Since protective capability and induced burden are generally directly related, it is important that we not over-protect just as it is important that sufficient protection be provided. The protective factor currently required by the U.S. Tactical Air Forces is 10^4, a criterion also accepted by the United Kingdom. There is some benefit perceived by going to a protective factor of 10^5 if such can be done without increasing the burden to crewmembers; and it becomes especially attractive if the burden can, in fact, be decreased. Fundamental to the question of protective factors, is a valid assessment of the anticipated operational scenario and the resulting levels of contaminant exposure. We hope that our integrated systems analysis and our aircraft ECS evaluation will help illuminate these questions.

With these objectives in mind, we have designated our longer term aircrew eye and respiratory protection development as the highest priority effort in our longer term program. In pursuit of these objectives, we are conducting five parallel efforts to obtain an improved headgear. You will hear more of these in a later paper. Regardless of the concept finally selected, it is almost certain that some form of pressurization and air flow must be provided to the headgear and that to obtain such auxillary air flow, aircraft modifications will be required.

The burdens of the near term equipment include discomfort, increased thermal loading, and visual field limitations. These are especially critical for aircrews and are being addressed in the longer term program.

Many of the limitations and burdens of the near term equipment are a direct result of the layering or add-on nature of these items. These additional pieces of equipment are added to the standard aircrew flight gear to provide required chemical protection. In our longer term program, we will attempt to integrate the chemical defense capability into standard aircrew gear so that the layering effect can be eliminated or reduced. Our first attempt at implementing this concept is the High Altitude Multi-Purpose Suit currently under development to replace the USAF -6 full pressure suit. We are attempting to incorporate chemical defense protective capabilities into the garment in addition to other capabilities not normally contained in full pressure suits; for example, anti-g and flotation capabilities.

Since the longer term program will be conducted in a more orderly fashion and in a somewhat less urgent environment, we will pursue questions of interoperability and standardization with more vigor. Once again, we consider the standardization or interoperability of consumables (or perhaps replaceables) as having the highest priority in this regard.

Over the past year, the AF Scientific Advisory Board, an eminent group of scientists and other professionals, reviewed the USAF Chemical Defense Program in great detail. Their final report complimented the Air Force, and particularly the Life Support SPO, on its conception of the two phase program and on its implementation of the near term efforts. In doing so, it warned against complacency and reminded us that progress toward the final goal has only begun. We couldn't agree more!

A PROPOS DES EQUIPEMENTS INDIVIDUELS DES PILOTES DE CHASSE DE L'ARMEE DE L'AIR

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I. GENERALITES.

En cas de conflit, les bases aériennes qui assument des missions essentielles constituent un objectif de choix pour l'adversaire qui va s'efforcer, soit de contrarier, soit d'annihiler leur activité.

Les spécialistes estiment qu'un des meilleurs moyens permettant d'atteindre ce but réside en l'utilisation des armes chimiques. C'est pourquoi chaque Nation se doit de prévoir une parade efficace à ce type d'attaque, en évaluant les effets probables des agressifs chimiques de guerre dispersés au niveau d'une base aérienne, en déterminant la nature des moyens de protection nécessaires et en décidant les mesures les plus appropriées adaptées à leur mise en oeuvre.

II. L'ATTAQUE CHIMIQUE.

Dans des conditions bien déterminées de température, de degré hygrométrique, de vent, de stabilité thermique et de précipitations, des agressifs chimiques peuvent neutraliser les activités d'une base aérienne (dont la dimension est relativement réduite) en combinant les effets atteignant les personnels et les matériels par la création d'une zone, où la concentration chimique est active.

L'action de l'attaque chimique est limitée dans une couche proche du sol, de sorte qu'avec l'altitude et l'éloignement, on se soustrait à ses effets. Les agents toxiques utilisés pénètrent dans l'organisme par la voie pulmonaire, par les muqueuses et le revêtement cutané. Certains composés, notamment les dérivés organophosphorés sont actifs à faible dose et présentent une toxicité importante dont on sait qu'elle pose des problèmes thérapeutiques et prophylactiques délicats à résoudre.

Les besoins : Pour pallier une attaque chimique, la protection individuelle est déterminante, mais elle n'a de sens que si la base aérienne bénéficie de moyens de protection collectifs dans lesquels elle s'intègre, à savoir :

- les moyens de détection et d'alerte
- les abris pour le personnel et les moyens opérationnels
- les moyens de décontamination
- les services médicaux de traitement et de surveillance du personnel

Lors d'une attaque chimique, les équipages devraient donc se trouver en alerte dans des abris aménagés d'où ils partiront pour accomplir leurs missions aériennes. Dans les cas les plus défavorables, ils devront parvenir à leurs avions après avoir parcouru une distance plus ou moins longue dans une atmosphère toxique et sur un terrain contaminé. Les avions eux-mêmes seront contaminés si des précautions particulières n'ont pas été prises ; en s'installant dans l'avion, ils auront à se connecter avec la source d'oxygène de bord, à effectuer le brélage au siège et à effectuer les manoeuvres de mise en route. Pendant le roulage et la phase de décollage, ils pourront encore être soumis aux toxiques pénétrant par le système de conditionnement d'air ou par la pollution éventuelle de l'habitacle. Dès une certaine altitude, relativement basse, l'avion s'échappe de la zone chimique.

Il faut donc, pour assurer une protection individuelle des équipages, élaborer un équipement composite permettant d'isoler les voies respiratoires et de protéger les muqueuses et la surface cutanée de l'atteinte de l'agent chimique, que ce soit durant le trajet abri-avion qu'au contact des surfaces contaminées de l'avion pendant la mission.

Cet équipement doit comprendre en outre la fourniture au sol, avant l'installation dans l'avion, d'air respirable ou d'oxygène.

III. L'EQUIPEMENT INDIVIDUEL.

L'étude des équipements individuels de protection sont effectués par l'Armée de Terre, qui, dans ce domaine, a poursuivi des recherches depuis de nombreuses années. A ce titre, elle a réalisé des ensembles de protection individuelle comprenant des survêtements, des masques dotés de cartouches filtrantes et de filtres anti-particules, des gants, des couvre-chaussures, qui peuvent être communs aux trois armées.

En ce qui concerne l'Aéronautique, ces équipements intéressent tout au plus le personnel au sol chargé de la mise en oeuvre et de l'entretien des flottes aériennes.

Par contre, il serait difficile d'admettre pour les équipages d'avions, dont l'environnement et les exigences opérationnelles sont très particuliers, l'absence de participation des Services Techniques Aéronautiques et du Service de Santé pour l'Armée de l'Air, dans la conception de ces équipements. En effet, la tenue de protection des équipages et tout spécialement des pilotes doit être telle qu'elle puisse :

1° s'intégrer aux équipements propres à l'avion (où la place est très mesurée) ; par exemple :

- paquetage de secours
- sangle de brélage
- siège éjectable
- connections radio
- connections anti-g
- connections oxygène, etc...

2° s'intégrer aux équipements individuels de vol ; par exemple :

- casque anti-choc
- parachute de secours
- alimentation en oxygène
- paquetage de survie

3° répondre à des spécifications particulières de confort minimal exigé pour maintenir intact le potentiel psychophysiologique des pilotes, nécessaire à l'accomplissement de leur mission, toujours délicate dans cet espace à trois dimensions, au milieu des facteurs nocifs du vol et des interventions ennemies.

C'est pourquoi, par exemple, l'équipement de protection ne devra pas apporter de contraintes thermiques ni, tout particulièrement, de contraintes respiratoires (résistances trop élevées à l'inspiration et l'expiration - espace mort nuisible - insuffisance du taux d'oxygène). La conception de l'équipement ne doit pas davantage apporter de gêne notable :

- dans les mouvements du pilotage
- dans l'observation des paramètres utiles au vol
- dans la préhension de certaines commandes
- dans l'agilité tactile des doigts ...

En bref, l'équipement de protection des équipages est donc bien particulier : il peut être obtenu par l'adaptation très poussée de la partie vêtement, mais demande une réalisation toute spéciale pour la protection de la tête et des voies respiratoires.

IV. LES SPECIFICATIONS DE L'ÉQUIPEMENT DE TETE.

En ce qui concerne les spécifications de l'équipement de tête, il faut admettre auparavant :

1° que la flotte aérienne, dans sa plus grande partie, n'a pas été conçue pour sa mise en oeuvre en ambiance "chimique" ;

2° que le risque chimique dans la vie d'un avion est très faible et doit être couvert de façon la plus "économique" possible.

C'est pourquoi, la protection doit se faire pratiquement au niveau individuel en utilisant les équipements de vol actuels, sans modification de l'avion. A partir de ces prémisses, les spécifications générales de l'équipement de tête peuvent être ainsi établies :

1° la protection de la partie tête doit être réalisée par intégration au casque de vol en utilisation dans l'Armée de l'Air et en respectant ses attaches, le libre jeu des visières et les équipements radiophoniques ;

2° la conception doit être telle que :

a) l'alimentation en oxygène puisse se faire à partir de la source de l'avion avec les caractéristiques physiologiques requises de débit, de résistances respiratoires et de taux d'oxygène ;

b) la connection d'oxygène soit du type "NO SPILL" s'opposant à l'introduction dans le circuit d'alimentation des contaminants toxiques ;

c) l'utilisation des visières optiques soit maintenue et que la vision extérieure et la lecture des instruments de bord ne subissent pas d'altération ;

d) le confort thermique déjà limité ne soit pas détérioré ;

e) l'augmentation de la masse du casque soit la plus réduite possible afin de ne pas rendre intolérable le port de cet équipement tout particulièrement au cours des accélérations et des vibrations ;

f) la liaison avec la protection du corps se fasse sans discontinuité.

V. CONCLUSION.

Ces éxigences ne rendent pas aisée la solution du problème sans accepter de compromis ; il faut être conscient que tout élément de protection particulière apportée à un pilote se fait aux dépens du confort le plus souhaitable. Déjà protégé contre l'abandon de bord, l'éblouissement, l'anoxémie, les chocs, les accélérations, il faut maintenant adjoindre à cela des protections vis-à-vis des hautes intensités lumineuses (flash nucléaire - laser) et des agents de la guerre chimique.

Cette mission difficile représente cependant un excellent ferment pour la recherche technologique et le maintien d'une veille scientifique permettant d'approcher et si possible de résoudre les problèmes posés par les menaces nouvelles.

Mais le risque est grand de rendre encore plus délicat l'accomplissement des difficiles missions imposées à nos pilotes en contraignant davantage leur potentiel psychophysiologique et de faire rêver un peu plus nos ingénieurs vers la conception de robots et d'avions sans pilotes.

US AIRCREW CHEMICAL DEFENSE ASSEMBLIES

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Summary

This paper discusses the current United States Air Force aircrew chemical defense ensemble and follow on engineering development efforts. Included is a brief description of the current aircrew chemical defense ensemble which is divided into four subsets: eye/respiratory/head, body, hand and foot protection. The associated chemical agent and flight qualification testing is discussed for each piece of equipment. The status of follow on development efforts which concentrate on the aircrew chemical defense eye/respiratory/head protection is reviewed.

Background

In 1976, the Life Support System Program Office (SPO) was given the program responsibility for the Research, Development, Test and Evaluation (RDT&E), and acquisition management of all aircrew chemical defense (CD) equipment.

A two phased program approach was taken; near term and follow-on. The objective of the near term program, or our "quick fix" program was to initiate the delivery of available equipment to the field beginning the latter part of 1977. This would enable us to establish an equipment baseline which would act as a catalyst for improving concepts, procedures, training, and logistics aspects. The follow-on program was to initiate efforts to eliminate or reduce the burdens or limitations of the near term equipment and to incorporate new technology, when available.

In 1976, the near term aircrew chemical defense equipment program was initiated and the following iterative process was employed to meet the 1977 deadline:

Survey Available Equipment
Select Candidate Equipment
Evaluate
Modify (If necessary)
Perform Qualification Testing
Perform Operational Test and Evaluation

After an 11 month effort, an Air Force corporate decision based on available information and results, was reached which selected the near term CD aircrew ensemble.

Near Term Aircrew CD Equipment

The Aircrew Chemical Defense (CD) ensemble is divided into four subsets: eye/respiratory/head protection, body protection, hand protection and foot protection.

Eye/Respiratory/Head Protection. The eye/respiratory/head CD aircrew protection is composed of: a mask, a filter assembly, flyers' helmet and protective hood.

Chemical Biological Oxygen (CBO) Mask, MBU-13/P: It is a full face silicone mask with a rigid plastic faceplate, an adjustable five point suspension harness, an oral-nasal cup which prevents fogging, a pressure compensated valve, a microphone which is compatible with the aircraft communications system, and side posts for mounting eyeglasses. The mask is oxygen rated. It is a single size mask and there are problems fitting long narrow faces. The other disadvantages include: no manual means of performing a valsalva maneuver, a 10% reduction in peripheral vision, and a pressure point due to the center buckle of the mask harness. A dual strap arrangement is used to attach the CBO mask to the flight helmet. (See Figure 1)

Chemical Biological Oxygen (CBO) Mask Filter Assembly, CRU-80/P: The filter assembly is made of butyl rubber and houses two M13A2 filter elements. These are the same filter elements that are used in our ground personnel mask (M17A1); therefore, from a filter standpoint we have interoperability between our ground crews and aircrews. For

ejection seat aircraft, the filter assembly attaches to the aircrew parachute harness via a wedge plate. For non-ejection aircraft the aircrewman uses a strap arrangement which fits over the shoulder and around the waist. The filter assembly connects to the hose of the mask thereby providing filtered air to the aircrewman's eye/respiratory region (See Figure 1)

Flyers Helmet, HGU-39/P: The standard USAF flight helmet is the HGU-26/P. The custom fit liner of the HGU-26/P caused severe pressure points when used with the mask harness; therefore, the HGU-39/P with a suspension harness was chosen for use with the CBO mask. It is a two size helmet, provides crash protection and posseses a headset that connects to the aircraft communications system via the CBO mask communication cord. (See Figure 1)

Aircrew Protective Hood, HGU-41/P: The hood is made of nylon coated with butyl rubber. It integrates with the CBO mask, fits over the flyers helmet, has an enlarged opening around the mask and a velcro strip down the front to facilitate a quick doffing. The hood provides liquid chemical warfare agent protection for the head and neck.

Qualification Testing: The eye/respiratory/head CD aircrew ensemble was qualified as chemical defense equipment by virtue of chemical warfare agent penetration testing of materials and sodium chloride testing was employed to determine mask peripheral seal adequacy.

This ensemble has been qualified for aircrews of fighter aircraft by Life Support SPO testing using state-of-the-art techniques, equal to those used to qualify the standard Air Force HGU-26/P helmet and MBU-5/P oxygen mask ensemble. Except for the hood flammability, limitations on performing the valsalva maneuver, and heat stress limitations (when used in conjunction with the whole body CD ensemble), no major differences in performance characteristics were observed between the CD aircrew eye/respiratory/head protective ensemble and the standard aircrew life support equipment ensemble currently being flown today. The use of the CD equipment even under conditions more severe than those tested, (e.g. (a) air combat maneuvers with the F-15 "G" profile, (b) ejection at windblast velocities greater than 500 KEAS, and (c) normal flight operations/ejection with a 30°seat back angle as in the F-16) would not subject the crewmember to significantly greater performance penalties during normal mission sorties or greater risks for injury upon emergency escape, than those encountered while wearing the standard aircrew life support equipment ensemble (i.e. the HGU-26 helmet/MBU-5 oxygen mask.)

Ejection: Ejection simulation consisting of windblast testing up to 500 knots and drop tower testing up to 20 G's was accomplished on both the CD aircrew eye/respiratory ensemble and the standard aircrew life support equipment. There was also limited sled testing of the CD ensemble at 600 knots. It was concluded that based on similarity of the observed responses, there is no discernable difference in the risk for aircrew injury on ejection between the standard and the CD ensembles for ejection at speeds up to 500 knots and at Gz (eyeballs down) accelerations up to 20 G's.

Flammability: The major flammability risk with the ensemble derives from the hood which will ignite on exposure to an ignition source and continue to burn when the ignition source is removed. For this reason, the hood was modified so that it can be easily doffed; consequently it can and should be removed when in the presence of an open flame or when exposed to superheated air.

Valsalva: The mask does not incorporate a means of occluding the nostrils to successfully perform a valsalva maneuver. Alternate means of accomplishing the valsalva maneuver, such as yawning, chewing, etc. should be tried. If these alternatives are unsuccessful, the procedure is to activate and hold the oxygen regulator in the "Test Mask" position to ensure maximum regulator output pressure and forcefully exhale against the regulator pressure.

Air Combat Maneuvers (ACM) Acceleration Forces: ACM profiles were accomplished by USAF School of Aerospace Medicine (USAFSAM) utilizing human subjects in the centrifuge. Acceleration was restricted to a maximum of 7Gz due to human subject limitations, and G onset rate was restricted to 1G/second due to centrifuge performance limits. There were no adverse factors observed during these tests that would preclude the use of this ensemble during normal flight profiles. Flights in aircraft such as the F-15, where aircraft performance characteristics exceed the parameters tested should be accomplished incrementally; upper limits of aircraft performance should be approached cautiously until the aircrew are able to assess the degree of limitation the equipment imposes on their own performance.

Altitude: During USAFSAM tests with human subjects using the CBO mask, MBU-13/P, and breathing oxygen at pressures representing those ordinarily delivered by standard regulators at cabin altitudes greater than 40,000 feet, some subjects experienced leaking masks. The time of useful consciousness for aircrew members exposed to these altitudes would be reduced if a significant mask leak rate developed. For fighter aircraft it is recommended that use of the CBO mask (which is similar to the MBU-5/P mask) be allowed up to an aircraft altitude of 50,000 feet. Because of the possibility of mask leakage

and the ensuing risk for hypoxia, if a decompression were to take place at greater than 40,000 feet, descent to below 40,000 feet should take place immediately. For other aircraft, including transport aircraft, which have slower descent rates, a maximum altitude of 45,000 feet is recommended, with descent to below 40,000 feet as soon as possible in the event of a decompression.

Breathing Resistance: USAFSAM testing found that the small increase in breathing resistance due to addition of the CBO filter was not significant for most subjects. At certain times when high flow rates were encountered, such as when a subject with a large vital capacity performed an M-1 maneuver during centrifuge tests, some respiratory distress was encountered. USAFSAM found that this could be overcome by having the subject set the regulator to the Emergency position. Consequently, if brief periods of breathing resistance (due to heavy exercise, etc) are encountered, it is recommended that this technique be utilized.

Eyeglass Usage: Some of the centrifuge, drop tower, and windblast tests were accomplished with USAF spectacles mounted by means of the adapter tabs located within the interior of the mask eye space. During drop tower testing at +Gz (eyeballs down) acceleration and during windblast testing, clay was placed in the eyes of the test manikin to record evidence of impact. Contact of the spectacle rim was evident in the eyebrow and upper nose areas but no impact to the eyes was observed and no spectacle breakage occurred. During ACM simulation testing on the centrifuge, the spectacles were not displaced.

Supplementary Testing: As with all life support equipment, the collection of additional test data concerning performance and compatibility of the near term aircrew CD ensemble with new life support equipment is an on-going process.

Body Protection. Aircrew CD body protection consists of a cotton undershirt and drawers, flyers charcoal impregnated undercoverall and the nomex flight suit.

United Kingdom (UK) Undercoverall. The UK undercoverall is a one-piece coverall constructed from a non-woven fabric. The material is treated with a fluoro-chemical to impart a certain degree of repellance to organic chemicals and the fabric inner surface is coated with activated charcoal. This garment is a nine size clothing system. The undercoverall is worn over a two piece, 100% cotton, lightweight, full length longjohn (undershirt and drawers) and under the standard Air Force nomex flyers suit. The long-johns are employed to avoid irritation to the skin from the undercoveralls' charcoal liner and to limit perspiration contamination of the undercoverall. This garment combination provides chemical agent and flame protection. The Air Force has purchased 27,000 undercoveralls and we feel this a major step towards NATO Interoperability (See Figure 2).

Testing. The undercoverall has undergone flammability, sizing, and agent penetration tests and evaluations by the US:

Flammability. ASD Engineering and the Air Force Materials Laboratory performed Vertical Flame Test (Federal Standard 191 Method 5903) on the undercoverall. This method is used in determining the resistance of cloth to flame and glow propagation, and the tendency to char. Based on five samples the flame time (time the specimen continues to flame after the burner flame is shut off) was zero seconds; the glow time (time the specimen continues to glow after it has ceased to flame) averaged 115 seconds; and, the char length (distance from the end of the specimen which was exposed to the flame to the end of a tear of the specimen through the center of the charred area) averaged 8.4 inches.

A JP-4 Burner test which provides the total heating effects that would be seen in a JP-4 fuel fire was performed on the undercoverall.

In summary, when the undercoverall is worn in conjunction with the Air Force standard nomex flyers suit, it will provide at least the same if not better thermal protection than the nomex flyers suit alone.

Sizing. The Aerospace Medical Research Laboratory, Crew Station Integration Branch conducted a validation of the Aircrew CD undercoverall. A total of 36 subjects were measured and evaluated in their indicated sizes of undercoveralls. The age of each subject was recorded and 13 body dimensions were measured. Most of the subjects were aircrewmen on current flying status. The test sample was sufficiently varied in body size, so that, the subjects were representative in most body dimensions measured from approximately the first to the 99th percentile. The results of the fit tests indicated the undercoverall is adequately sized to accommodate the Air Force aircrewmen.

Agent Penetration. Agent penetration testing was conducted at Chemical Systems Laboratory, Aberdeen Proving Ground, Maryland. The undercoverall fabric (unworn and worn for up to 48 hours) was placed over cotton underwear and under the nomex flyers suit and tested with Mustard (HD) and Sarin (GB) agent droplets. This clothing combination will meet the US Army overgarment requirements for exposure to liquid and vapor forms of HD and GB.

Hand Protection.

Neoprene Glove: A commercial neoprene glove was selected for aircrew hand protection. It is 17 mil thick, 12 inches long and comes in four sizes. The neoprene gloves are used in conjunction with the nomex flight gloves. The neoprene gloves whether worn over or under the nomex gloves provide the same level of flame protection. The increased thickness of the neoprene/nomex glove combination reduces tactile sensitivity.

Foot Protection.

Plastic Tube Sock: For foot protection, we selected a 4 mil polyethylene bag which is extruded tubing with an 1/8 inch heat seal at one end. It is of one size, comes in a roll of 500, and is disposable. The tube sock is worn over the standard cotton sock and under the standard flight boot. There is also a plastic overboot which fits over the standard flight boot. It is used only between the shelter and the aircraft. For example, the aircrewman will wear the overboot from the shelter to the aircraft and before entering the aircraft the overboot will be removed. The main purpose of the overboot is to limit gross contamination from being carried into the cockpit.

Heat Stress

Early limited thermal studies associated with selecting items to make up the near-term chemical defense ensemble identified a problem in that the wearer may experience some physiological effects due to heat stress.

After a review of the problem, USAF School of Aerospace Medicine indicated that extended flight operations during a medium to high temperature environment may tax aircrews beyond their physical limits. Although laboratory studies and interim guidelines for wear of the near-term CW protective clothing had been accomplished, it was determined it was necessary that actual in-cockpit temperatures and effects be gathered. This data could be used to ascertain aircrew tolerance to the thermal burdens inherent with the wear of the aircrew near-term CW protective clothing.

A joint study between the USAF School of Aerospace Medicine (USAFSAM) and the Royal Air Force Institute of Aviation Medicine (RAF IAM), was performed at Eglin AFB, Florida during April-June 1978 to assess the thermal effects of CD equipment flown in warm weather.

Members of a test squadron served as volunteer subjects, flying simulated combat missions in F-4 aircraft. The front seat pilot wore CD equipment, while the rear seat (safety) pilot wore normal clothing. Cockpit thermal conditions and physiological status of both crewmen were recorded in flight. Twenty-two missions were flown, consisting of 1-3 sorties each. Data collection involved personnel from USAFSAM, Tactical Air Weapons Center (TAWC), and RAF IAM. A final report is expected in early 1979.

Operational Test & Evaluation (OT&E). OT&E of the Aircrew CD Ensemble was performed by USAF Tactical Air Warfare Center, Eglin AFB, Florida. The following limitations were noted:

a. The ensemble is extremely warm.

b. The mask harness causes hot spots.

c. The hood is flammable.

d. Aircrew members experiencing an ear block cannot valsalva without breaking protective seal.

e. Eye/respiratory protection cannot be quick-doffed.

The official conclusion from the operational test and evaluation of the aircrew equipment in F-4 aircraft was as follows: "In spite of numerous shortcomings, limitations, and problem areas associated with the aircrew ensemble, tactical missions can be satisfactorily completed in F-4 aircraft."

Since the end of 1977 and continuing today, the above described aircrew chemical defense equipment is being delivered to our field units. Training in its use has been initiated.

Follow-On Program. The purpose of the follow-on program is to improve the baseline established by the near term equipment. Our most critical concern is to improve the aircrew eye/respiratory protection. This would be the replacement of the CBO mask. To accomplish this task we are pursuing five options: an integrated CD aircrew helmet, an over-the-helmet hood-blower system; an integrated aircrew CD and flashblindness protective system; an under-the-helmet hood blower system (UK Aircrew NBC No. 5); and an aircrew mask (aircrew version of the XM-29 mask).

CD Aircrew Helmet. A two contractor competitive design study for an integrated CD Helmet system has been initiated. The requirement calls for a lightweight (3 to 3.5 pound) helmet, with a chemical defense capability, compatibility with flashblindness, laser protection, and helmet mounted sights. A helmet prototype from each contractor is expected in summer 1979.

Over-the-Helmet Hood-Blower System. Per request of Tactical Air Command, our engineering division prototyped an over-the-helmet hood-blown filtered air system for conceptual evaluation. This concept would utilize the standard helmet and oxygen mask. It would provide a filtered blown air supply into the hood, thereby, creating a positive pressure with a continuous outward flow of filtered air. The prototype will be flight tested in the fall/winter of 1978. If this concept is acceptable, further development efforts would be required.

Aircrew CD/Flashblindness System. In the near future, we will provide our bomber and tanker aircrews with Thermal/Flashblindness Protective Goggles. The basic component which makes up the lens portion of each goggle is a ceramic containing lead, lanthanum, zirconate and titanate. The lens is electrically operated and reduces light transmission by varying the degree of polarization. The goggle system is attached to the helmet and weighs approximately one pound. The goggles impose visual restrictions on the aircrew since it allows 20% light transmission and a limited visual field. The Life Support System Program Office has requested the developer of the goggles, Sandia Laboratories, to perform a design study to reduce the size and weight of the present configuration, improve visual characteristics, and incorporate chemical defense protection for fighter aircrews. This design study is expected to be completed by summer 1979.

UK Aircrew NBC Respirator No. 5. The United Kingdom has completed engineering development of the Aircrew NBC Respirator No. 5. The Respirator No. 5 consists of an oronasal mask, a faceplate and an impermeable hood which completely covers the head and neck together with a chest mounted supply manifold. Filtered air is supplied at a slight positive pressure to the mask and hood compartments of the respirator. In September 1978, we received two Respirator No. 5's for evaluation via Air Standardization Coordinating Committee, Working Party 61. Our plan is to perform development and compatibility test and evaluation, operational test and evaluation and an investigation of the required aircraft modifications.

XM-29 Aircrew Mask. In the area of aircrew chemical defense mask, we are monitoring the US Army engineering development of the XM-29 mask which will replace the M17 ground personnel mask and the M24, helicopter aircrew mask. As prototypes become available, they will also be tested and evaluated for fighter aircrew applications, but we feel it will have the same shortcomings as the CBO mask.

Status Summary. The follow-on aircrew eye/respiratory protection program status can be summarized as follows:

The aircrew eye/respiratory protection is the most critical follow-on program.

To achieve the required level of protection for aircrew eye/respiratory protection a filtered blown air system technique is required because of difficulties with achieving an adequate face seal.

A filtered blown air system will necessitate aircraft modifications which will be the pacing item from a schedule standpoint.

Our five options are in various phases of research and development with the UK Respirator No. 5 under evaluation, the XM-29 mask having entered engineering development and, the CD Helmet, Integrated Flashblindness/Chemical Defense system and the over-the-helmet blown air system in the conceptual design phase.

We feel we are addressing all viable technical approaches (i.e., helmet system, over-the-helmet hood blower, under-the-helmet hood blower, and mask) for improved aircrew eye/respiratory protection.

Aircrew CD Body/Hand/Foot Protection. In the area of aircrew body protection, the major goal would be to inherently design chemical defense protection in all equipment. Our first area of activity is to incorporate chemical protection requirements into our next generation flight suit and pressure suit. Presently, we are awaiting the final report of the joint study performed by USAFSAM and RAF IAM to assess the thermal effects of the Aircrew CD equipment. This will assist in determining the extent of the thermal burden imposed on aircrews and identify the cooling requirements for body protection. We have identified to the US Army a technical need for a chemical warfare agent protective material which is flame resistant. This material could be used for hoods, gloves, body protection, etc. Presently, the follow-on aircrew hand and foot protection involves: identifying future requirements, developing a thin walled glove to allow for improved operation of aircraft controls and evaluating the United Kingdom Charcoal impregnated sock.

Program Summary. In summary, the near term or "quick fix" chemical defense equipment program is coming to a close with delivery of aircrew chemical defense equipment to the field. This will establish baselines for equipment, concepts, procedures and training from which we can further build our chemical warfare defenses. The follow-on research, development, test and evaluation programs have been initiated with the objective of reducing or eliminating the burdens and limitations of the near term aircrew equipment.

Figure 1: CBO Mask, MBU-13/P; CBO Filter, CRU-80/P; and, Flyers Helmet, HGU-39/P

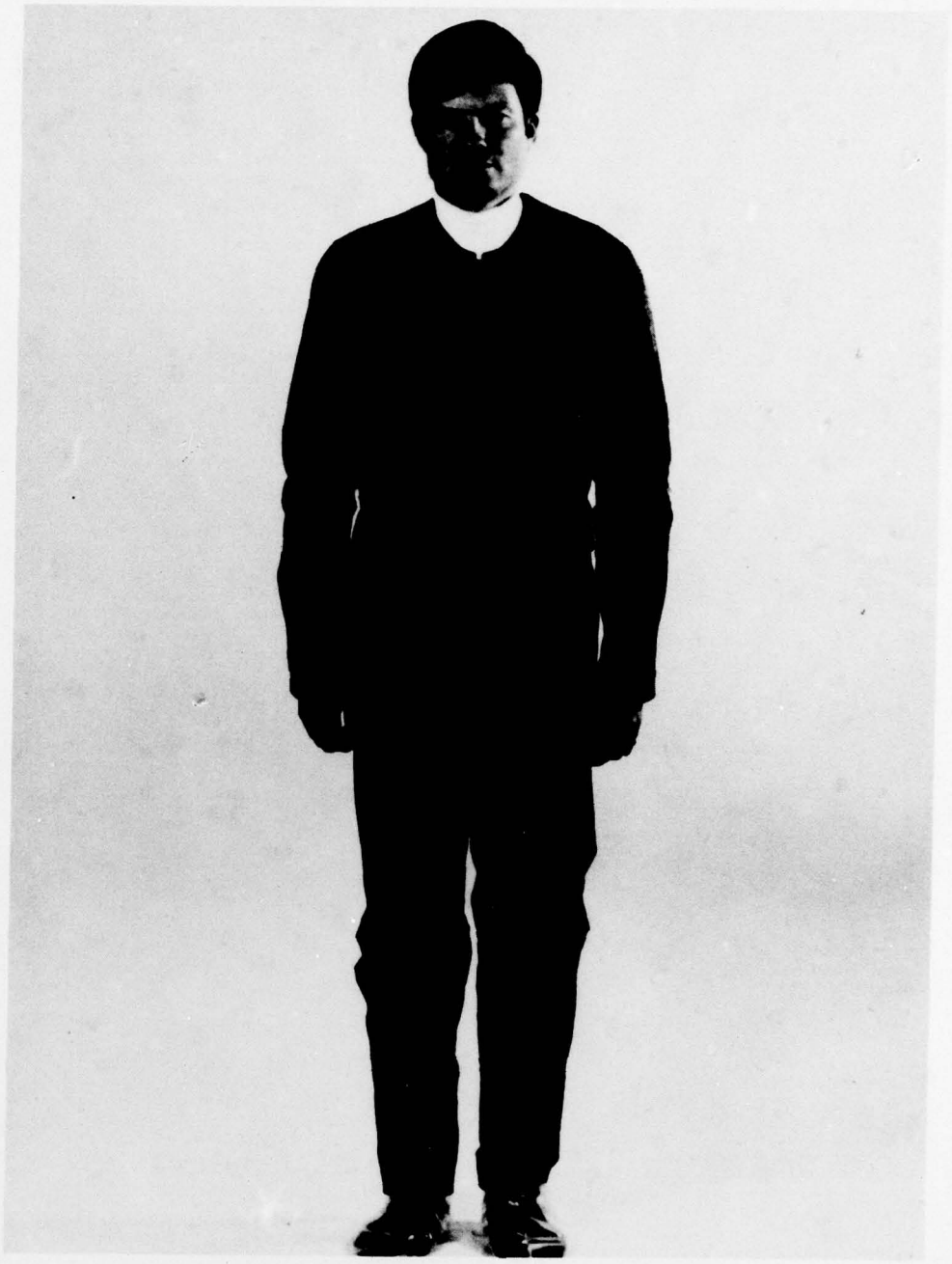

Figure 2: UK Aircrew Charcoal Undercoverall

FRG AIRCREW CHEMICAL DEFENCE ASSEMBLIES

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SUMMARY

1. NBC-protection gloves for high performance aircraft pilots

2. SAr spherical adsorber systems

3. The NBC-protective suit (or garment) for German propeller-aircraft pilots

(a) construction of the materials
(b) life-time
(c) influence of water and sweat

4. Flame-proofing for NBC-protective clothing

1. NBC PROTECTIVE GLOVES FOR HIGH PERFORMANCE AIRCRAFT PILOTS

Protective gloves serve two fundamental purposes: either their object is to protect against effects inherent in the human hand, or as in the case of pilot's gloves - to protect the hand itself against external effects.

A pilot's hand have many tasks to fullfil: sometimes they act as a gripping instrument, sometimes as a localising feeler, sometimes as a sensory check, which feeds back sensory orders which have been executed, and through their sensitivity asses the quality of the execution and correct any shortcomings in it.

This highly important instrument has to date been protected against mechanical damage and temperature changes by a soft leather glove. Very often the pilot wears this glove from early his theoretical and during simulator training, so that it becomes virtually an integral part of his sensory system. Many pilots deprived of their gloves feel extremely ill at ease, at all events, they feel insecure.

Since the greater part of the mechanical learning routines, which the pilot acquires in the course of training, are conditioned learning programmes, inducing automatic reaction to a number of well learnt situations, it is understandable that he should oppose any change in his sensory system. Unfortunately, there is no evidence of any technical method promising succes in making leather resistant to harmful nuclear and chemical warfare agents.

Here a answer to this much - discussed problem. Two gloves, each made of particularly thin leather are drawn over each other. The outer surface of the inside glove is covered with spherical adsorber. Then the cuffs of the two gloves are stitched together. The resultant harmful vapour adsorbent pilot's glove yields virtually nothing to the standard

glove as regards gripping ability, sensitivity of touch or length of life. Yet it is fully protective, if one accepts the viewpoint that durable agents will at no time be found in the cockpit. The protective glove has given results of 0,4 µg/cm²/6hr when tested by Method DB 3. It is sufficiently soft and flexible enough to operate small knobs, e. g. aircraft switches and fuses, even when they are outside the pilot's field of vision, and to check the execution of the operation by sense of touch.

The adsorptive layer, which is sandwiched in the space between the two individual gloves brings me straight to the second part of this paper.

2. SAr SPHERICAL ADSORBER SYSTEMS

Spherical adsorbers, SAr for short, open up completely new prospects as materials for NC protective uses. Spherical adsorbers are generally synthetic products, e. g. viscose, or derivatives from petrochemical carbonisation and subsequent drum processes. The marble-shaped adsorbers, ideally with a diameter of between 0,1 and 0,6 mm posses a far higher effective adsorptive capacity than the activated carbon particles currently incorporated into protective materials. The reason for this is simple. The adhesives most commonly used for activated carbon cover the entire particles. With SAr, only the lower part is attached to the base, leaving a much greater area free for effective adsorption.

3. THE NBC-PROTECTIVE SUIT (OR GARMENT) FOR GERMAN PROPELLER-AIRCRAFT PILOTS

These spherical adsorbers injected into foamed polyurethane, provide the flexible filter, which combined with a special outer material serves as the basis of our protective clothing for propeller aircraft pilots.

The outer material is flame-proofed (definition and figures later). It consists of three layers:

First an impregnated cotton fabric
Secondly, a connective layer
Thirdly, a mineral fibre grid with a high aluminium content.

The three components are bonded together by microwave rolling.

Protective clothing, made from these materials - with an SAr filter layer, have a guaranteed life of not less than 10 years under controlled storage conditions. The clothing's storage life can be considerably increased by use of special packing methods.

In addition, the suits can be cleaned in washing machines, if the recommended methods are used.

The influence of water and sweat can be neglected. In tests we found out the following figures:

Method DB 3

Material	quantity penetrated in µg/cm² (6 h)			Ø	type of experiment
SAr	0.2	0.2	0.2	0.2	(dry)
SAr	0.2	0.2	0.2	0.2	(sweat)
SAr	0.2	0.2	1.1	0.5	(water)

Influence of sweat poisoning:
The charcoal part of the samples was soaked for 6 hours in a solution of artificial sweat. The artificial sweat was produced according to: (Biochemisches Taschenbuch, herausgegeben von H. M. Ranen, zweiter Teil. Springer Verlag Berlin 1964 -p.372-).

Influence of water:
The charcoal part of the samples was soaked for 6 hours in water. The adhering water was removed by drying with a tissue.

In addition experiments were carried out to study the effect of "rain".

Experiment A: outer layer wetted before contamination.
Experiment B: outer layer wetted after contamination.

Method DB 3

Material	quantity penetrated in µg/cm² (6 h)	Ø	type of experiment
SAr	0.1 0.2 0.2 0.5 0.5	0.3	A
SAr	0.0 0.2 0.2 0.2 0.2 0.2 0.2 0.3 0.5	0.2	B

4. FLAME-PROOFING FOR NBC-PROTECTIVE CLOTHING

The importance of flame-proofing for protective clothing has in the past been dangerously neglected. A protective suit's primary object should be to meet this need. The need, in our view, extends not only to the Air Force, but also to the Navy and more particularly to the Army. For these uses it is far from adequate to comply with the nonexacting industrial standard testing methods. The protective garment should be able to withstand a radiant heat temperature of 900 - 1000° C for 25 seconds and a similar flame temperature for a minimum of 16 seconds. In the process, the material may be partly destroyed, but it must not catch fire. During the period concerned, the temperature beneath the outer garment, garment and underwear, must at not time exceed 60° C.

The described materials meet these demands. In the film to be shown the temperature recorded beneath the underwear never rose above 46° C. The wearer's skin temperature never rose over 40° C. The film was shot for research purposes, which is why we must ask for your forbearance over it's quality, and we must remind you that the time ratio is 3 : 1; every three seconds in the film represents 1 second in the actual time.

Film:

Outdoor temperature: 16° C

Source of fire: petroleum

Amount of fuel: 1.200 litres

Extend of fire: 50 m²

Duration of pre-burn: 1 minute

The first suit, which catches fire, is an NBC-overgarment w i t h o u t flame proofing.

It is striking that with the second and third flame-proofed NBC-suits all the materials worn under the NBC-overgarment are combustible but remain totally unaffected. The fabric of the combat suit - below the NBC-overgarment, does not show the slightest trace even of carbonisation.

We believe that an NBC-overgarment made from this material is the simplest and most cost-effective way to provide soldiers with protection against NBC-contamination, fire, burning material and explosion flash. The material provides valuable protection against heat blasts of 30 cal/cm²/sec.

INTEGRATION OF PROTECTION AGAINST CHEMICAL WARFARE AGENTS WITH AIRCREW PERSONAL EQUIPMENT

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The intrinsic function of aircrew personal equipment and life support equipment, in general, is the protection of the aircrew member from hostile factors in the flight environment. This type of equipment provides the necessary support throughout the flight sequence from entry into the aircraft cockpit to return to the air base either in the originally occupied aircraft or in the hands of the rescue forces.

For management and analytic convenience, we generally divide aircrew life support and personal equipment into three subsystems: (1) aircraft environmental, (2) escape and descent, and (3) survival and recovery. The aircraft environmental subsystem includes all of the equipment required to allow the aircrew member to function in the flight environment and to maintain his physiological homeostasis. These items range from simple flight suits to the new sophisticated On-Board Oxygen Generating System. The second subsystem, escape and descent, encompasses all of the equipment necessary to allow the aircrew member to escape from his aircraft in time of emergency and to descend safely to the earth's surface. This subsystem obviously involves ejection seats, parachutes, and personnel lowering devices. The final subsystem, survival and recovery, includes all those items of clothing and equipment required to allow the crewmember to survive in any environment in which he may find himself (or herself) after escaping from a disabled aircraft and to successfully interface with the rescue forces. Arctic survival clothing, survival kits, life rafts, and life preservers are some of the important components of this subsystem.

In the early days of aviation ("It All Started in Dayton in 1903"), aircrew protective equipment was limited to those pieces of clothing and other paraphernalia which were sufficient to ward off the low temperature and windblast effects of flight at low altitudes and low air speeds. As man and his flying machine flew higher, faster, and for longer durations, additional protective capabilities had to be incorporated

As each new capability was incorporated, problems arose in integrating the new capability into the previously accepted ensemble. It is not necessary here to relate the problems associated with providing breathing oxygen (unpressurized and pressurized), anti-g protection, and high altitude protection. In very recent years, it has become necessary to integrate protection against nuclear flashblindness and lasers into the flying outfit of the military pilot.

While the threat of chemical warfare has existed at least since World War I, Air Forces have not considered the threat to be significant enough to incorporate appropriate protection into the aircrew life support equipment. The advent of the recognition of this requirement within the last few years has created a new challenge to the life support community to provide the required protection with the least burdensome integration of that protection into already existing flight gear. The simplest solution to providing protection against a new threat is to provide an additional protective layer - simple, for the designer if he can disregard the additional burden placed on the user. The most difficult solution to pursue is a fully integrated protective enhancement which adds no additional equipment or layers to the existing ensemble. This latter approach is so difficult in fact that it might realistically be considered Utopian.

The U.S. Air Force has pursued a two part strategy for satisfying its aircrew chemical warfare protective requirements. The first phase, called the near term program, had as its objective providing an operational capability to the forces in the field as soon as possible recognizing that there would be performance limitations and aircrew burdens associated with its use. The second phase, the longer term program, is intended to provide a more complete operational capability with a significantly reduced burden on the user. The equipment resulting from the near term program has been described to you in detail by Major Leone and Lt Colonel Fallon in their paper presented on Wednesday. Clearly the essence of the near term solution was, for the most part, provision of an additional protective layer in spite of the additional burden imposed.

In the longer term effort, the principal goal with regard to aircrew equipment is to incorporate chemical defensive capabilities into existing standard components of the flight ensemble.

For convenience of discussion, we normally divide the aircrew chemical defense protective ensemble into four subsets: eye/respiratory protection; body protection; hand protection; and foot protection. Integrating chemical defensive capabilities into aircrew head gear is a further complication of an already complex problem. Aircrew head gear has the basic requirement of providing protection of the head from impact with external surfaces, attenuation of excessive sound pressure levels, and the provision of physiological oxygen requirements. It also provides, in many cases, protection from the optical effects of the sun and facial protection against windblast, birdstrikes, and other biodynamic stresses to the face and head. Currently, we are adding to the existing head gear the capability to protect the wearer against nuclear flashblindness (the PLZT Program). In addition, efforts are underway to use the aircrew head gear as a platform for mission oriented systems such as

the helmet mounted sight and the helmet mounted display. This set of capabilities and uses already presents a formidable, if not unattainable, integration problem before any consideration is given to the addition of chemical defense requirements. Superimposing the requirement to operate in a chemical defense environment completes the challenge which we now face and which we are pursuing through a start-from-scratch integrated design. It should be recognized from the outset that any design solution to this consolidated head gear requirement that results in a piece of hardware to be supported by the human head and weighing more than about four pounds will be totally unacceptable for operational use. In fact, anything above three and one-half pounds would find little support in the operational community.

In the area of body protection against chemical agents, our view of the objective is somewhat easier to perceive while its realization may be just as remote. Our objective is to incorporate chemical defensive capabilites into a standard flight suit. In assessing the difficulty of this problem, it is important to recognize that the U.S. Air Force and, in fact, the U.S. Armed Forces, consider fire retardance as an absolutely basic requirement for aircrew flight suits. Since we are separately pursuing the development of a flight suit having even more protection against fire than the current Nomex flight suit, I foresee no possibility of a trade-off that would incorporate chemical defensive qualities while reducing the fire retardant capabilities below that contained in the current Nomex suit. With this in mind, we identified sometime ago the absence of a candidate flight suit material that is both fire retardant and chemical defensive as being one of the major technological barriers to significant progress in aircrew chemical defensive ensembles. This technology need is currently being addressed both by the U.S. Army and the U.S. Air Force material technology communities.

We are currently engaged, however, in a development effort to incorporate chemical defensive capabilites into what is already a multi-layered aircrew item - the full pressure suit. This program called the High Altitude Flying Outfit is attempting to upgrade the Air Force pressure suit inventory by producing a pressure suit that will incorporate the technology advances emanating from the space program over the past two decades and by satisfying other aircrew needs in the pressure suit as opposed to the wearing of separate garments. As an example, we hope to make multiple use of inflatable bladders for altitude protection, anti-g protection, and flotation. We are also using this program as the first opportunity to design chemical protection into an aircrew garment in the original development specification. We are currently evaluating the initial prototypes and the eventual success of this endeavor remains to be seen.

For the protection of the aircrew member's hands, we are currently using in the near term program the layering concept in that two pairs of gloves are worn (1) the Nomex fire retardant glove and (2) a neoprene chemical agent resistant glove. Again, we encounter the technological barrier of the nonavailability of a single fire retardant chemical protective material. Since the need for finger dexterity and sensitivity are well known restrictions to be overcome in a single glove, the exacerbation of this obstacle in a two-layered glove system is obvious. Again, significant progress must undoubtedly await the development of such a material.

With regard to protection of the feet, the U.S. Air Force is currently using what may be the world's simplest and cheapest solution - the "plastic tube sock." Much to our pleasant surprise, comfort does not seem to be a serious issue with this item. Nevertheless, for reasons of simplicity and savings in time for donning and doffing, we would prefer to incorporate chemical defensive capabilities into the standard flight boot.

These are some of the salient considerations associated with the integration of protection against chemical warfare agents with aircrew personal equipment. But, the protection of the aircrew member through personal equipment is a concept which assumes that such protection can not be provided in any other way. Integration of chemical agent protection into life support systems on a superior plane would eliminate the need for providing protection through personal equipment - a shirt-sleeve environment, so to speak. Such a concept would require protection of the cockpit interior at all times from the introduction of chemical agents and would require the effective filtration of influent air by the environmental control systems.

If the integrity of the cockpit could be assured, one is left with the problem of providing a system that would encapsulate the crewmember from the time he departed the alert facility to the moment he entered his "clean" cockpit. While such a system can be conceptualized with reasonable facility, the cost of such a system would be formidable, both for initial investment and for logistics support. Questions of interoperability would be exacerbated as would problems of reliability and availability. We do not foresee the design of such a system.

Fundamental to the difficulty of providing any protection system is the protective factor that is deemed essential. The protective factor, in turn, must be based upon a valid and detailed analysis of the anticipated operational scenarios as well as a complete understanding of the toxicology of the agent. We look to the biomedical community to pursue the toxicological data, especially the low level behaviorial and performance decrement effects of unique concern to aircrews. We in the systems development community on the other hand, intend to pursue with vigor the systems analytic approach to the various operational scenarios that are anticipated. We intend also to fully evaluate the capabilities of existing aircraft environmental control systems and to take maximum advantage of their current potential capabilities for reducing the protection that must

be provided through personal equipment.

Our ultimate goals will not be reached until such time as every aircraft designer, every support equipment designer, and every aircrew life support equipment designer considers chemical warfare agents to be as comman a threat in his design as conventional ordnance, meteorological conditions, and the natural environmental envariables encountered in air operation.

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15. Abstract

The high-level performance required of aircrew and ground personnel make air operations especially vulnerable to chemical warfare agents which are highly attractive to an aggressor since they can cause large numbers of casualties without damaging materials.

The capability of NATO Forces to maintain air operations while under attack with chemical agents depends on effective personal and collective protection for the aircrew and ground personnel while allowing them to perform adequately their operational duties.

This publication, containing 10 papers, is the unclassified Supplement to the main portion of papers presented at the Aerospace Medical Panel's Specialists' Meeting held in Brussels, Belgium, 22–26 January 1979. The remaining 22 papers (all classified) have been published as AGARD CP-264 (NATO SECRET). The unclassified and classified papers were published separately in order to permit wider distribution. Titles included are:

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AGARD Conference Proceedings No.264 (Supplement) Advisory Group for Aerospace Research and Development, NATO MAINTENANCE OF AIR OPERATIONS WHILE UNDER ATTACK WITH CHEMICAL AGENTS Edited by J.Ernsting Published September 1979 54 pages The high-level performance required of aircrew and ground personnel make air operations especially vulnerable to chemical warfare agents which are highly attractive to an aggressor since they can cause large numbers of casualties without damaging materials. The capability of NATO Forces to maintain air P.T.O	AGARD-CP-264 (Suppl.) Airforce operations Vulnerability Military chemical agents Flight crews Airforce personnel Military chemical operations	AGARD Conference Proceedings No.264 (Supplement) Advisory Group for Aerospace Research and Development, NATO MAINTENANCE OF AIR OPERATIONS WHILE UNDER ATTACK WITH CHEMICAL AGENTS Edited by J.Ernsting Published September 1979 54 pages The high-level performance required of aircrew and ground personnel make air operations especially vulnerable to chemical warfare agents which are highly attractive to an aggressor since they can cause large numbers of casualties without damaging materials. The capability of NATO Forces to maintain air P.T.O	AGARD-CP-264 (Suppl.) Airforce operations Vulnerability Military chemical agents Flight crews Airforce personnel Military chemical operations
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This publication, containing 10 papers, is the unclassified Supplement to the main portion of papers presented at the Aerospace Medical Panel's Specialists' Meeting held in Brussels, Belgium, 22–26 January 1979. The remaining 22 papers (all classified) have been published as AGARD CP 264 (NATO SECRET). The unclassified and classified papers were published separately in order to permit wider distribution.

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