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AD NUMBER
AD814366
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AD814366

DEPARTMENT OF THE ARMY
ARMY CONCEPT TEAM IN VIETNAM
APO San Francisco 96243

AVIB-AAD 16 May 1967

SUBJECT: Final Report - Evaluation of Crew Member's Improved Fire Resistant Flight Coveralls (ACA-45/67I)

MAY 22 1967

TO: Commanding General
United States Army Vietnam
ATTN: AVHGC
APO 96307

1. REFERENCES

a. Letter, AGAM-P (M), (17 Jul 64) ACSFOR, DA, 31 Jul 64, Headquarters, Department of the Army, subject: Army Troop Test Program in Vietnam (U), as amended.

b. Letter, CDCMR-O, Headquarters, US Army Combat Developments Command, 9 February 1966, subject: Department of the Army Approved Small Development Requirement (SDR) for Clothing System for Army Aviation Crewmembers.

c. Message, CG NLABS, Unclas AMXRE 195, 7 February 1967, subject: One Piece Flying Suits.

d. Message, CG USARV, Unclas AVHGC-DH 09430, 14 February 1967, subject: Fire Resistant Flight Suits.

e. Summary Report, Edgewood Arsenal, Md, February 1967, subject: Effectiveness of Aviator Garments in Protecting Against Gasoline Fires.

f. Letter, AVIB-AAD, Army Concept Team in Vietnam, 17 February 1967, subject: Improved Fire Resistant Flight Coveralls.

g. Message, OACSFOR Unclas DA 803119, 2 March 1967, subject: Fire Resistant Flight Uniform (ENSURE DA 174).

h. Message, CG USARV, Unclas AVHAV-RA 13839, 5 March 1967, subject: Evaluation of Improved Fire Resistant Flight Coveralls.

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i. Letter, AVHGC-DH, USARV, 30 March 1967, subject: Fire Resistant Flight Coverall Questionnaire.

j. Message, ACTIV 0078, 6 April 1967, subject: One-Piece Flying Suits.

k. Message CG NLABS, Unclas AMXRE-CCE 551, 10 April 1967, subject: Fire Resistant Flight Suits.

2. PURPOSE

The purpose of this evaluation was to determine acceptability, final design criteria, basis of issue, and the trade-offs incident to adoption of the improved "NOMEX" fire resistant flight coveralls.

3. BACKGROUND

a. Reference 1a established the policy for ACTIV test programs in Vietnam.

b. Reference 1b, inclosure one, describes the essential requirements for the two-piece flying suit under the approved SDR.

c. In reference 1c CG, Natick Laboratories advised USARV that 100 to 200 NOMEX flight coveralls incorporating several design improvements would be shipped to Vietnam by 31 March 1967. This message also stated that single layer NOMEX would not provide required fire protection and that two layers of 4.4 ounce NOMEX fabric represents the maximum level of fire protection within the present state of the art and the minimum which Natick Laboratories would recommend.

d. In reference 1d, CG USARV, directed ACTIV to plan an expedited evaluation of the 200 flight coveralls from Natick.

e. In reference 1e, Natick Laboratories, as a result of tests conducted at Edgewood Arsenal, stated the following conclusions:

> There is no textile material available at this time which, in single layer, will provide a significant degree of protection against gasoline fires. Nomex in single layer deteriorated by flame and itself supports flames which will ignite any under-clothing, and burn the skin in unexposed areas.
>
> Fire retardant treated cotton fabrics do suppress flame but decomposition products - tars and heated gases - will

transmit heat through the fabric to the skin and will create burns because of the high temperatures. Barrier under-layers of sufficient thickness could reduce this hazard but, in tropical clothing systems where under-layers are minimal, these burns would exceed 2° burns over a large part of the skin surface.

A double layer system, either both layers of Nomex or fire retardant treated cotton outer layer and Nomex under-layer, gives the best protection against gasoline fires, but even this is not adequate to avoid serious burns over a considerable part of the skin surface.

The lower part of the body covered by trousers, and also the back, are the areas which are most susceptible to ignition. These areas in any event should be double layer.

Based upon evidence presented in the report, Natick stated ".... it is evident that a uniform using a double layer system is the only system which can be recommended for aviators clothing. For comfort purposes, the double layer over the chest could be considered the only exception to the double layer requirement."

f. By reference 1f, ACTIV requested CG, USARV to designate specific tests units throughout Vietnam.

g. In reference 1g, OACSFOR, DA, advised USARV that their ENSURE requirement for fire resistant flight coveralls was not approved, that DA desired that the new improved fire resistant flight coveralls be evaluated, and that the ENSURE requirement should be resubmitted if appropriate.

h. By reference 1h, CG USARV, designated certain major units as participants in the accelerated evaluation of the improved fire resistant flight coveralls.

i. Reference 1i provided each individual evaluator with information and guidance in the conduct of the test.

j. Recognizing the purpose for having fire resistant flight coveralls is to increase the potential survivability in an aircraft fire, ACTIV queried US Army Natick Laboratories (reference 1j) concerning the protection offered by the various uniforms. The reply from the Laboratory (reference 1k) reported their estimate of the time in seconds one might survive (not more than 60% of body area suffering not more than first degree burns) if exposed to a JP-4 flash fire while wearing various uniforms as follows:

TABLE 1

Survivability According to Uniform Worn

Uniform	Survival Time (Seconds)
Untreated Jungle Fatigues	1.0
Normal Fatigues	1.0
Standard Flight Suit	1.0
Treated Jungle Fatigues	3.0
Treated Normal Fatigues	3.0
Treated Standard Flight Suit	3.0
Single Layer NOMEX	4.0
Double Layer NOMEX	7.0

k. The original "NOMEX" flight coveralls tested in Vietnam in 1966 was an altered version of the flame resistant flight coveralls developed by the US Navy. It was determined unsatisfactory for wear in Vietnam because of physical discomfort and irritation caused by the coarsely woven fabric. In addition, the coveralls were made of double layer fabric which was found to be excessively warm. The improved flight coverall is made of a closer, smoother woven NOMEX material designed to be less irritating. Several design changes were made in the coverall to correct deficiencies reported in the previous evaluation. To expedite the procurement of a desirable flame resistant flight coverall for wear in Southeast Asia, an accelerated evaluation was directed by United States Army, Vietnam.

4. DESCRIPTION OF MATERIEL

The 201 flight coveralls shipped to Vietnam from Natick Laboratories for evaluation were made of 4.4 oz per square yard "NOMEX" flame resistant fabric, shade OG 107. Of these, 134 coveralls were of single layer fabric; the remaining 67 had a double layer of fabric on the entire back of the coverall. The sleeves on all coveralls were single layer with pockets located on each upper arm. The right pocket closes with a small velcro fastener and the left one closes by zipper. Other pockets are located on the chest; front, upper legs; and front, lower legs. The pockets on the chest and legs have zipper closures covered by "NOMEX" flaps. An opening with a covered zipper is located on each side at the hip. Velcro fasteners are on the sleeve cuffs, at the waist on each side, and on the leg bottoms. The coveralls have shoulder loops and a standard size collar with pointed tabs. Pencil holders are located on the left upper arm and the right lower leg pockets. The flight coverall design is illustrated in Figure 1.

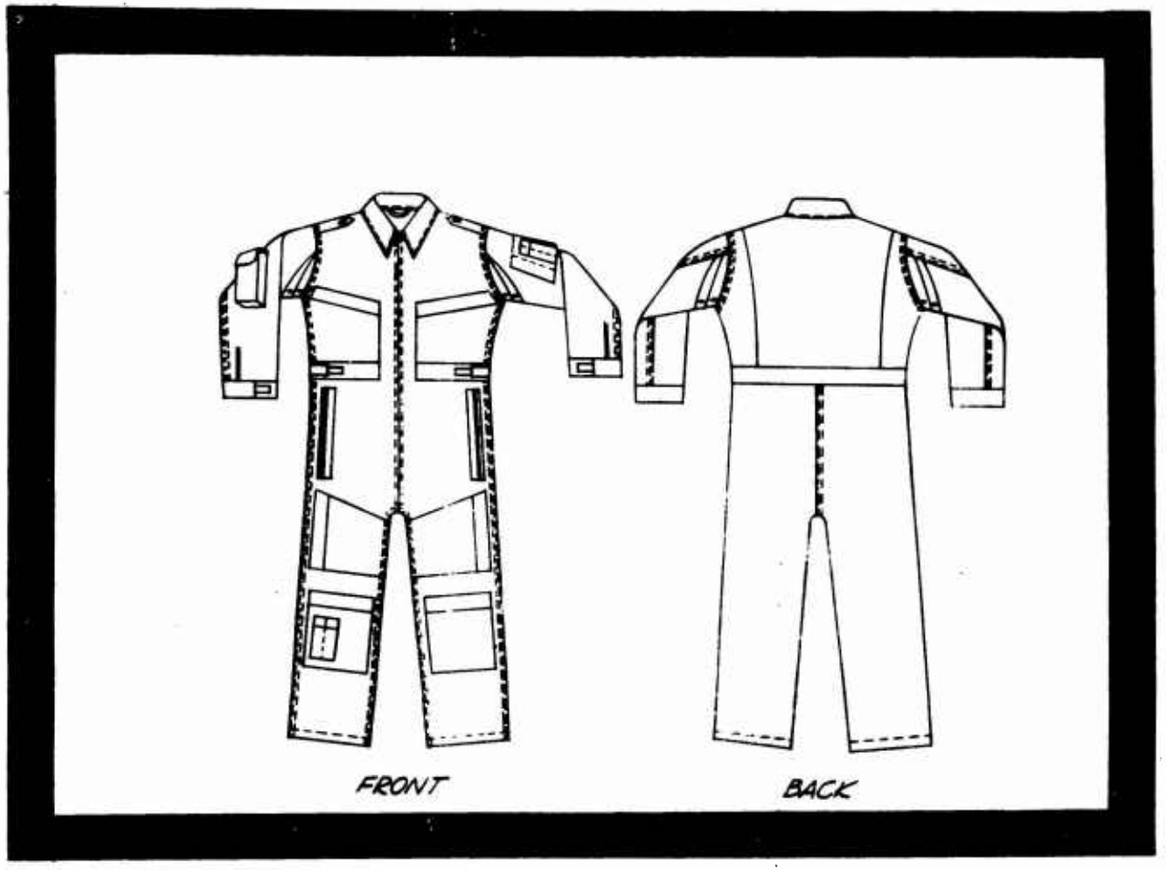


FIGURE 1. Coverall (uniform), Army aviation crew member, tropical.

5. PROCEDURE

a. It was desired to evaluate user reaction to the flight coverall in each of the climatic conditions found in Vietnam. These conditions were found in the central plateau, delta region and coastal plain. The units selected provided a sampling of the three climatic conditions and of crews of O-1, OV-1, UH-1, and CH-47 aircraft. The evaluators included eight individuals who had participated in the earlier test of the NOMEX coveralls concluded in October 1966. A few selected officers of the 1st Aviation Brigade and ACTIV also participated in the evaluation.

b. Selected aviators and aircrew members (188) were issued one flight coverall each. These personnel were required to wear the coverall on odd days and the other normal garment on even days. One hundred thirty questionnaires completed and returned by individual evaluators were analyzed to form the basis for this report.

6. DISCUSSION AND FINDINGS

a. The questionnaires were designed to evaluate durability, fit, maintainability, comfort, design and acceptability of the flight coveralls. Each of these factors is discussed below.

(1) Durability

Over 98 percent of the evaluators reported that the fabric retained its strength after sustained wearing. Two aviators reported torn coveralls without further explanation. No other comment was recorded concerning durability.

(2) Fit

Fit of the improved flight coverall was generally satisfactory. Eighty-one percent of the evaluators reported a good fit and conformation to standard Army sizes. Fourteen percent of the evaluators stated that their coveralls did not fit well and did not conform to standard Army sizes. Several of the evaluators commented that the coverall was baggy and loose in the back and legs.

(3) Maintainability

Six percent of the evaluators reported adverse effects resulting from cleaning and washing. However, most of the comments indicated only a change of color which was anticipated from information supplied by the fiber manufacturer who is making improvements in the

dyeing process to correct this deficiency.

(4) Comfort

(a) Thermal

Figure 2 presents the evaluators comparison of thermal comfort between the NOMEX flight coveralls and the standard Army flight suit and between the flight coveralls and jungle fatigues. The data presented indicate the coveralls are somewhat warmer than either the standard Army flight suit or jungle fatigues and that the double layer coverall is judged as being somewhat warmer than the single layer coverall.

(b) Fabric Feel

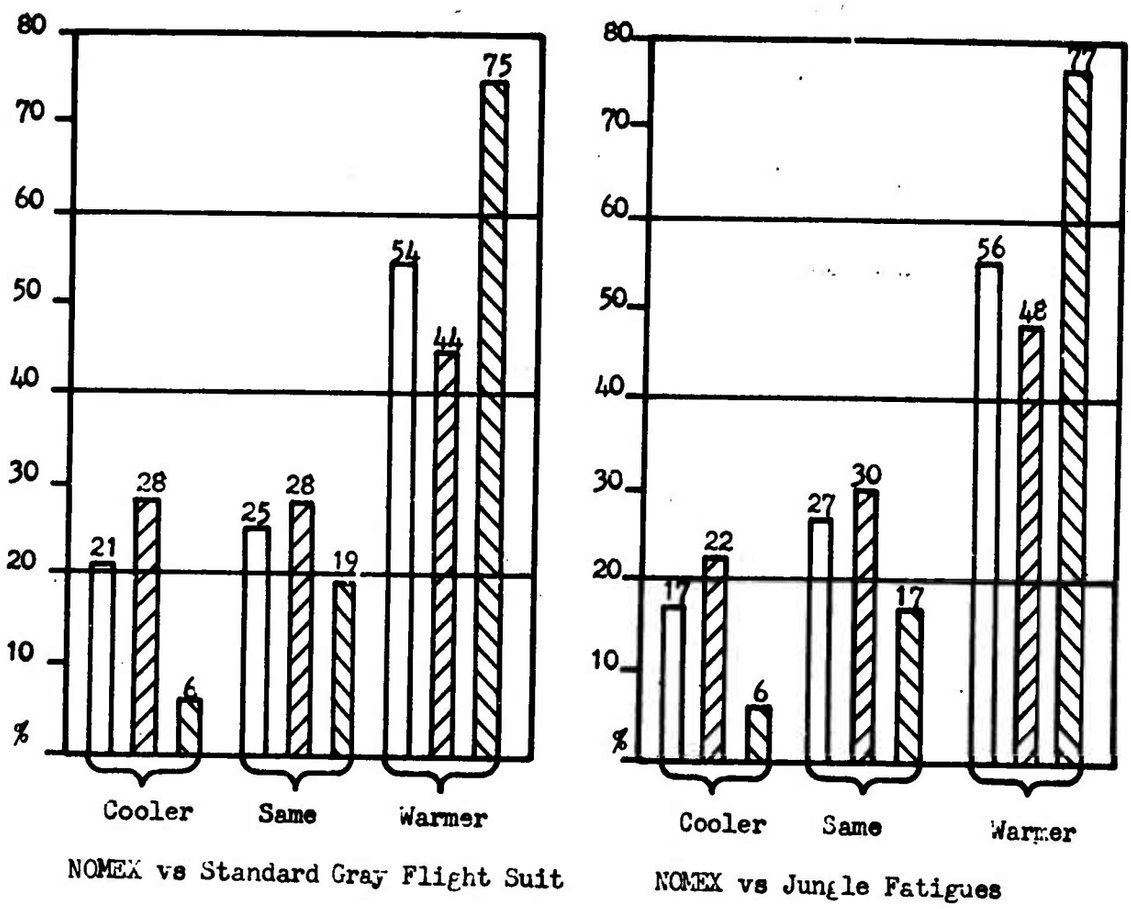
Figure 3 presents the evaluators comparison of the fabric feel between the NOMEX flight coveralls and the standard Army flight suit and between the flight coveralls and jungle fatigues. The data presented indicate the coveralls are somewhat less comfortable than either the standard Army flight suit or jungle fatigues. Inspection of Figure 3 indicates the double layer coverall is somewhat less comfortable than the single layer coverall. Of the eight evaluators who participated in the earlier flight coverall evaluation, five reported the degree of comfort was the same, while three reported that the new coverall was more comfortable.

(5) Design

Fifty-five percent of the evaluators expressed dissatisfaction with the design of the flight coveralls. Design deficiencies noted frequently were: zipper covers caused zippers to jam and restricted entry to the pockets; position of the pocket on the lower pant leg; pocket on the upper right sleeve; location of zippers on the upper pant leg pocket; presence of unnecessary side openings at the hips; direction of zipper operation on the breast pockets; and closure direction of the velcro fasteners on the leg and sleeve cuffs which caused them to catch on objects. Design suggestions submitted most frequently are illustrated in Figure 4.

(6) Acceptability

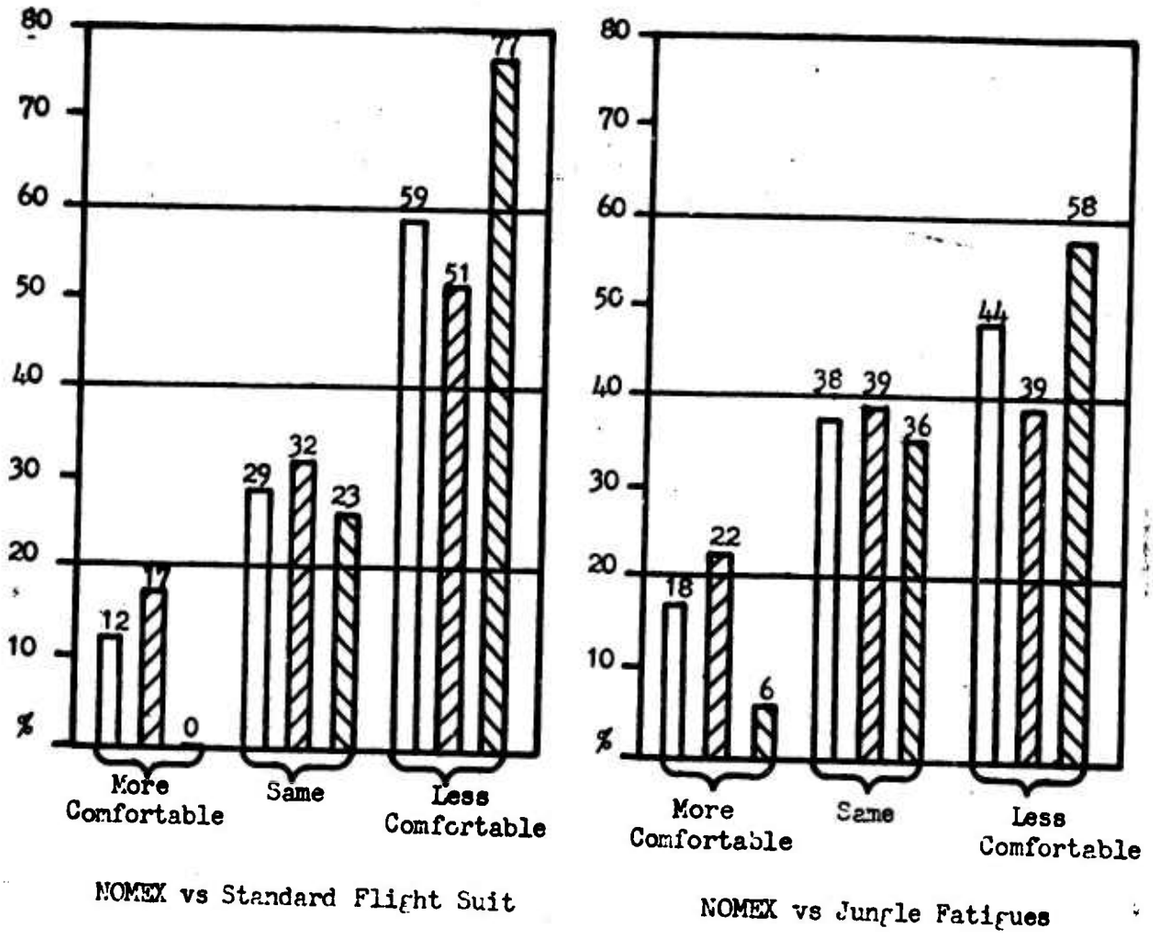
(a) One important aspect of the evaluation was the acceptability of the NOMEX flight coveralls to the evaluators. The NOMEX coveralls, as shown in paragraphs 6a(4)(a) and 6a(4)(b) above were judged to be somewhat less comfortable than either the standard Army one-piece flight suit or jungle fatigues. Thus, a trade-off between comfort and



KEY

- Combined Responses
- Responses, Evaluators, Single Layer NOMEX Suits
- Responses, Evaluators, Double Layer NOMEX Suits

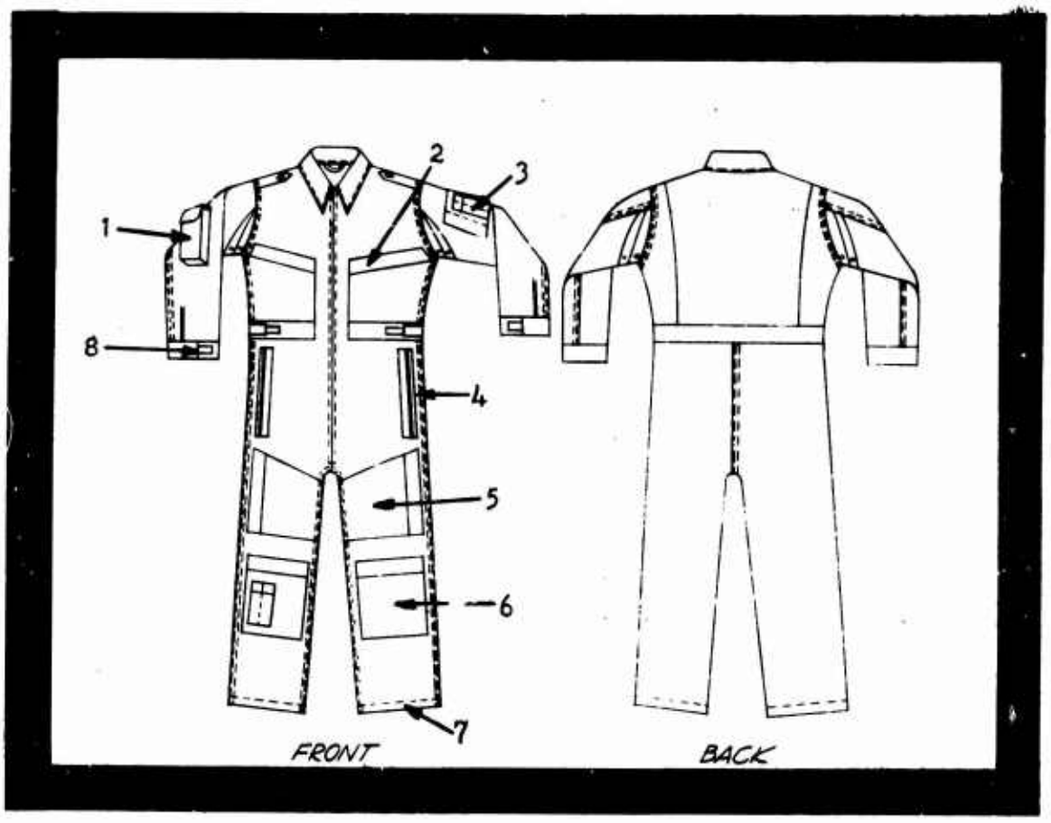
FIGURE 2. Comparative Thermal Comfort.



KEY

- Combined Responses
- Responses, Evaluators, Single Layer NOMEX Suits
- Responses, Evaluators, Double Layer NOMEX Suits

FIGURE 3. Comparative Fabric Comfort.



1. Eliminate pocket.
2. Reverse direction of zipper and eliminate zipper flaps.
3. Redesign to be same size and design as on standard flight suit.
4. Eliminate side openings at the hip.
5. Redesign to be same as standard flight suit.
6. Move to side of leg as on standard flight suit.
7. Eliminate velcro closure and add drawstrings.
8. Reverse velcro closures.

FIGURE 4. Recommended modifications of the improved NOMEX flight coverall.

added protection from fire is necessary to provide a basis for a recommendation regarding adoption of the NOMEX coverall.

(b) Two questions in the evaluation questionnaire were designed to elicit information necessary for this part of the analysis. One question asked the evaluators whether they recommended that flight coveralls be worn by all aircrewmen in RVN. Seventy-one percent answered in the affirmative. The other question asked them to recommend when the coveralls should be worn. The responses to this question favor adopting the coveralls as shown in Table 2.

TABLE 2

Evaluator Recommendations

Response alternative	Percent
On all flights	54.3
On tactical, but not on administrative flights	8.7
About half the time	8.7
During night flights only	6.3
Never	22.0

(c) Comparison of the responses to the two questions cited in b above revealed that individuals' answers to them were extremely consistent. Further, inspection of the raw data revealed a high degree of consistency in the answers to these questions and the evaluation of comfort, i.e., those who recommended the NOMEX flight coveralls tended to rate it comfortable on the evaluation questions discussed in paragraph 6a(4)(a) and 6a(4)(b). It was originally intended to correlate the comfort rating and recommendations. However since inspection of the data revealed the almost one-to-one correlation, it was decided to proceed with analysis of the data as summarized in Table 2 above.

(d) To provide a basis for making a recommendation between double and single layer suits, the first step was to determine if there was a significant difference between units, climatalogical area, and aircraft. To test the effects of these factors, three simple analyses of variance were performed. The questionnaire scale was arbitrarily weighted one through five for analysis. The results of the analyses are presented in Table 3.

TABLE 3

ANALYSIS OF VARIANCE

Units

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Test
Units	7	91	13	5.9 Significant beyond 1% level of confidence
Within	119	259	2.2	
Total	126	350		
Climatological area (Coastal Plain, Delta, Central Plateau)				
Climate	2	5	2.5	.9 Not significant
Within	124	345	2.8	
Total	126	350		
Aircraft (Fixed wing, rotary wing)				
Aircraft	1	8	8	3.0 Not significant
Within	125	342	2.7	
Total	126	350		

(e) The effect of units is significant beyond the one percent level of confidence. The other two main effects are less than the accepted significance level, i.e., five percent level of confidence. This indicates that group factors tended to affect the ratings of the coveralls, but climatological area and type of aircraft had no significant effect on the ratings.

(f) Since the between units effect is significant, it seems that the decision between double and single layer suits should be based on the results obtained from units where both kinds of suits were issued. Using this portion of the sample, the ratings of the double and single layer suits are as shown in Table 4. These data indicate the user evaluators are prone to accept some degree of discomfort for the protection provided by the coveralls.

TABLE 4

Recommendations for coveralls use by units issued both type suits

Weighting	Response alternative	Single	Double
5	On all flights	44	19
4	On tactical, but not on administrative flights	9	1
3	About half the time	7	1
2	During night flights	4	4
1	Never	11	8
		75	33

(g) Using the weighting scheme shown in Table 4 above, the mean obtained for double layer coveralls is 3.6 and the mean for single layer is 3.9. This difference in means if not significant statistically (t=.11; 2.6 required for significance) and is not considered of practical significance.

b. The determination to adopt the NOMEX flight coverall must incorporate a recommendation for either the single or double layer material. According to the data presented here, the decision should be made on some basis other than user evaluation, since the difference in the u[illegible] [illegible]ing single and double layer coveralls is non-significant. The other most relevant factor in making a determination is the degree of protection provided. Table 1 identifies the additional survival time potential by treating uniforms now worn and by single and double layer NOMEX. The survival time (10 seconds) specified by the Department of the Army (reference 1b) exceeds that offered by any of the uniforms now available, including NOMEX. By treating the uniforms now worn, an increase in potential survivability is immediately available to US Army Vietnam. Single layer NOMEX is little better than treated jungle fatigues, but has the advantage that its fire-resistant qualities are permanently retained without further treatment.

c. Little specific information was developed during the brief evaluation period, except that the coverall is durable, on which to recommend a basis of issue. Interviews with various evaluators established that two coveralls should be the minimum issue if adopted. The enlisted aircrew members, who are required to perform many manual tasks on the ground, would experience a shorter wear-out period. Rather than issue more flight coveralls to the crew chiefs and gunners, a small stock could be maintained in each unit supply to provide replacements. The basis of issue must consider that the Department of the Army has approved a Small Development Requirement (SDR) for clothing for aviation crew members. The

uniform under development is to be a two-piece garment similar in appearance to the standard utility uniform. The two-piece suit would enable the crew chief and gunners to perform their ground duties more comfortably, since the upper part of the basic garment may be removed. It is observed throughout US Army Vietnam that this practice is commonly followed; a one-piece garment would require the upper torso to be covered at all times when it is worn.

7. FINDINGS

a. The flight coveralls evaluated were sufficiently durable for operational use.

b. The NOMEX flight coverall was considered maintainable under field conditions.

c. Eighty-one percent of the evaluators reported a good fit; fourteen percent did not.

d. Fabric feel and thermal comfort were improved over that afforded by the NOMEX coverall tested in 1966, but the coverall is still less comfortable than the standard Army flight suit or jungle fatigues.

e. Flap-type zipper covers were undesirable.

f. The closures provided at the bottom of the pant legs were undesirable.

g. The pocket on the upper right sleeve was undesirable.

h. The lower pockets were poorly positioned.

i. Zipper operation on the breast pockets was opposite to the desired direction.

j. Side openings at the hips were not desired for use in Vietnam.

k. A large majority of the evaluators recommended adoption of the flight coveralls for use in Vietnam.

l. There was no significant difference in recommendations from users regarding adoption of single and double layer coveralls.

m. The basis of issue should be at least two per individual.

n. Double layer NOMEX most nearly affords the survival time

specified by the Department of the Army as an objective. Single layer NOMEX is little better than treated uniforms now available.

8. CONCLUSIONS

a. Modifications suggested in Figure 4 should be incorporated into the coverall design.

b. Aircrew personnel will accept single or double layer NOMEX coveralls about equally.

c. The "NOMEX" fire resistant coverall tested is serviceable, maintainable and acceptable, if modified as suggested herein, for use by Army aircrew members in the Republic of Vietnam.

d. A minimum issue of two flight coveralls is necessary for each aircrew member.

e. The survival time for aircrew members in flash fires can be significantly increased by treating the uniforms they are now wearing.

f. Single-layer NOMEX is little better than treated uniforms.

g. Double-layer NOMEX provides a significant increase in protection over other materials, treated or untreated.

9. RECOMMENDATIONS

a. The NOMEX flight coverall, if adopted, be modified to incorporate design recommendations presented in this report.

b. Aircrew members be issued a minumum of two flight uniforms.

c. Headquarters US Army, Vietnam decide among the following concerning uniforms to be worn by Army aircrew members in Vietnam until the two-piece flight uniform is furnished against the SDR by the Department of the Army.

(1) Continue to wear untreated flight clothing (one second estimated protection).

(2) Impregnate the flight clothing now being worn by the Borax process (three second estimated protection).

AVIB-AAD 16 May 1967

SUBJECT: Final Report - Evaluation of Crew Member's Improved Fire Resistant Flight Coveralls (ACA-45/67I)

(3) Submit an ENSURE requirement for double-layer NOMEX flight coveralls modified as recommended above (seven seconds estimated protection).

1 Incl
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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Army Concept Team in Vietnam (ACTIV) APO San Francisco 96243	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE
EVALUATION OF CREW MEMBER'S IMPROVED FIRE RESISTANT FLIGHT COVERALLS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
FINAL REPORT - 1 Apr to 30 Apr 1967

5. AUTHOR(S) *(First name, middle initial, last name)*
OAKES, Keith W., Maj, TC

6. REPORT DATE 16 May 1967	7a. TOTAL NO. OF PAGES 16	7b. NO. OF REFS 11
8a. CONTRACT OR GRANT NO. b. PROJECT NO. NONE c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ACTIV Project No. ACA-45/67I 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* NONE	

10. DISTRIBUTION STATEMENT
Distribution of this report is unlimited

11. SUPPLEMENTARY NOTES NONE	12. SPONSORING MILITARY ACTIVITY US Army Vietnam APO San Francisco 96243

13. ABSTRACT

Flight coveralls made of an improved Nomex fire resistant material were evaluated by aviation units in Vietnam. If certain modifications are made, the fire resistant coverall tested is serviceable, maintainable, and acceptable for use by US Army aircrew members in Vietnam. Single layer Nomex has little better fire resistant qualities than chemically treated uniforms. Double-layer Nomex provides a significant increase in protection over other materials, treated or untreated.

It is recommended that USARV take action based on report conclusions.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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Security Classification

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Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
US Army flight coveralls						
Fire resistant flight coveralls						
Improved Nomex material, fire resistant						
Counterinsurgency environment, Vietnam						

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Security Classification