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Tropical Wearing Trials of Protective Clothing

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ABSTRACT

This report deals with wearing trials of protective clothing in the tropics under conditions simulating actual combat, and the effects of this wear on both the men and the clothing. It is divided into two parts. The first part is a description of the wearing trials and test conditions. The wearing trials were carried out with about 100 Marines during combat maneuvers in the jungles of Panama. The trials were divided into three phases of six, six and three days each. The clothing tested included the special design Navy issue protective suit, two types of shorts and socks. The clothing was impregnated with S-145 by the plain solvent, solvent-plus-zinc oxide and water suspension methods. Unimpregnated clothing of the same type was used as a control. During each phase of the trials the clothing was worn continuously and the men were examined daily for evidences of skin irritation. Individual daily records were kept by the medical officer as to the number and intensity of the lesions produced on different parts of the body.

The second part of the report deals with the results of the trials. Only 3 out of 94 men in the trials were casualties due to the clothing. The relative irritancy of the clothing was evaluated by the number and severity of the lesions produced. The differences in irritation caused by the three types of impregnated clothing were too small to be regarded as important. In general, the plain solvent type clothing was the least irritating and the water suspension the most irritating, although the greatest variation for the complete trials was only 14%. The unimpregnated clothing was 55-75% as irritating as the impregnated clothing. S-330 Protective Ointment was used during part of the trials and produced only a few cases of mild irritation.

Representative clothing was analyzed for active chlorine content and tensile strength after each phase. All three types of impregnated suits lost 50% or more of their active chlorine after six days of wear. After nine days of wear, which included one standard laundering of the suits, the loss of active chlorine was about 78%. There was essentially no loss in tensile strength of the suits during the wearing trials.

Representative solvent-plus-zinc oxide and water suspension type suits which had been worn six days in the wearing trials were tested against H vapor in the chamber. Unworn impregnated suits were run as controls. Men dressed in these suits were exposed daily to a CT of 1200 (0.020 mg. H/1 for 1 hr.) at 90°F and 65% R.H. The men in the solvent-plus-zinc oxide suits

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ABSTRACT continued-----

tolerated an average of 1.2 exposures and those in the water suspension suits 1.75 exposures, all having relatively severe burns. The men in the control group were given an average of 2.75 exposures and had moderate burns.

Comments were requested of the men who wore the clothing in the trials. The opinion of the officers and men who participated was that the clothing is not unduly uncomfortable and does not reduce fighting efficiency to any great extent.

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AUTHORIZATION

1. This work was authorized under Project No. 547/41, "Maintenance, Bureau of Ships" dated 16 December 1940. The problems which are proposed for study were given in BuShips letter 8-S77-2 (Dz), serial 811 of 17 December 1940.

STATEMENT OF PROBLEM.

2. These trials were conducted to determine whether wear of standard issue Navy impregnated protective clothing could be tolerated in tropical areas. Three different procedures have been used to impregnate protective clothing, namely, the solvent process, the solvent process with zinc oxide stabilizer, and the water suspension process with zinc oxide stabilizer. Since the water suspension process was most recently adopted and will probably replace the other two methods, it became of paramount importance to measure the irritation produced by this type of clothing in the tropics.

3. Previous wearing trials of impregnated protective clothing had shown that severe conditions of wear in a tropical climate were necessary to bring out irritation effects. Therefore, it was necessary to conduct these wearing trials under tropical conditions simulating actual combat.

4. Since Navy protective clothing is of a special design it was deemed advisable to include unimpregnated protective clothing as a control. The unimpregnated clothing also served as a test of the design and type of cloth as well as a control for determining irritation due to factors other than impregnation.

5. Protective ointment of the latest experimental type (S-330) was also tested for irritancy under the severe conditions of the wearing trial.

KNOWN FACTS BEARING ON THE PROBLEM

6. The Chemical Warfare Service conducted a large scale wearing trial at Camp Paraiso, Canal Zone, March 26 to May 21, 1943. The results were reported in Final Report SPCVU 422.3 dated June 15, 1943 and Phase 3: Tropical Zone Tests, Parts I, II, and III. These tests showed that clothing containing the impregnite S-461 could not be tolerated in the tropics. It was further demonstrated that two-layer protective clothing (impregnated long underwear) was more irritating than one layer protective clothing (unimpregnated short underwear). Clothing impregnated by the water suspension process with zinc oxide stabilizer was more irritant than clothing impregnated by the solvent process without stabilizer.

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7. Small scale wearing trials designed to determine irritancy upon wearing have been conducted in temperate climates by the Chemical Warfare Service by this Laboratory. The CWS Report T.D.M.R. 779 "Field Test to Determine the Tolerance of Men in Temperate Summer Climate to Water Suspension Impregnated Clothing" describes the results of a series of wearing trials carried out in the summer of 1943 at Edgewood Arsenal, Maryland. The authors conclude that the results must be taken as unconfirmed indications inasmuch as the climatic conditions and irritation effects were variable. In this series of tests indications were obtained that a water suspension system containing calcium carbonate instead of zinc oxide as a stabilizer was no more irritating than the solution system. Other systems which compared favorably with the solution process were: (1) Water suspension system containing 2.75% PVA instead of 5.00% (2) Solution-suspension system containing calcium carbonate stabilizer (3) Solution system preceded by a treatment with an alginate-methacrylate solution. Upon the basis of these results it was recommended that confirmatory wearing trials be carried out in a tropical zone.

8. Skin irritation has not been noted in reports of wearing trials conducted by the British or other nations. The NDRC has conducted extensive investigations of patch tests designed to show up irritant effects of impregnated clothing. The results have not been encouraging inasmuch as patch tests are not sufficiently sensitive to show up small differences in irritation.

THEORETICAL CONSIDERATIONS

9. The wearing trials conducted by the Chemical Warfare Service in the spring of 1943 at Camp Paraiso, clearly showed that the water suspension process of impregnation produced greater irritation than did the solvent process of impregnation. There are several possible explanations for this result.

10. Since in this same wearing trial it was found that solvent impregnation caused more irritation than unimpregnated clothing there must be either a mechanical or chemical cause of the irritation. A comparison of solvent impregnated clothing with unimpregnated clothing in feel and handle does not support the belief that such mechanical differences would account for the irritation. Irritation might be produced by the impregnate, CC-2; the binding agent, chlorinated paraffin; or residual solvent, tetrachloroethane. Consideration of the chemical nature of these three agents leads to the conclusion that irritation must be produced by the impregnate. The impregnate contains active chlorine and may therefore be irritant as such or cause irritation by decomposing or hydrolyzing to give chlorine and hydrochloric acid.

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11. There are two added chemical agents in clothing impregnated by the water suspension process which might promote irritation. One of these is the dispersing and emulsifying agent, polyvinyl alcohol (PVA). This agent has film-forming properties and causes a detectable stiffening of impregnated fabric. However, this would cause mechanical rather than chemical irritation. The stabilizer zinc oxide may promote irritation from the standpoint of absorbing hydrochloric acid during the decomposition of impregnate and becoming converted to zinc chloride. Zinc chloride is known to be corrosive and irritating in concentrated aqueous solutions.

12. Of probably greater importance from the standpoint of irritation is the surface deposition of the impregnate. In the water suspension process the impregnate is deposited on the fabric from an aqueous dispersion. If the impregnate is not of sufficiently small particle size or is not well deflocculated, surface deposition will occur by virtue of the filtering action of the clothing. Evidence of this surface effect is shown by the fact that pre-dyed clothing impregnated by the water suspension process becomes whitened in shade to such an extent that it is necessary to add dyes. The nature of the fabric will also influence the amount of surface deposition of the impregnate since a loose fabric with low twist thread would be expected to show less filtering action than a tightly woven fabric containing high twist threads.

13. Navy protective clothing is designed as a loose fitting garment which might reasonably be expected to minimize irritation.

PREVIOUS WORK DONE AT THIS LABORATORY

14. Small scale wearing trials have been conducted by this Laboratory at the Naval Operating Base, Key West, Florida and at the Naval Training Station, Bainbridge, Maryland. The results of the test at Key West were summarized in a Memorandum to the Director C-S77-2, dated 15 June 1943. In this test solvent process clothing with and without stabilizer was worn. No irritation was found but the wearing period was only for 8 hours per day and subjects carried out their routine duties aboard a destroyer.

15. Two series of wearing trials conducted at NTS, Bainbridge, Maryland have not been described in a formal report. The first series was carried out in July 1943 and the subjects were recruits undergoing their boot camp training. Some irritation was noted but the difference between the solvent and aqueous process of impregnation was slight. The impregnate S-461 was noticeably more irritant. However, the men wore the clothing for only 8 hours

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per day and spent a considerable portion of this time in class rooms. The second Bainbridge series was conducted in the fall of 1943 under more temperate climatic conditions and no irritation was observed.

EXPERIMENTAL PART

Part I - Description of Test and Test Conditions.

A. Personnel

16. One of the purposes of the wearing trials was to subject protective clothing to wear in the tropics under conditions as closely resembling actual combat as possible. Accordingly, the tests were carried out during a tactical maneuver involving two groups of men. The first group consisted of approximately 165 men of the 164th Guard Company. The men were all qualified in jungle warfare. The second group consisted of approximately 100 men from the 4th Guard Company, USMC. These men had some jungle experience, but their normal duties were in guard detail. The Caribbean Defense Command Mobile Forces was responsible for the planning and conduct of the maneuvers subject to recommendations and requests of the CWS, and Navy representatives.

17. The first group of men was under the cognizance of the CWS and the results of this part of the wearing trials will be reported by them. The second group was under the cognizance of the Navy with Marine Corps observers and the results obtained with this group are described in this report.

B. Maneuvers and Meteorological Conditions

18. The essential feature of the maneuver consisted of a supposed landing of the second group (Marines) several miles from the Panama Canal. Their purpose was to attack and destroy one set of locks. The first group (Army) was to defend the Canal by intercepting the attackers. The maneuver lasted for 2-1/2 weeks and the time was spent in the thick jungles of Panama. There were several long forced marches through the heavy undergrowth and swamps of that area. At night the men slept on the ground without changing their clothing.

19. The test was conducted in three phases. The first phase lasted six days. On the first and second days the men marched 15 and 17 miles, respectively. The following four days the men were engaged in maneuvering and fighting against the opposing troops. The second phase began after a 36-hour rest at base camp, during which the men wore their own clothing. This phase also lasted six days and was similar to the first except that

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the marches were on the second and fourth days. The third phase began after another 36-hour rest at base camp. It lasted three days and consisted of daily forced marches of approximately 15 miles each, since it had already been noticed that the greatest irritation produced by the clothing resulted from the marching.

20. In order to add realism to the maneuvers both smoke screens and tear gas were employed. The tear gas used was CNB and was sprayed on the troops by low flying aircraft. On the first day of the maneuver a platoon of 36 men was exposed to liquid spray and as a result six of the men had to be evacuated to a hospital due to extensive blisters of the hands, arms, faces, necks and shoulders.

21. The average temperature during the trials was 78°F and the average relative humidity was 78%. Both temperature and relative humidity were remarkably constant from day to day. However, the usual daily fluctuations were observed. The meteorological data is summarized in Table I.

Table I

Summary of Weather Conditions During Trials

Temp. in °F, RH in %. Nos. in parenthesis are max. deviations.

Time of day	Phase 1		Phase 2		Phase 3	
	T	RH	T	RH	T	RH
0600	70(4)	92(2)	78(2)	93(2)	75(1)	95(2)
1200	85(2)	56(8)	84(4)	59(13)	86(1)	61(1)
1800	77(1)	77(6)	80(7)	77(12)	79(1)	80(3)
2400	75(4)	75(4)	76(1)	82(4)	77(1)	83(4)

22. The meteorological data was taken at the weather station at Chorrera, a small village, and not in the jungle where the weather conditions were probably more severe. Although the trials were conducted during the dry season and no rain fell at any time, the conditions were such that the men perspired freely, especially during the marches. Their clothing was often wringing wet, especially in those areas covered by packs, belts, etc., and those areas where profuse sweating occurs naturally.

C. Protective Clothing

Introduction

23. Due to the events leading up to the actual conduct of this wearing trial clothing was not available for distribution in accordance with a well designed plan.

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24. The Chemical Warfare Service originally planned to conduct a wearing trial in the Southwest Pacific area. At the Navy's request the Chemical Warfare Service agreed to include two sets of Army clothing impregnated by the Navy. These were to be impregnated by the solvent process with zinc oxide stabilizer and by the water suspension process with zinc oxide stabilizer.

25. The locale of the test was then changed from the Southwest Pacific area to the Panama Canal Zone. The CWS then learned that the number of subjects available for the wearing trials was quite small. This fact necessitated omitting some of the groups desired by the CWS and they concluded that the Navy clothing could not be run in their test.

26. Shortly before the test was to be started arrangements were made for 100 Marines to act as subjects for wearing Navy clothing. It was deemed necessary and desirable to use these men for four groups of clothing rather than two groups. To the two sets of clothing originally impregnated for inclusion in the Army test, was added a set of unimpregnated clothing and a set impregnated by the solvent process without stabilizer. There was not sufficient time to prepare and ship the clothing including impregnated underwear and socks, therefore, unimpregnated and solvent process suits were shipped to Panama without matching socks or underwear.

27. Inasmuch as chamber tests at this Laboratory indicated that ordinary G.I. nainsook shorts offered sufficient second layer protection it was desired to include these in the wearing trial. Some of these shorts were impregnated by the water suspension process and shipped by air to Panama in time for the second phase of the wearing trials. It was possible to procure from the Army Impregnating outfit in Panama a quantity of nainsook shorts impregnated by the solvent process and by the solvent process with zinc oxide stabilizer.

Protective Suits

28. The protective suit was used by the Navy is a special item of clothing designed for use against vesicant agents. It consists of two pieces, trousers and jumpers. The trousers are of the overall type with suspender straps and a high waist. The jumper is of the parka type with a hood attached to the neck. Both trousers and jumpers are very loose fitting.

29. The protective suit is made of an 8 ounce unbleached cotton twill designated as Arnzen Cloth. The cloth is woven of low twist yarn containing long staple cotton fibers. The cloth receives a minimum of finishing treatments.

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Second Layer Clothing

30. Only one layer of protective clothing is now issued by the Navy; namely, the two-piece suit described above. However, two types of impregnated short drawers were worn in these trials. One type consisted of the standard Army protective long underwear drawer with the legs cut off at mid-thigh. These drawers are made of unbleached rib knit cotton fabric of about 6-1/2 ounce per square yard in weight.

31. The other type of drawer used was the standard Navy summer issue short cotton nainsock drawer.

Socks

32. The socks worn in these trials were rib knit cotton-wool socks containing about 30% wool and 70% unbleached cotton. The socks used for impregnation are a standard item of clothing and not a special item of protective clothing.

D. Impregnation Procedures

Water Suspension Process

33. The water suspension impregnated clothing, except for the nainsock shorts, was impregnated at the Impregnation Plant, Naval Clothing Depot, Brooklyn, New York. The procedure used was practically the same as that employed by Army T of O, M-2 plants. The impregnating bath, however, has a slightly different composition. The solids content is given below in the proportions used to make one batch of concentrated suspension.

<u>Material</u>	<u>Pounds</u>
XX-CC-4	900
Chlorinated Paraffin	640
Zinc Oxide	170
Polyvinyl alcohol	34
Daxad 11	6.4
Duponol M. E.	1.3
Dispersible Color	77

34. An identical impregnation bath was used to impregnate the nainsock shorts but this was done in one of the portable impregnating plants stationed at this Laboratory.

Solvent Process

35. Impregnation of Arzen suits by the solvent process was done at the Naval Clothing Depot. A tetrachloroethane solution containing

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7% CC-2 and 5-1/4% chlorinated paraffin was used. For simultaneous dyeing the solution contained 6.3% of flushed pigment No. 3031.

36. Nainsook shorts were impregnated by the solvent process by the Chemical Section, Headquarters, U.S.A. at Corozal, C.Z. The shorts were soaked in a 60°C solution of tetrachloroethane containing 5.1% CC-2 and 3.8% chlorinated paraffin. After soaking, the garments were squeezed out lightly by hand and hung out in the shade to dry. An analysis of the garments showed they contained 7.2% CC-2.

Solvent Process with Zinc Oxide Stabilizer

37. Arnsen suits and rib knit drawers were impregnated by the solvent process with zinc oxide stabilizer at the Naval Clothing Depot in Brooklyn. The procedure is similar to that used for the solvent process. Zinc oxide in the amount of 15% by weight of the CC-2 used is added to tetrachloroethane containing a small amount of soya lecithin (1% by weight of zinc oxide). Dispersion of the zinc oxide is obtained by recycling the suspension through a centrifugal pump. The solution temperature is maintained between 30 and 40°C rather than 60°C. Soaking, extracting, and drying are carried out in the same machine.

38. Some nainsook shorts were impregnated by the solvent process with zinc oxide stabilizer in Panama. This impregnation was done by the Chemical Section of Headquarters, U.S.A. Corozal, C.Z., who were unfamiliar with the process. They noted that when chlorinated paraffin was added to the hot solution (60°C) of tetrachloroethane containing CC-2 and zinc oxide, dense white fumes were given off. The solution and the garments became dark in color and the cloth had obviously become tendered. Presumably free acid in the chlorinated paraffin initiated decomposition of the solution by reacting with the zinc oxide. The garments analyzed for only 0.87% CC-2 and had a low tensile strength.

E. Distribution and Manner of Wear

39. The wearing trial was divided into three separate phases of six days each. The clothing worn in each of the phases was different. During the first phase men wore the clothing continuously for 144 hours without bathing or changing. At the end of this period a 36 hour rest followed at the base camp during which the men wore their own clothing. The second phase also consisted of 144 hours of continuous wear followed by a rest period of 36 hours in camp. The third and last phase consisted of 72 hours of continuous wear under more rigorous conditions.

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First Phase

40. The clothing worn during the first phase included four types of outer garments and two types of underwear shorts and socks. Unimpregnated, solvent impregnated, solvent plus zinc oxide, and water suspension impregnated suits were worn whereas the underwear and socks were impregnated by either the solvent plus zinc oxide or the water suspension process. The underwear consisted of Army rib knit long underwear drawers which had been cut off at mid-thigh. The distribution of clothing among the 104 men starting the first phase is shown in the following table.

Table II

First Phase Distribution of Clothing

<u>Suits</u>	<u>underwear shorts</u>	<u>socks</u>
31 Unimpregnated	2 Unknown 22 Solvent zinc oxide 7 Water suspension	2 Unknown 24 Solvent zinc oxide 5 Water suspension
10 Solvent	2 Unknown 6 Solvent zinc oxide 2 Water suspension	2 Unknown 4 Solvent zinc oxide 4 Water suspension
30 Solvent Zinc Oxide	6 Unknown 15 Solvent zinc oxide 9 Water suspension	4 Unknown 18 Solvent zinc oxide 8 Water suspension
33 Water suspension	4 Unknown 10 Solvent zinc oxide 19 Water suspension	3 Unknown 11 Solvent zinc oxide 19 Water suspension

Second Phase

41. The suits worn during the second phase were of the same four types as those worn in the first phase. They were fresh suits that had not been worn previously. However, the underwear worn during the second phase was light weight nainsook shorts rather than heavy rib knit underwear. Also the shorts corresponded to the suits with regard to the type of impregnation. The socks were similar to those worn in the first phase and were impregnated either by the solvent plus zinc oxide or water suspension process. The distribution of clothing among the 90 men engaged in the second phase is given in the following table.

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Table III
Second Phase Distribution of Clothing

Suits	Nainsook shorts	Socks
22 Unimpregnated	22 Unimpregnated	8 Unknown 6 Solvent zinc oxide 8 Water suspension
23 Solvent	23 Solvent	9 Unknown 7 Solvent zinc oxide 7 Water suspension
23 Solvent zinc oxide	23 Solvent zinc oxide	8 Unknown 11 Solvent zinc oxide 4 Water suspension
22 Water suspension	22 Water suspension*	9 Unknown 2 Solvent Zinc Oxide 11 Water suspension

*These shorts were worn for the last four days only since they did not arrive from the States in sufficient time for distribution and wear for the entire six days.

42. During the second phase S-330 Protective Ointment was also tested for irritancy. Over a period of 48 hours the men applied the ointment five times to their faces, necks, hands and forearms. The ointment was not removed between applications.

Third Phase

43. The clothing worn in the third phase was made up of first and second phase clothing which had been laundered. The underwear was the rib knit type worn in the first phase rather than the nainsook shorts worn in the second phase. Unworn clothing was included in each group as a control. The distribution of clothing among the 84 men in the third phase is shown in the table to follow.

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Table IV

Third Phase Distribution of Clothing

<u>Suits</u>	<u>Underwear and Socks</u>
18 Washed	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
21 Unimpregnated	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension
3 Fresh	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
18 Washed	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension
21 Solvent	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
3 Fresh	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension
18 Washed	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
21 Solvent zinc oxide	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension
3 Fresh	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
18 Washed	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension
21 Water suspension	6 Unimpregnated 6 Solvent zinc oxide 6 Water suspension
3 Fresh	1 Unimpregnated 1 Solvent zinc oxide 1 Water suspension

F. Physiological Examinations and Recording

44. All personnel involved were given physical examinations before the tests began. Any skin lesions, especially fungus infections which are very common in the tropics, were recorded. However, unless a man was definitely sick he was not eliminated from the trials to prevent the test from being too artificial. Individual record sheets were filled out for each man for each phase (see Appendix A, Plate I). The physical examinations were made daily in the field, usually in the evening, and were

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recorded on the spot. The method of recording skin irritation was an arbitrary one, being based on that used by the CWS group, so that the tests could be correlated as much as possible. The following classification was used:

- 1 = slight lesions
- 2 = moderate lesions
- 3 = severe lesions
- 4 = casualty-producing lesions, eliminating a man from test.

45. During the readings of the lesions on the men an attempt was made to eliminate heat rash and other skin lesions which were not related to the chlorine dermatitis produced by the impregnated clothing. As the trials progressed, it was noted that the number and severity of the reactions due to the clothing decreased as the men became acclimated to the clothing and the maneuvers. The irritation was most pronounced on that part of the body between the waist and medial thighs, the worst areas being the hips and medial thighs.

46. Also significant was the fungicidal and bactericidal action of the impregnated clothing. This was most apparent on the fungus infections on the feet. The mild and moderate infections either remained static or showed definite improvement. Severe fungus infections tended to become worse. Secondary infection of the many minor cuts and abrasions incurred was almost nil in spite of the fact that first aid dressings often were lost.

Part II - Experimental Results

A. Evaluation of Irritation

47. The physiological effects produced by the different types of impregnated clothing during the wearing trials were evaluated in three ways, namely: (1) The number of casualties produced, (2) A calculated value called the "irritation index" and (3) The maximum severity of the lesions.

48. Out of 94 men in the test only three resulted in casualties due to irritation by the clothing. These all occurred in the first phase, one on the second day from a water suspension type suit and the other two on the fourth day from solvent + zinc oxide type suits. The remaining 91 men (97% of the total) wore the protective clothing for a maximum of fifteen days under the severe conditions of the test without becoming casualties. Therefore it may be said that for practical purposes Navy issue protective clothing is non-casualty producing even under severe conditions of wear.

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49. The number of casualties due to the clothing was too small to permit a relative measure of the irritant qualities of the different types of clothing. To obtain this relative irritancy the "irritation index" and maximum severity of lesions were used.

50. The "irritation index" for an individual or a group was calculated by multiplying the average number of lesions per man by the average severity of these lesions. This gives the product of the frequency of occurrence and the severity of the lesions and is a measure of the total irritation or damage to the skin caused by the clothing. A typical example of the method used is given in Appendix A.

51. The maximum severity of the lesions for one individual is the numerical value of the most severe lesion and for a group it is the average of the most severe lesions for each man. This gives a measure of the tendency of a certain type of clothing to produce casualties since it would be expected that continued aggravation of the lesions on a man would cause the most severe lesion to reach the casualty level first regardless of the total number of milder lesions.

52. In the wearing trials the men wore impregnated suits and shorts. These two layers have been evaluated independently. The summarized data for the outer layer given in Table V includes values for the different types of clothing for each phase. The values given for the impregnated clothing are for all the men wearing each type of outer garment regardless of the type of shorts they wore in the first phase. The controls in the first phase wore plain suits but impregnated shorts, hence these values, which are given in parenthesis, are not used in calculating the averages for all the phases. The complete data are given in Appendix A.

Table V

Summarized Irritation Data for Outer Layer

Phase	Irritation Index				Maximum Severity			
	Control	Solv.	Solv. + ZnO	H ₂ O susp.	Control	Solv.	+ ZnO	H ₂ O susp.
1	(2.87)	4.73	4.90	5.36	(1.67)	1.90	2.10	2.23
2	1.53	2.18	3.05	3.10	0.95	1.18	1.57	1.45
3	1.53	2.87	1.73	2.13	0.87	1.40	1.07	1.23
Ave.	1.53	3.26	3.23	3.53	0.91	1.49	1.58	1.64

53. Evaluation of the inner layer includes all men wearing each type of shorts regardless of the outer layer. The controls wore unimpregnated suits and shorts. Summarized data are given in Table VI. The complete data are given in Appendix A.

Table VI

Summarized Irritation Data for Inner Layer

Phase	Irritation Index				Maximum Severity			
	Control	Solv.	Solv. + ZnO	H ₂ O susp.	Control	Solv.	Solv. + ZnO	H ₂ O susp.
1	1.-	-	4.07	4.82	-	-	1.85	2.12
2	1.53	2.18	3.05	3.10	0.95	1.18	1.57	1.45
3	1.53	-	2.10	2.60	0.87	-	1.13	1.30
Ave.	1.53		3.07	3.51	0.91		1.52	1.62

54. The differences in irritation caused by the three types of impregnated clothing as measured by either the irritation index or maximum severity methods are too small to be regarded as important. The greatest variation evaluated by either method for all three phases was only 14%. The results for the inner layer are in excellent agreement with those for the outer layer.

55. Excluding the first phase in which there were no absolute controls, the unimpregnated clothing was about 55-75% as irritating as the impregnated clothing when measured by either method of evaluation or by either layer.

56. It was noticed during the trials that prolonged marching increased the irritant effects of the clothing. This is shown by the higher irritation values for the first phase over the second phase since in the second phase the marching was broken up by periods of relative inactivity. In the third phase the irritation was also low in spite of the long marches, but this is undoubtedly due to the much lower active chlorine content of the suits.

57. In the third phase both new and worn and laundered clothing were used. The worn and laundered clothing was slightly less irritant than the new clothing. However this may have been due to the much lower active chlorine content of the laundered clothing. Complete data are given in Appendix A.

58. There was not enough irritation on the feet of the men to permit evaluation of the different types of impregnated socks. In general the impregnated socks were not only non-irritating but appeared to have a beneficial effect in that they lessened the extent and severity of the fungus infections on the feet.

59. The lack of irritation from the S-350 Protective Ointment used during the trials corroborates further the non-irritant properties of this ointment. The few cases of irritation from the ointment were all mild.

B. Active Chlorine and Tensile Strength Retention

59. Representative suits from the wearing trials were analyzed for active chlorine and tested for tensile strength. Samples for analysis were taken from six different parts of each suit, three from the jacket and three from the trousers. Results of the analyses are summarized in Table VII, which gives the average active chlorine content of the suits before and after wear for each phase of the wearing trials and the percent of active chlorine retained. The percent retention values in the third phase are calculated for that phase only and do not include the effects of wear and laundering from the first phase. For comparative purposes the values for the new (control) suits used in the third phase are included. More complete data are given in Table XX in Appendix B.

Table VII

Active Chlorine Content of Suits Before and After Wearing Trials

Phase	Impregnation Type	Active Chlorine Content (mg./cm. ²)		Percent Retention
		Before Wear	After Wear	
1	Solvent (plain)	.37	.18	49
	Solvent + ZnO	.39	.16	41
	Water-suspension	.65	.21	32
2	Solvent (plain)	.27	.14	52
	Solvent + ZnO	.39	.15	38
	Water-suspension	.65	.31	48
3	Solvent (plain)	.16	.08	50
	Solvent (plain)(control)	.27	.18	67
	Solvent + ZnO	.15	.09	60
	Solvent + ZnO (control)	.39	.23	59
	Water-suspension	.25	.14	56
	Water-suspension (control)	.65	.39	60

In the first two phases, which lasted six days each, all three types of impregnated suits lost 50% or more of their active chlorine content. At the end of each of these phases the active chlorine content of the two solvent types was approximately at the minimum

reimpregnation level accepted at present. The water-suspension type was higher due to the higher initial loading of impregnate.

60. In the third phase, which lasted three days, the loss of active chlorine for the three types of impregnated new (control) suits was in general agreement with the other phases when the time of wear is considered. The worn and laundered suits (from the first phase) continued to lose their Cl^+ at approximately the same rate as before. At the end of the third phase the water suspension suits were at the minimum reimpregnation level. The other types were considerably lower.

61. For new suits the average chlorine retention for the three phases was 56% for the solvent (plain), 46% for solvent + zinc oxide, and 47% for the water-suspension types. The suits which were used in both the first and third phases showed an over-all retention of 22% for the solvent (plain), 23% for the solvent + zinc oxide, and 22% for the water-suspension types.

62. The tensile strength for the three types of impregnated suits did not change appreciably during the wearing trials. Tabular data are given in Table XXI in Appendix B. The retention of tensile strength of the clothing was also shown by the excellent physical condition of the suits after the trials. In spite of the rough treatment these suits received there were no snags or tears in any of them.

63. Representative shorts from the wearing trials also were analyzed. In the first phase both the solvent + zinc oxide and water-suspension types lost about 50% of their active chlorine. In the second phase where all three types of impregnated Nainsook shorts were used the results for the two solvent types are questionable because of the methods of impregnation used. The tensile strength of both types was very low immediately after impregnation indicating the presence of acid on the cloth. After wear no zinc oxide was found on the solvent + zinc oxide shorts, although zinc was present. In the third phase the solvent + zinc oxide type shorts which had been used in the first phase retained their Cl^+ , whereas the water-suspension type continued to lose it. More complete data are given in Table XXII in Appendix B.

C. Chamber Tests

64. Representative clothing from the wearing trials was tested in the chamber against H vapor in order to obtain a measure of the loss in protection afforded by the clothing after wear in the tropics. The suits from the first phase of the wearing trials had been laundered and reused in the third phase. The active chlorine content of these suits was too low to permit standard

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chamber tests. Accordingly, the suits chosen for the chamber tests were taken from the second phase of the wearing trials. The suits impregnated by the plain solvent and solvent + zinc oxide processes had about the same active chlorine content. The average value was 0.15 mg. Cl⁺/cm.² which is accepted at present as the reimpregnation level. The average active chlorine content of the water suspension impregnated suits was 0.31 mg./cm.². Previous work at this Laboratory has shown that the protection against H vapor given by the two solvent types of impregnated suits is very similar. Therefore only the solvent + zinc oxide and water suspension types were tested in the chamber. Shorts of the corresponding types of impregnation were used in conjunction with the suits to be tested in order to give added protection to the scrotal region. The shorts were taken from the third phase.

65. The methods of dressing the men and testing the clothing in the chamber were similar to those described in NRL Report No. P-2208, "Chamber Tests on Human Subjects." The men wore the following in the chamber: worn impregnated suits and rib-knit shorts; new impregnated gloves and two pair of socks; unimpregnated undershirts; masks and overshoes. S-330 protective ointment was applied to the neck and face extending just inside the edge of the mask facepiece.

66. The men were exposed to H vapor in the gas chamber at a CT of 1200 (0.020 mg. H/l. for one hour) and at 90°F and 65% R.H. The clothing was worn for four hours after each exposure after which the men were allowed to bathe. The complete series consisted of successive daily exposures of the same men dressed in the same clothing until each man was withdrawn from the test by the Medical Officer.

67. Physiological readings were taken 24 hours after each exposure and a man was withdrawn from the test when he showed a moderate to severe erythema on any part of the body. Readings were also taken at 24, 48 and 72 hours after the last exposure of each man.

68. For comparative purposes a control test was conducted at the same time on four men dressed in new suits and shorts impregnated by the water-suspension process. The dressing and exposure conditions were the same. Results of the test are summarized in Table VIII which gives the number of successive exposures given the men dressed in each of the different types of clothing and the relative severity of the resulting burns. The complete physiological data are given in Appendix C.

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Table VIII

Chamber Exposures of Men Dressed in Worn Suits

CT = 1200 (0.020 mg. H/l. for 1 hr.), T = 90°F, R_h = 65%

Type of Impregnation	No. of Men	No. of Exposures and Nature of Burns		
		1	2	3
Solvent + ZnO	5	4 (severe)	1 (moderate)	
Water Suspension	4	2 (severe)	1 (severe)	1 (severe)
Control (new suits)	4	0	1 (moderate)	3 (moderate)

69. The most severe burns on each of the four men dressed in the solvent + zinc oxide suits which "broke" on the first exposure resulted in vesication 48 to 72 hours after exposure. Three of these were of casualty severity. The one man in the water suspension suit which "broke" on the second exposure also was vesicated but was not of casualty severity. All of the other men in the water suspension suits developed papular erythema type burns. None of the men in the control suits developed more than moderate erythema type burns. Previous work at this Laboratory has indicated that under these conditions of testing, the men in the control suits could have received two or three more exposures before being vesicated or becoming casualties. The slightly better protection given by the water-suspension type impregnated suits over the solvent + zinc oxide type is due to the higher active chlorine content of the former type. However, both types gave a low order of protection when compared to the control suits.

D. Subjects' Opinions and Comments

70. At the conclusion of the wearing trials the men were given a series of questions for comment relative to the wearability of protective clothing in the tropics. The questions and answers are given in Table IX, the answers being recorded as percentages of the 80 to 85 answers to each question.

Table IX

Subjects' OpinionsI. Protective Suits.

- a. How did the protective suit compare with your ordinary hiking or fatigue clothing? Better, 61%. Worse, 15%. Same, 24%.
- b. Do you like the hood? Yes, 98%. No, 2%.
- c. Do you like the suspenders on the trousers in preference to a belt? Suspenders, 55%. Belt, 43%. Indifferent, 2%.
- d. Do you like the closed front on the jacket in preference to an open front? Closed, 69%. Open 30%. Indifferent, 1 %.

II. Protective Shorts.

- a. Do you prefer the nainsock to the ribbed-knit type shorts? Nainsock, 52%. Ribbed knit, 48%.

III. Socks.

- a. Do you prefer wearing impregnated socks over the bottom of your trousers to wearing leggings? Socks, 68%. Leggings, 32%.
- b. Do you prefer the impregnated to the plain socks? Impregnated, 66%. Plain, 12%. Same, 22%.

IV. Ointment.

- a. Did the ointment bother or irritate you? Yes, 2%. No, 66%. Slight, 32%.

Conclusions and Comments

71. The men generally preferred the impregnated clothing to their hiking or fatigue clothing because of its durability and design. Practically all the men liked the hood and many of them commented on its general usefulness. When worn down over the back it was not in the way and during the day the men occasionally wore it as a sunshade. At night when the men slept on the ground the hood was worn for comfort and particularly as a barrier against insects.

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The only difficulty the men had with the hoods was in buttoning them up rapidly. Suspenders were preferred only slightly more than belts. However, a few men complained of the suspenders cutting their shoulders and suggested they be made wider. The men preferred a closed front to an open one on the jacket because it didn't snag on the brush as easily and also helped keep insects out.

72. A few suggestions made by the men included: (a) putting tapes on the cuffs of the sleeves and trousers so that they can be pegged, (b) making a better fitting suit, (c) putting a gas proof opening in the trousers so that a man is not required to undress partially to urinate, and (d) changing the position of the pockets. During the trials a number of the men actually cut a slit in the front of the trousers to facilitate urination. The pockets in the present designed suits are too low so that they fold over when the drawstring of the jacket is tied in place. In the trials they were directly underneath the cartridge belt and therefore were useless. Also the pockets on the trousers were hit by the butts of the rifles slung over the men's shoulders so that the contents of the pockets were smashed.

73. Opinion was about evenly divided on the type of shorts the men preferred. However the wearing qualities of the rib-knit shorts were considerably better than the nainsook type since on rough handling the nainsook shorts tore more easily.

74. The men generally preferred wearing socks over the cuffs of the trousers to wearing leggings. This was mainly because the leggings tended to rub and cut the calf of the leg during long marches. Most of the men preferred the impregnated socks to plain socks because they wore better and caused no discomfort. Many men claimed that the wearing of impregnated socks definitely reduced the extent and severity of fungus growths on their feet. A few men felt that the socks and clothing reduced body odors due to sweat.

75. In most cases the ointment did not irritate or bother the men. There were only two men who claimed a true irritation or discomfort because of the ointment. It is obvious therefore that this ointment can be used as a prophylactic in the tropics without causing undue irritation to the men.

76. The officers who participated in the test stated that the wearing of protective clothing did not reduce the fighting ability of the men nor fatigue them unduly. Therefore the use of this clothing would not be expected to reduce appreciably the efficiency of forces in actual combat.

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SUMMARY AND CONCLUSIONS

1. Wearing trials of protective clothing were carried out in the tropics under conditions simulating actual combat in order to determine the effects of wear of this clothing both on the men and the clothing. The test was carried out with about 100 Marines and was divided into three phases of six, six and three days each. The men wore the clothing continuously during each phase while engaged in combat maneuvers in the dense jungles of Panama. There were several long forced marches through the heavy undergrowth and swamps of that area. The average temperature during the trials was 78°F and the R.H. was 78%. The men perspired freely most of the time.
2. The protective clothing tested consisted of Navy issue protective suits, rib-knit and nainsook shorts and socks. These were impregnated with CC-2 by the water suspension process with zinc oxide stabilizer, by the solvent process with zinc oxide stabilizer and by the plain solvent process. During each phase all three types of impregnated clothing were worn, and unimpregnated clothing of the same type was used for a control. In the third phase laundered clothing from the first phase was used.
3. Only three out of 94 men in the test became casualties due to the clothing. All occurred in the first phase. One of them was wearing a water suspension type suit and the other two solvent-plus-zinc oxide suits. Since the other 91 men wore the protective clothing until the test was completed it may be said that for practical purposes Navy issue protective clothing is non-casualty producing even under severe conditions of wear.
4. In order to compare the relative irritancy of the different types of impregnated clothing, each type was evaluated by the number and severity of the lesions produced. It was found that differences in irritation caused by the three types were too small to be regarded as important. In general, the plain solvent type clothing was the least irritating and the water suspension type the most irritating, although the greatest variation for the complete trials was only 14%. Unimpregnated clothing was 55-75% as irritating as the impregnated clothing. Evaluation of the results by either the suits or shorts was in excellent agreement. Worn and laundered clothing was slightly less irritant than new clothing, probably because of its lower active chlorine content.
5. The greatest irritation produced by the clothing occurred as a result of prolonged marching, and the lesions produced occurred mostly between the hips and middle of the thighs.

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6. The impregnated socks did not produce enough irritation to permit evaluation of the different types of impregnation.
7. The impregnated clothing generally appeared to have some beneficial effect in that it reduced the extent and severity of moderate and mild fungus infections, especially on the feet.
8. S-330 Protective Ointment was applied to the face, neck and wrists of the men five times during a period of 48 hours. Since only a few cases of mild irritation were observed it was concluded that S-330 can be used as a prophylactic against H in tropical climates.
9. Clothing removed at the end of each phase was analyzed for active chlorine and tensile strength retention. In six days wear the plain solvent type suits dropped from an average of 0.32 to 0.16 mg. Cl⁺/cm.² (50% retention), the solvent-plus-zinc oxide dropped from 0.39 to 0.16 mg. Cl⁺/cm.² (41% retention) and the water suspension dropped from 0.65 to 0.26 mg. Cl⁺/cm.² (40% retention). After washing and three days more wear, the chlorine contents were 0.08, 0.09 and 0.14 mg./cm.² respectively.
10. The plain solvent and solvent-plus-zinc oxide types of impregnated clothing required reimpregnation after only six days wear in the tropics. The water suspension type, due to its higher initial loading of chlorine, required reimpregnation after nine days wear including one laundering.
11. The loss in active chlorine content of the shorts was similar to that of the suits.
12. The tensile strength of the three types of clothing remained essentially the same throughout the trials.
13. Solvent-plus-zinc oxide and water suspension type suits which had been worn six days in the wearing trials were tested against H vapor in the chamber. Men, dressed in these and unworn suits (controls), were exposed daily to a CT of 1200 (0.020 mg. H/l. for 1 hr.) at 90°F and 65% R.H. The men in the solvent plus zinc oxide suits tolerated an average of 1.2 exposures and had relatively severe burns. This confirmed that these suits required reimpregnation. The men in the water suspension type suits tolerated an average of 1.75 exposures and had relatively severe burns. Therefore these suits were close to but not at the reimpregnation level. The men in the new suits (controls) were given an average of 2.75 exposures and had moderate burns.

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14. At the conclusion of the trials comments were requested from the men who had participated. The clothing was not unduly uncomfortable and in some respects was preferred to fatigue clothing. The officers and observers concluded that the clothing does not reduce fighting efficiency to any great extent.

RECOMMENDATIONS

1. It is recommended that Navy issue protective clothing impregnated by the solvent process, solvent process with zinc oxide stabilizer and water suspension process be considered suitable for continuous wear in the tropics since these trials have shown that these three types of clothing do not cause undue irritation or fatigue.
2. It is recommended that S-330 Protective Ointment be considered suitable for use in the tropics since these trials have shown that it does not cause undue irritation when worn for 48 hours.
3. It is recommended that, when protective clothing is worn continuously under active combat conditions in the tropics, it be tested for impregnate content every week.
4. It is recommended that tapes be put on the cuffs of the sleeves and trousers so that a gas tight seal may be effected.
5. It is recommended that a suitable gas-proof fly opening in the trousers be designed.
6. It is recommended that suitable design rib-knit protective shorts be developed to overcome the disadvantages found for other types of shorts worn in these trials.
7. It is recommended that efforts be continued to develop newer types of protective clothing which will withstand tropical wearing conditions for a longer period of time and still retain protective efficiency.

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APPENDIX A

Detailed Evaluation of Irritation

1. Plate 1 shows the form used and the manner of recording the irritation data during the test. The form shown for the illustration represents the readings for the first phase on one subject wearing a solvent + ZnO suit and solvent + ZnO shorts. The totals at the foot of the page represent: total numbers of lesions/total severity of lesions/maximum severity. Thus after the first day the subject had two lesions, the total severity was two (1+1) and the maximum severity was one.

2. The first step in the evaluation of the irritation produced by the various types of protective clothing consisted of obtaining combined totals for each type of impregnation for each phase. Table X shows the totals for solvent suits with solvent + ZnO shorts in the first phase. Tables similar to this were prepared for each combination of suits and shorts for each phase.

Table X

1st Phase Combined Totals for Solvent Suits with Solvent + ZnO Shorts

(No. of Lesions - Total Severity of Lesions - Maximum Severity)

Subject Number	Days					
	1	2	3	4	5	6
1	1-1-1	2-4-2	3-8-3	2-4-2	2-3-2	2-3-2
2	1-2-2	1-1-1	2-3-2	2-3-2	1-1-1	2-2-1
3	3-2-2	4-9-3	4-10-3	6-12-3	3-6-2	5-8-2
4	2-4-2	4-6-3	2-4-3	3-6-3	4-8-3	3-7-3
5	4-5-2	10-16-2	4-7-2	6-14-3	5-10-2	5-9-2
6	0-0-0	2-3-2	1-1-1	1-2-2	1-1-1	1-1-1
7	1-1-1	3-6-3	4-5-2	1-2-2	4-6-2	1-1-1
Combined Total	12-17-10	26-45-16	20-38-16	21-43-17	20-35-13	19-31-12

3. In the above table the combined totals indicate the total number of lesions - the total severity - and the total maximum severity of all lesions present each day of the first phase for all men wearing solvent suits with solvent + ZnO shorts.

4. The second step in the evaluation involved converting the combined totals to average values. For this purpose the following calculations were made:

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Using the combined total for each day -

- (a) total number of lesions divided by the number of men gives the average number of lesions per man.
- (b) total severity divided by the total number of lesions gives the average severity of each lesion.
- (c) total maximum severity divided by the total number of men gives the average maximum severity per man.

5. Thus for example, taking the combined total for the first day in Table X, the average number of lesions per man was $12/7$ or 1.7; the average severity of each lesion was $17/12$ or 1.4; the average maximum severity per man was $10/7$ or 1.4.

6. The third step in the evaluation was the calculation of the irritation index for each combination of suits and shorts in each phase. This was done by obtaining the product of the average number of lesions per man and the average severity of each lesion. Thus in the above example, the irritation index for solvent suits with solvent + ZnO shorts on the first day of the first phase was 1.7×1.4 or 2.4.

7. By means of the foregoing calculations, the two values used as criteria for final evaluation were obtained: i.e. irritation index and maximum severity. In the following series of tables these values are tabulated for outer and inner layers for each phase, and finally combined for all phases.

Table XI

Irritation Data for Outer Layer - 1st Phase

Day	Irritation Index				Maximum Severity			
	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.
1	2.0	1.8	2.4	2.4	1.2	1.1	1.2	1.2
2	4.0	6.1	6.1	6.7	2.0	2.2	2.3	2.6
3	3.8	5.5	6.2	6.9	2.1	2.3	2.6	2.7
4	3.1	6.1	5.5	5.9	1.9	2.3	2.4	2.5
5	2.1	4.6	4.6	5.3	1.4	1.8	2.1	2.3
6	2.2	4.3	4.6	5.0	1.4	1.7	2.1	2.1
Ave.	2.87	4.73	4.90	5.36	1.67	1.90	2.10	2.23

The data given in Table XI are shown graphically in Plates 2 and 3.

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Table XII

Irritation Data for Inner Layer - 1st Phase

Day	Irritation Index		Maximum Severity	
	Solv.+ZnO	H ₂ O-Susp.	Solv.+ZnO	H ₂ O-Susp.
1	2.1	2.4	1.1	1.2
2	5.3	6.0	2.2	2.4
3	5.2	6.0	2.2	2.6
4	4.6	5.2	2.2	2.4
5	3.7	4.5	1.7	2.1
6	3.5	4.8	1.7	2.0
Ave.	4.07	4.82	1.85	2.12

The data in Table XII are shown graphically in Plates 4 and 5.

Table XIII

Irritation Data for Both Layers - 2nd Phase

Day	Irritation Index				Maximum Severity			
	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.
1	1.2	1.7	1.8	1.8	0.8	0.9	1.1	1.0
2	1.6	2.4	4.0	3.1	0.9	1.4	1.7	1.3
3	1.8	2.0	3.4	2.0	1.1	1.2	1.6	1.3
4	1.7	2.1	3.4	2.6	1.0	1.2	1.7	1.4
5	1.7	2.7	3.0	4.6	1.0	1.4	1.9	2.0
6	1.2	2.2	2.7	4.5	0.9	1.0	1.4	1.7
Ave.	1.53	2.18	3.05	3.10	0.95	1.18	1.57	1.45

These data are presented graphically in Plates 6 and 7.

Table XIV

Irritation Data for Outer Layer - 3rd Phase

Day	Irritation Index				Maximum Severity			
	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.
1	0.8	1.7	0.8	0.8	0.6	1.0	0.6	0.6
2	1.6	3.1	2.0	2.4	1.0	1.6	1.3	1.3
3	2.2	3.8	2.4	3.2	1.0	1.6	1.3	1.8
Ave.	1.53	2.87	1.73	2.13	0.87	1.40	1.07	1.23

The results shown above are also presented graphically in Plates 8 and 9.

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Table XV

Irritation Data for Inner Layer - 3rd Phase

Day	Irritation Index			Maximum Severity		
	Control	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.+ZnO	H ₂ O-Susp.
1	0.8	0.9	1.2	0.6	0.6	0.8
2	1.6	2.4	2.7	1.0	1.3	1.4
3	2.2	3.0	3.9	1.0	1.5	1.7
Ave.	1.53	2.10	2.60	0.87	1.13	1.30

These values are also given graphically in Plates 10 and 11.

Table XVI

Irritation Data for Outer Layer - All Phases

Day	Irritation Index				Maximum Severity			
	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.	Solv.+ZnO	H ₂ O-Susp.
1	1.3	1.7	1.7	1.7	0.9	1.0	1.0	0.9
2	2.4	3.9	4.0	4.1	1.3	1.7	1.8	1.7
3	2.6	3.8	4.0	4.0	1.4	1.7	1.8	1.9
4	2.4	4.1	4.5	4.3	1.5	1.8	2.1	2.0
5	1.9	3.7	3.8	5.0	1.2	1.6	2.0	2.2
6	1.7	3.3	3.7	4.8	1.2	1.4	1.8	1.9
Ave.	2.05	3.41	3.61	3.98	1.25	1.53	1.75	1.77

The above results are shown graphically in Plates 12 and 13.

Table XVII

Irritation Data for Inner Layer - All Phases

Day	Irritation Index			Maximum Severity		
	Control	Solv.+ZnO	H ₂ O-Susp.	Control	Solv.+ZnO	H ₂ O-Susp.
1	1.0	1.6	1.8	0.7	0.9	1.0
2	1.6	3.9	3.9	1.0	1.7	1.7
3	2.0	3.9	4.0	1.1	1.8	1.9
4	1.7	4.0	3.9	1.0	2.0	1.9
5	1.7	3.4	4.6	1.0	1.8	2.1
6	1.2	3.1	4.7	0.9	1.6	1.9
Ave.	1.53	3.15	3.82	0.95	1.63	1.75

These results are presented graphically in Plates 14 and 15.

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8. In order to obtain a means of easy comparison of the irritation effects of the various impregnation systems, ratios of irritation index and maximum severity were calculated. These ratios were calculated with the controls as 1.00 and also with the solvent or solvent + ZnO as 1.00. The values are tabulated in Table XVIII.

Table XVIII

Ratios of Irritation Effects

<u>Layer - Phase</u>	<u>Irritation Index Ratios</u>				<u>Maximum Severity Ratios</u>			
	<u>Control</u>	<u>Solv.</u>	<u>Solv.+ZnO</u>	<u>H₂O</u>	<u>Control</u>	<u>Solv.</u>	<u>Solv.+ZnO</u>	<u>H₂O</u>
Outer - 1st	1.00	1.65	1.71	1.87	1.00	1.14	1.26	1.54
	0.61	1.00	1.04	1.13	0.88	1.00	1.11	1.17
Inner - 1st			1.00	1.18			1.00	1.15
Both - 2nd	1.00	1.43	1.99	2.02	1.00	1.24	1.65	1.53
	0.70	1.00	1.40	1.42	0.81	1.00	1.33	1.23
Outer - 3rd	1.00	1.88	1.13	1.39	1.00	1.61	1.23	1.41
	0.53	1.00	0.60	0.74	0.62	1.00	0.77	0.88
Inner - 3rd	1.00		1.37	1.70	1.00		1.30	1.49
	0.73		1.00	1.24	0.77		1.00	1.15

9. The final step in the evaluation was the combination of all values from all phases to obtain a grand average figure for each type of impregnation for the entire test. It is these values which are shown and discussed in Tables V and VI in the body of the report.

10. A comparison of the irritation produced by worn and laundered clothing with that produced by new, unlaundered suits was obtained in the third phase of the test. These irritation data are given in Table XIX.

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Table XIX

Irritation Data - Effect of Laundering

Days	Irritation Index		Maximum Severity	
	New	Laundered	New	Laundered
1	1.0	1.1	0.8	0.7
2	3.1	2.4	1.6	1.3
3	3.3	3.0	1.6	1.5
Ave.	2.47	2.17	1.33	1.17

These values are also shown graphically in Plates 16 and 17. The ratios of irritation effects are as follows.

Irritation Index		Maximum Severity	
Laundered	New	Laundered	New
1.00	1.14	1.00	1.14

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DAILY MEDICAL INSPECTION

NAME John Doe

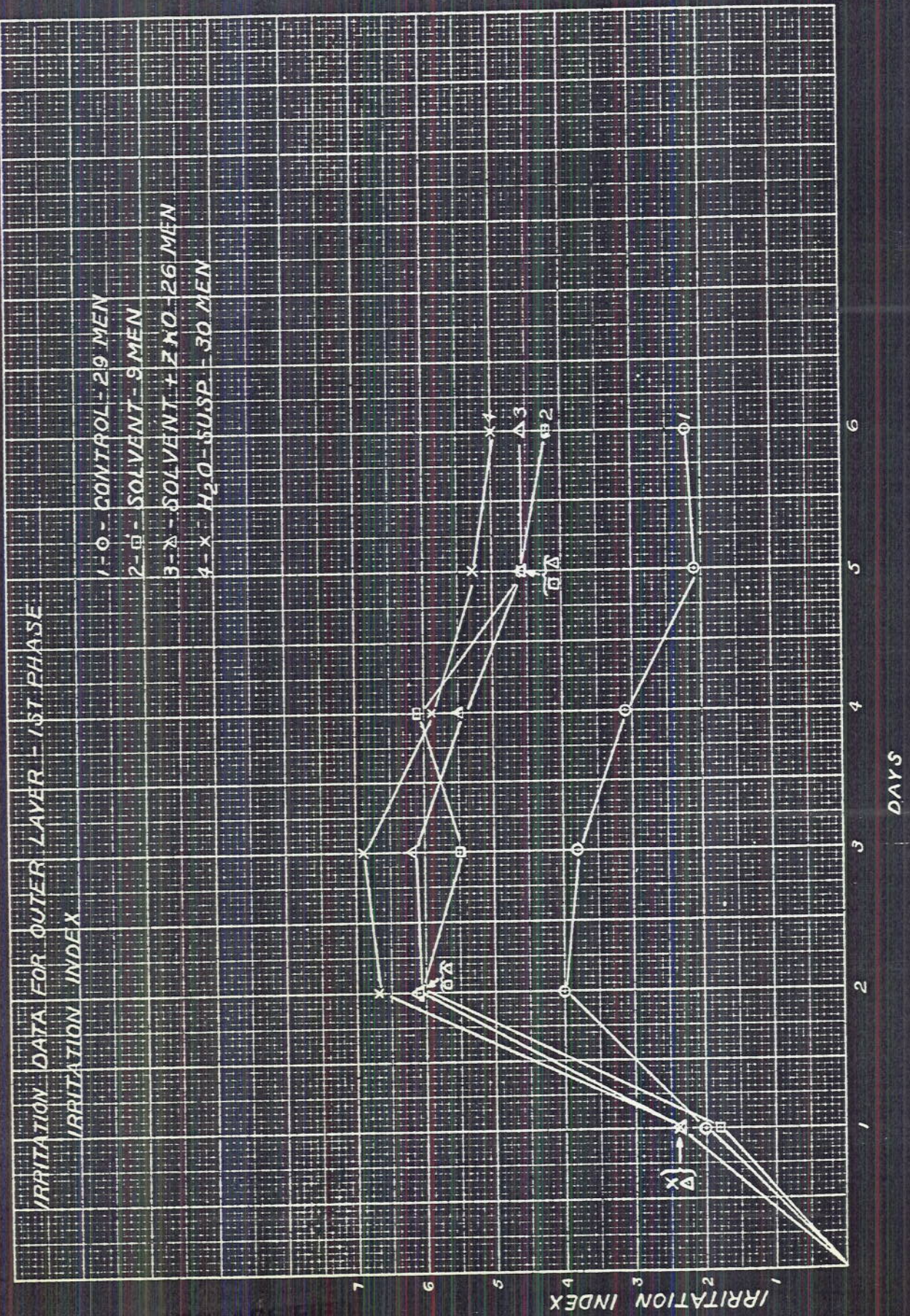
GROUP 1st Platoon PERIOD 1st phase GARMENT NO. Solvent + ZnO

	DAY					
	1	2	3	4	5	6
BASE OF NECK	1					
SHOULDERS	1	1				
ANT. AXILL.FOLDS						
POST.AXILL.FOLDS						
ARMS						
FRONT OF ELBOW						
FOREARMS						
WRISTS						
CHEST						
UPPER BACK		2	2			
LOWER BACK		2	2		1	1
ABDOMEN		3	3	3	2	1
WAIST		3	3	2	3	2
BUTTOCKS						
FRONT OF THIGHS				3		
BACK OF THIGHS						
MEDIAL THIGHS		1	2		1	
SIDES OF THIGHS						
CROTCH						
SCROTUM		2				
PENIS						
BACK OF KNEE						
LEGS						
TOTAL	2/2/1	7/4/3	5/2/3	3/3/3	4/1/3	3/1/2

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PLATE NO. I

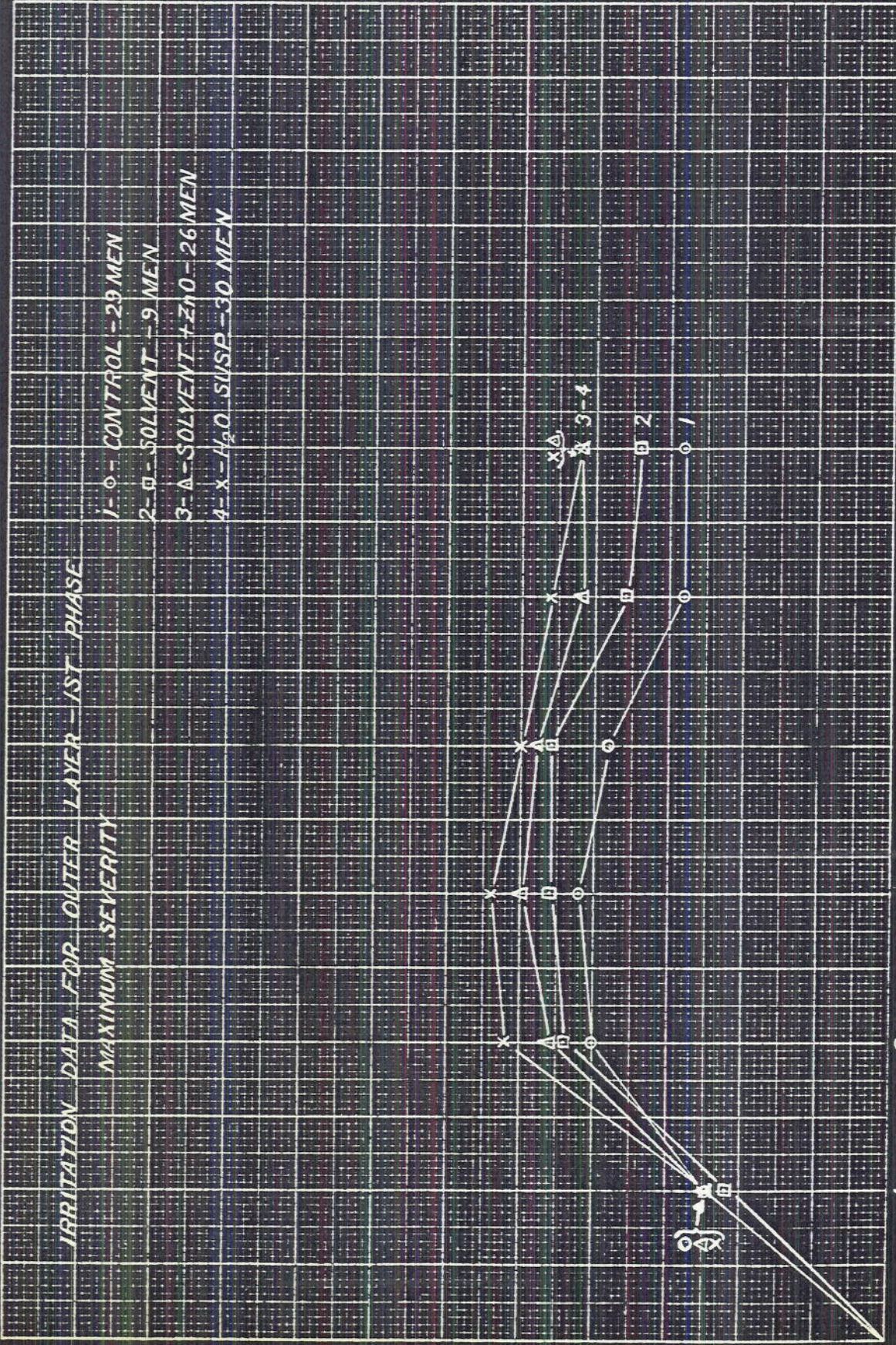
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IRRITATION DATA FOR OUTER LAYER - 1ST PHASE

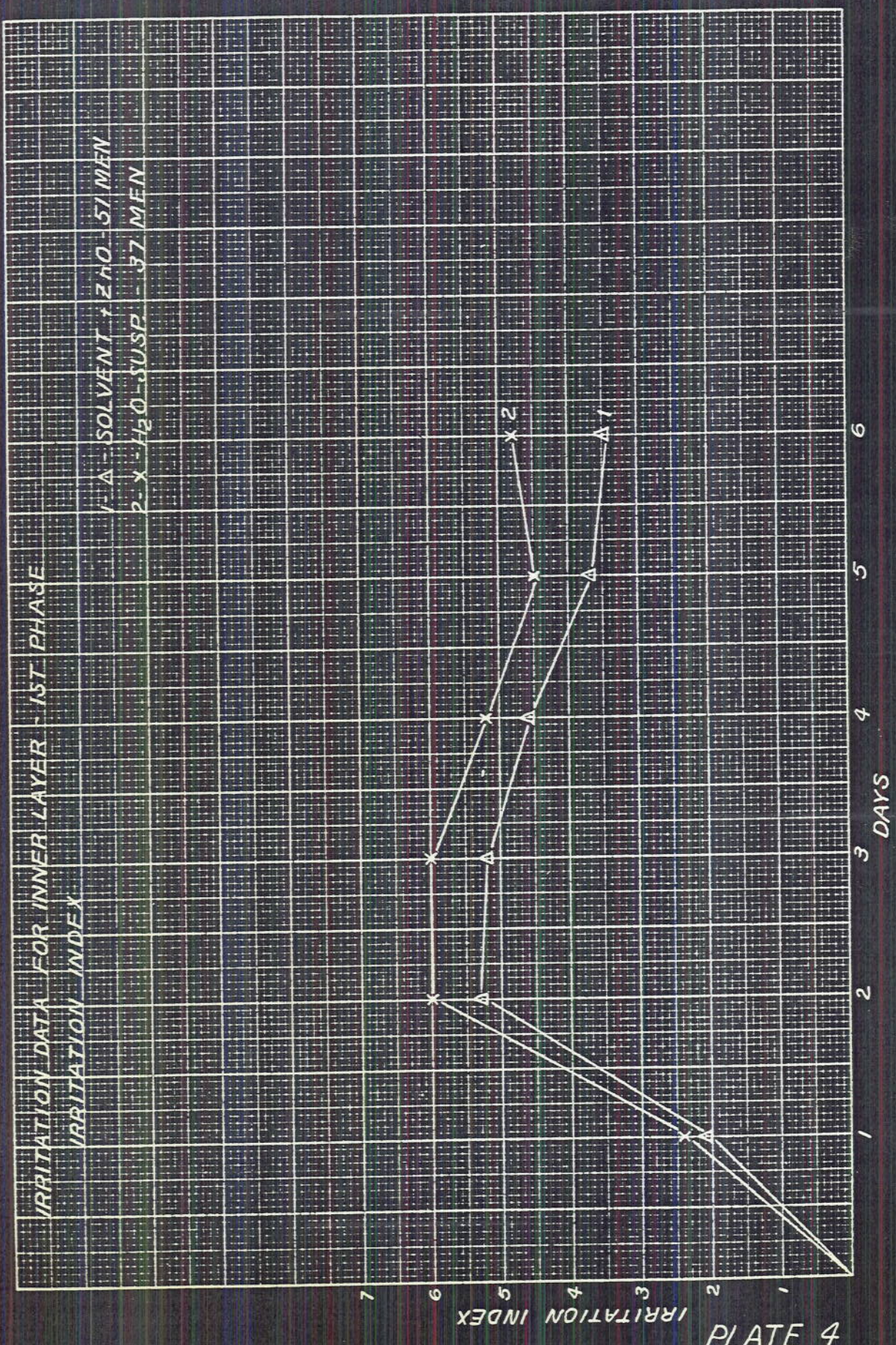
MAXIMUM SEVERITY

- 1- O - CONTROL - 29 MEN
- 2- □ - SOLVENT - 9 MEN
- 3- Δ - SOLVENT + ZnO - 26 MEN
- 4- X - H₂O SUSP - 30 MEN



DAYS

MAXIMUM SEVERITY



IRRITATION DATA FOR INNER LAYER - 1ST PHASE
IRRITATION INDEX

1 - A - SOLVENT + ZNO - 51 MEN
2 - X - H₂O - SUSP. - 37 MEN

6
5
4
3 DAYS
2
1

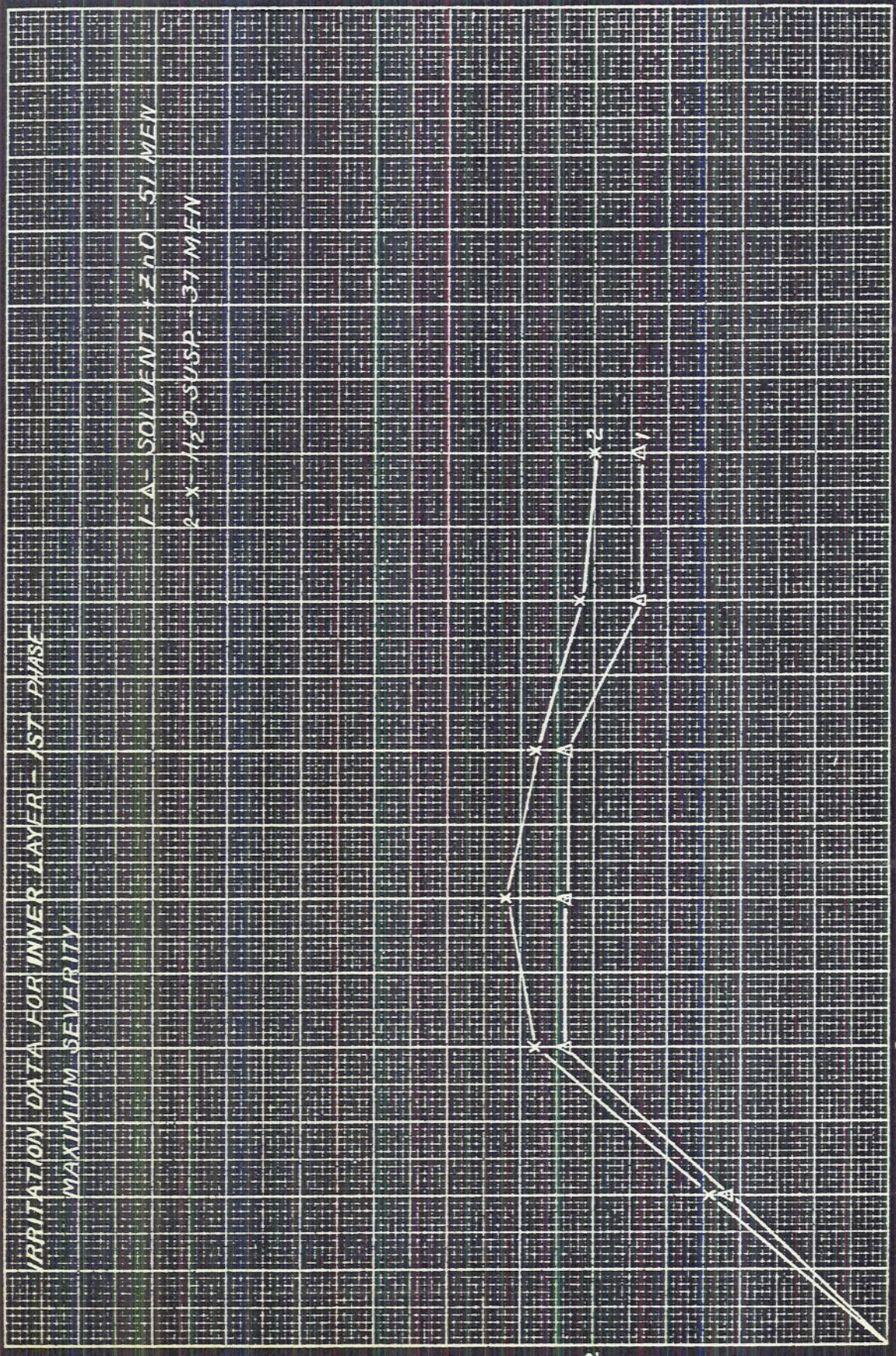
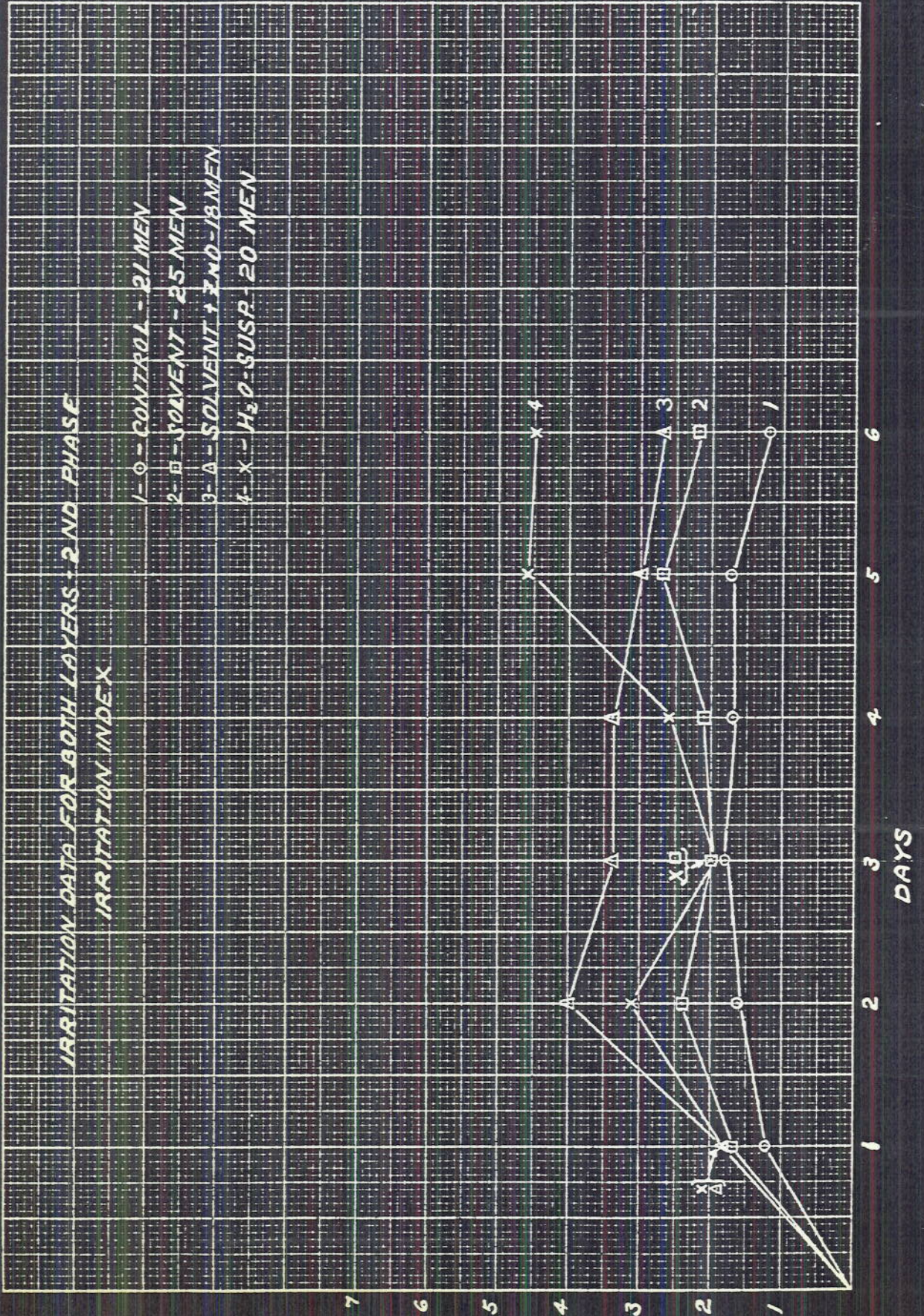


PLATE 5

IRRITATION DATA FOR BOTH LAYERS - 2ND PHASE

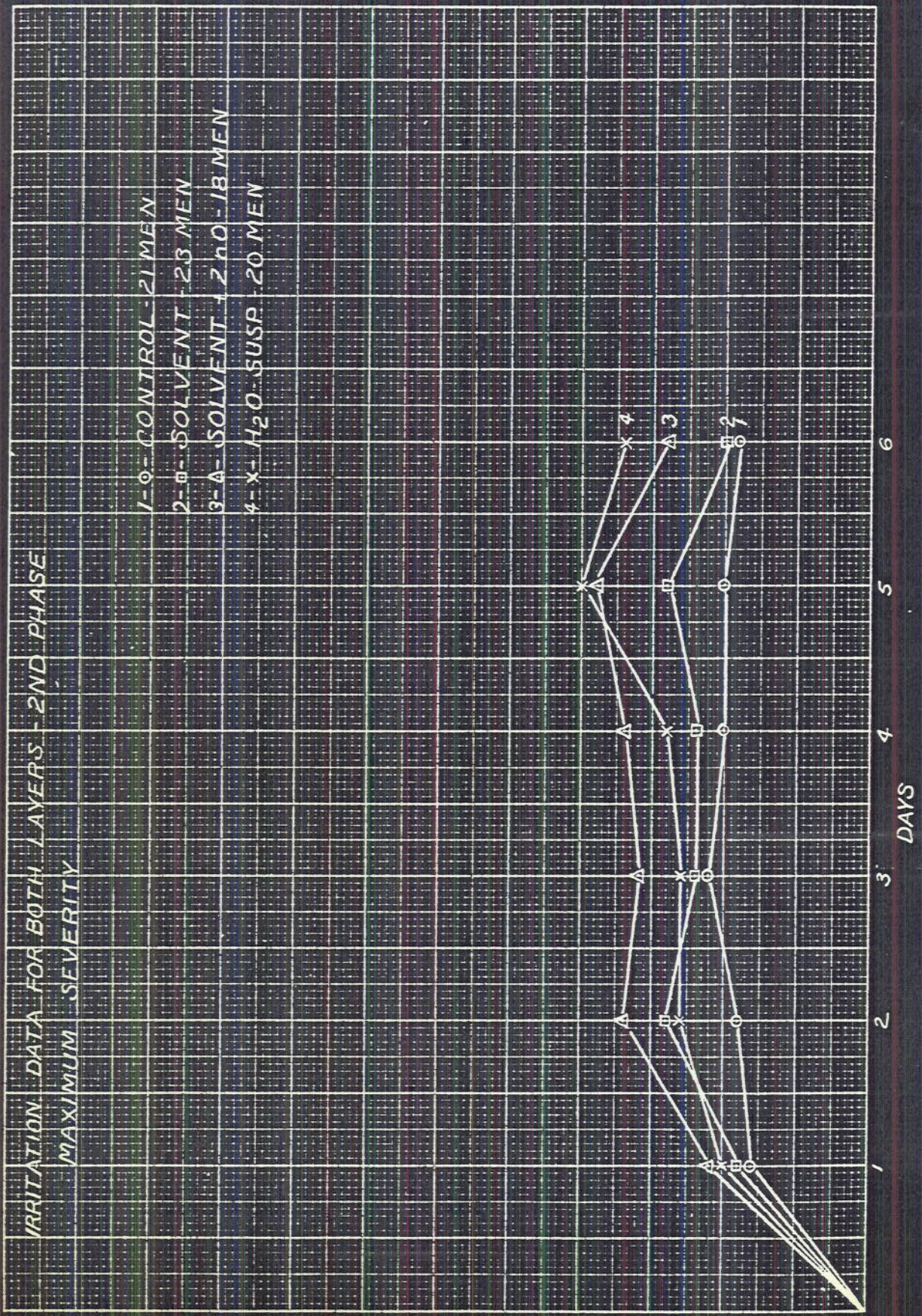
IRRITATION INDEX

- 1- O - CONTROL - 21 MEN
- 2- □ - SOLVENT - 25 MEN
- 3- Δ - SOLVENT + ZND - 18 MEN
- 4- X - H₂O-SUSP - 20 MEN

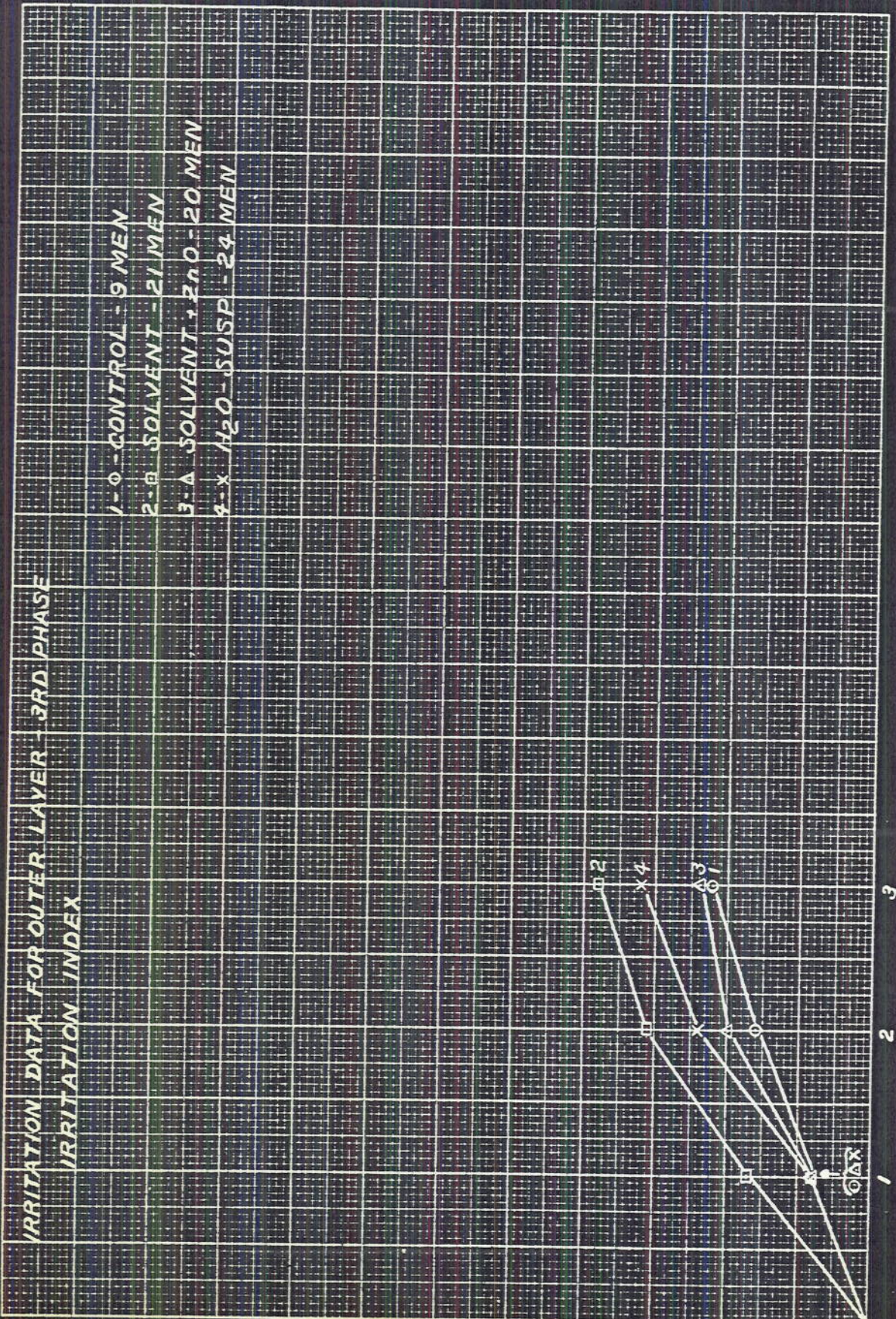


IRRITATION INDEX

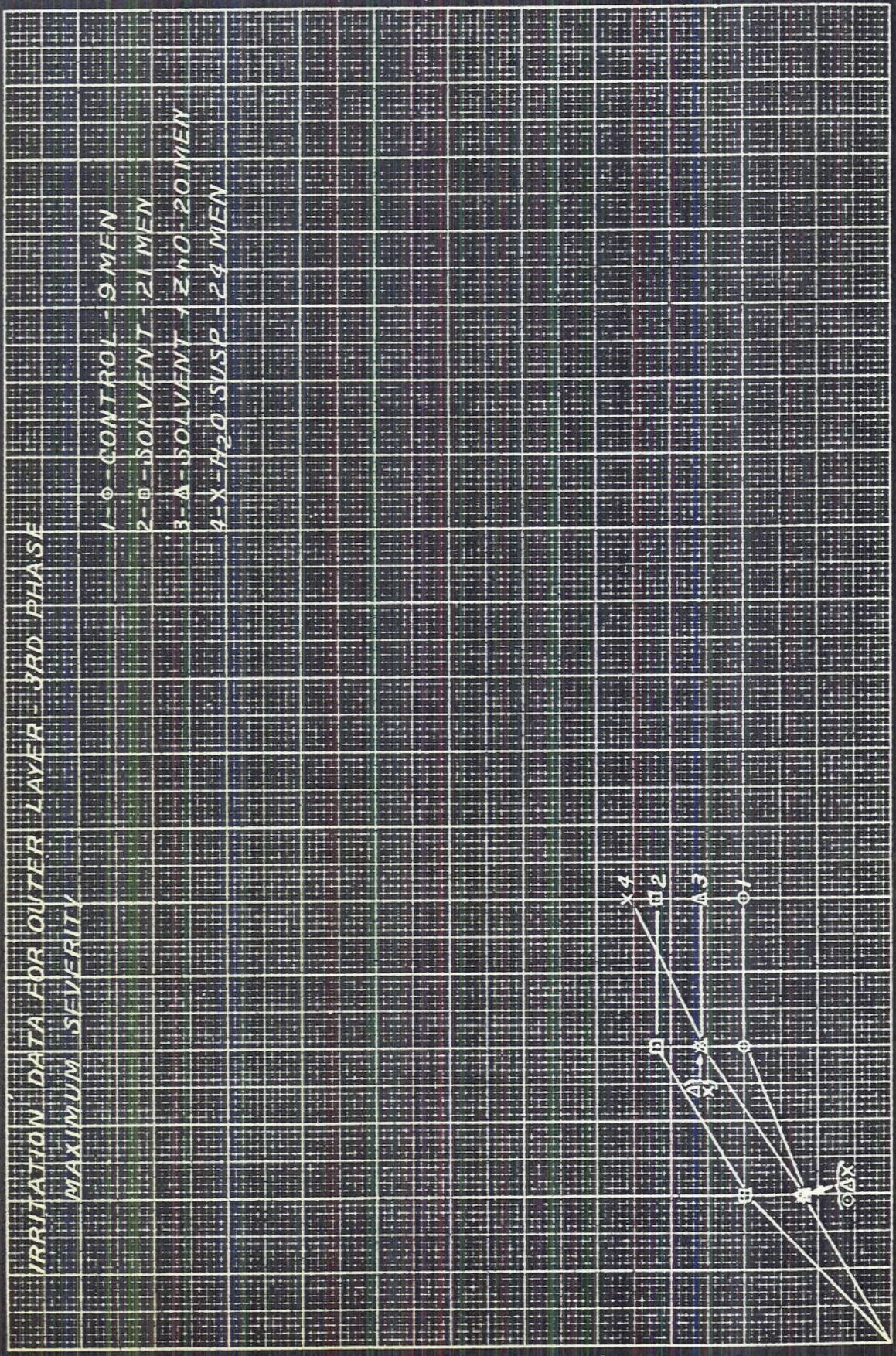
DAYS



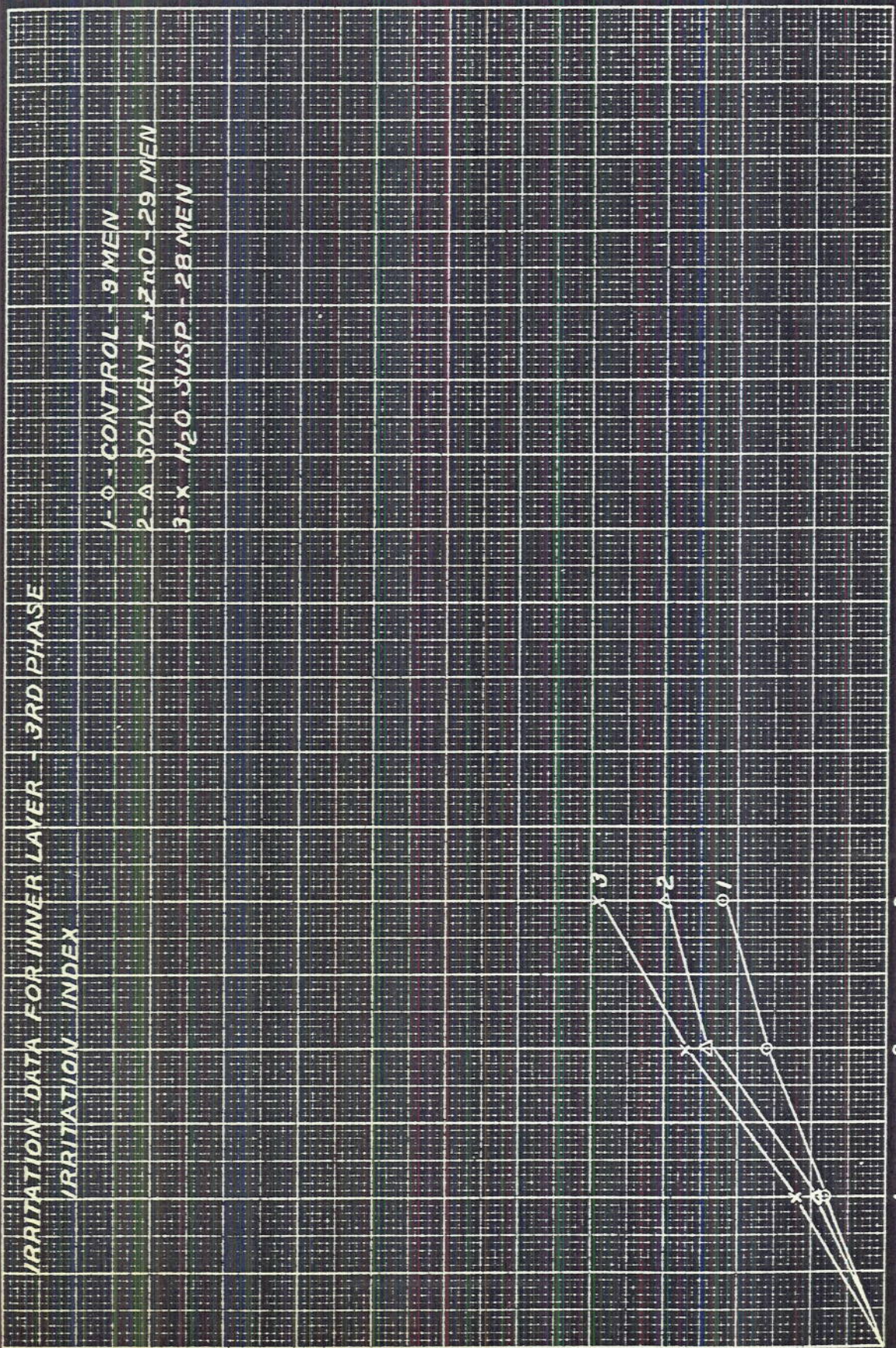
MAXIMUM SEVERITY
PLATE 7



8 PLATE 8



6 PLATE 9
MAXIMUM SEVERITY

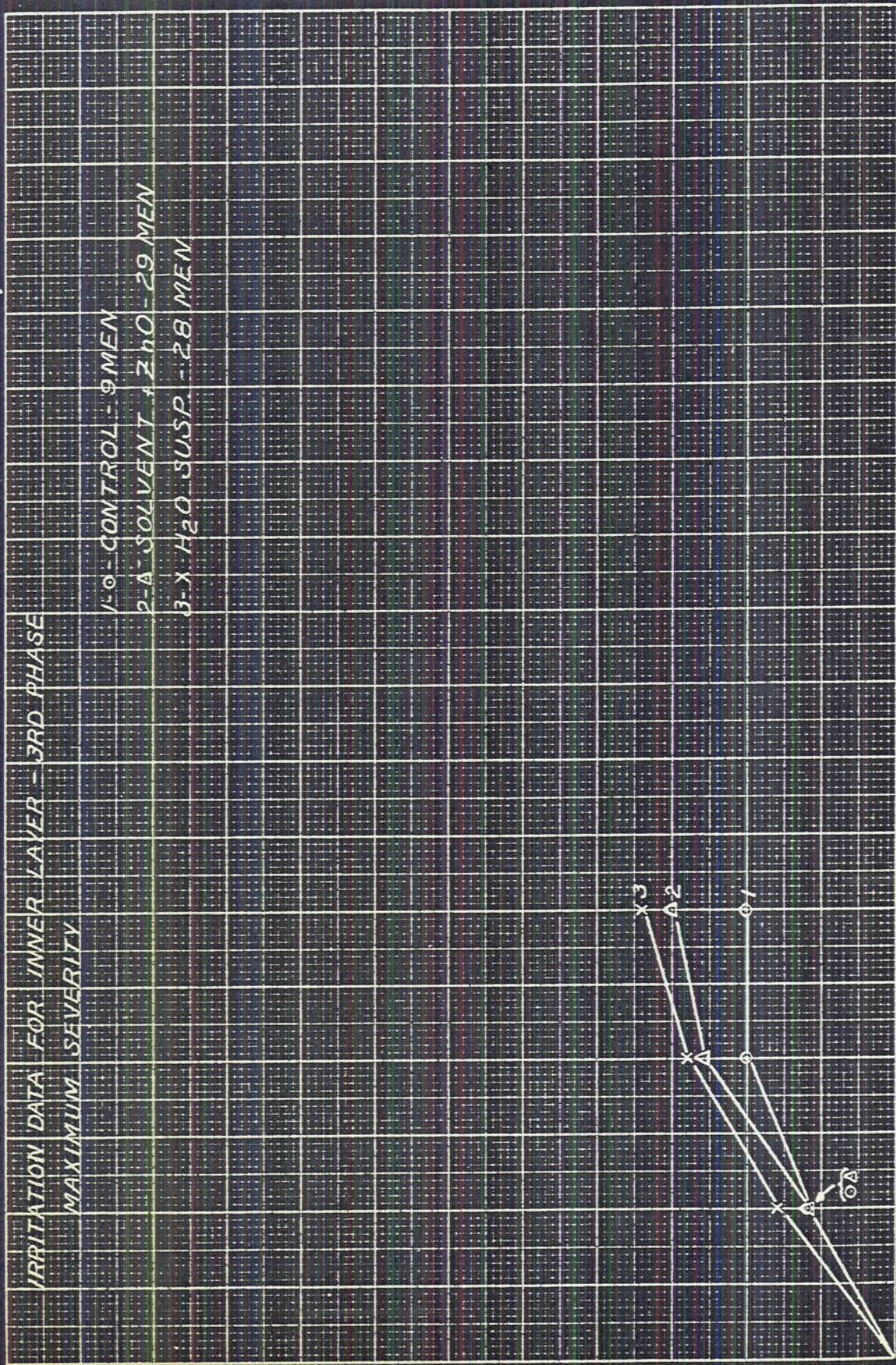


IRRITATION DATA FOR INNER LAYER - 3RD PHASE
IRRITATION INDEX

1-O - CONTROL - 9 MEN
2-Δ SOLVENT + 20 - 29 MEN
3-X H₂O JUSP. - 28 MEN

DAYS

IRRITATION INDEX



MAXIMUM SEVERITY

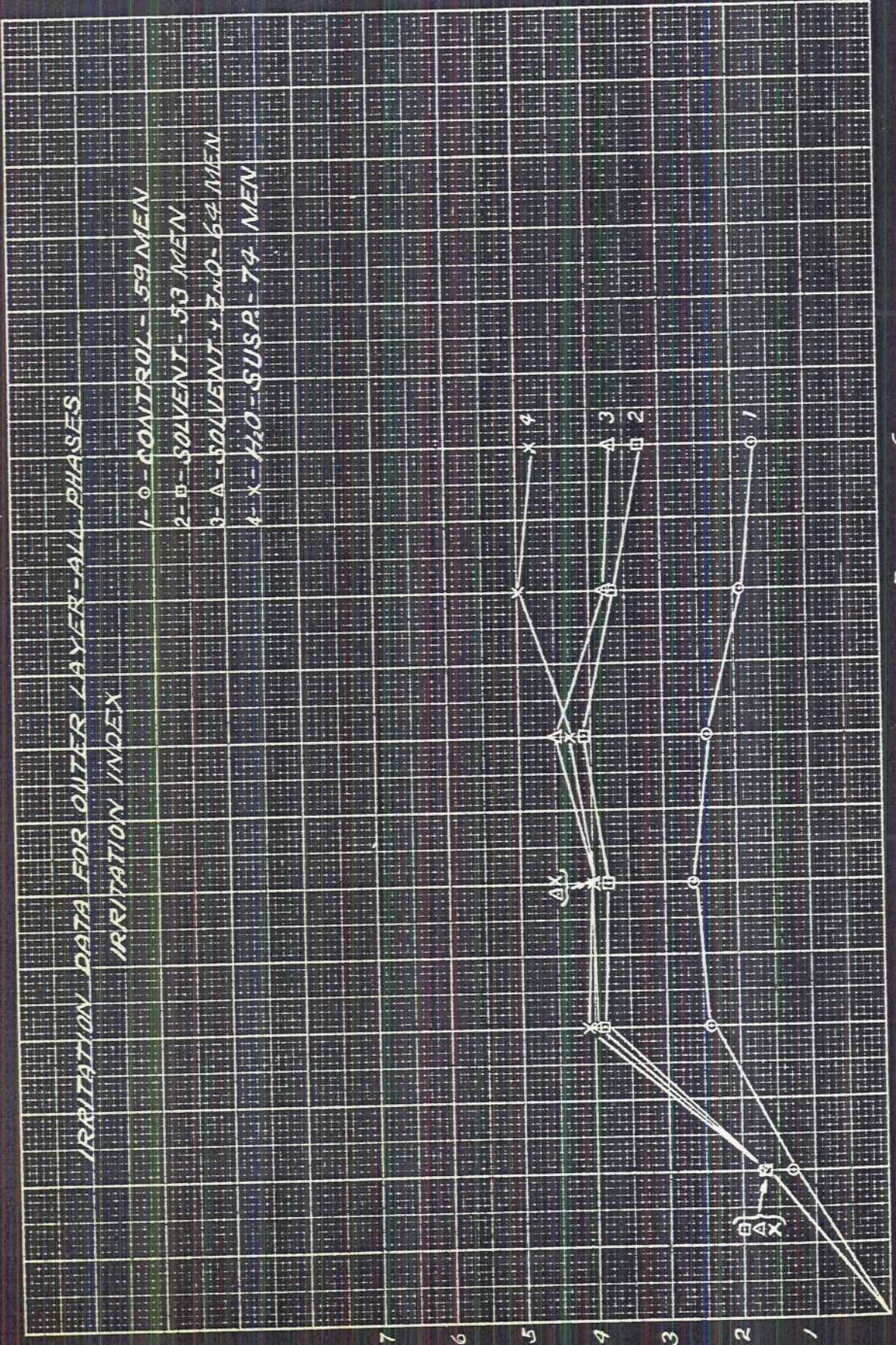
PLATE II

DAYS

IRRITATION DATA FOR OUTER LAYER-ALL PHASES

IRRITATION INDEX

- 1-O-CONTROL-59 MEN
- 2-B-SOLVENT-53 MEN
- 3-A-SOLVENT+ZnO-64 MEN
- 4-X-H₂O-SUSP-74 MEN



DAYS

IRRITATION INDEX

CI 51018

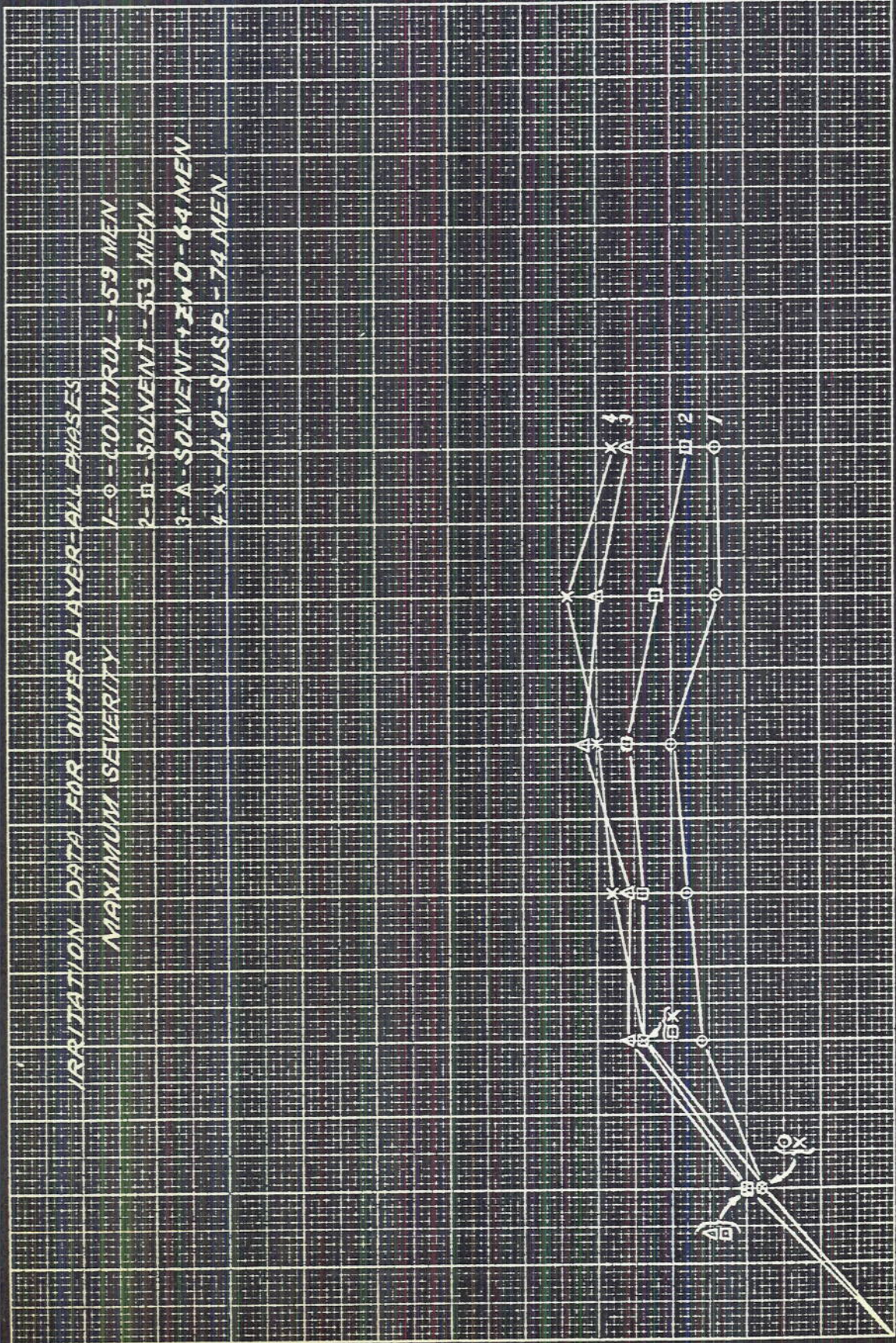
IRRITATION DATA FOR OUTER LAYER-ALL PHASES
MAXIMUM SEVERITY

1-0 - CONTROL - 59 MEN

2-0 - SOLVENT - 53 MEN

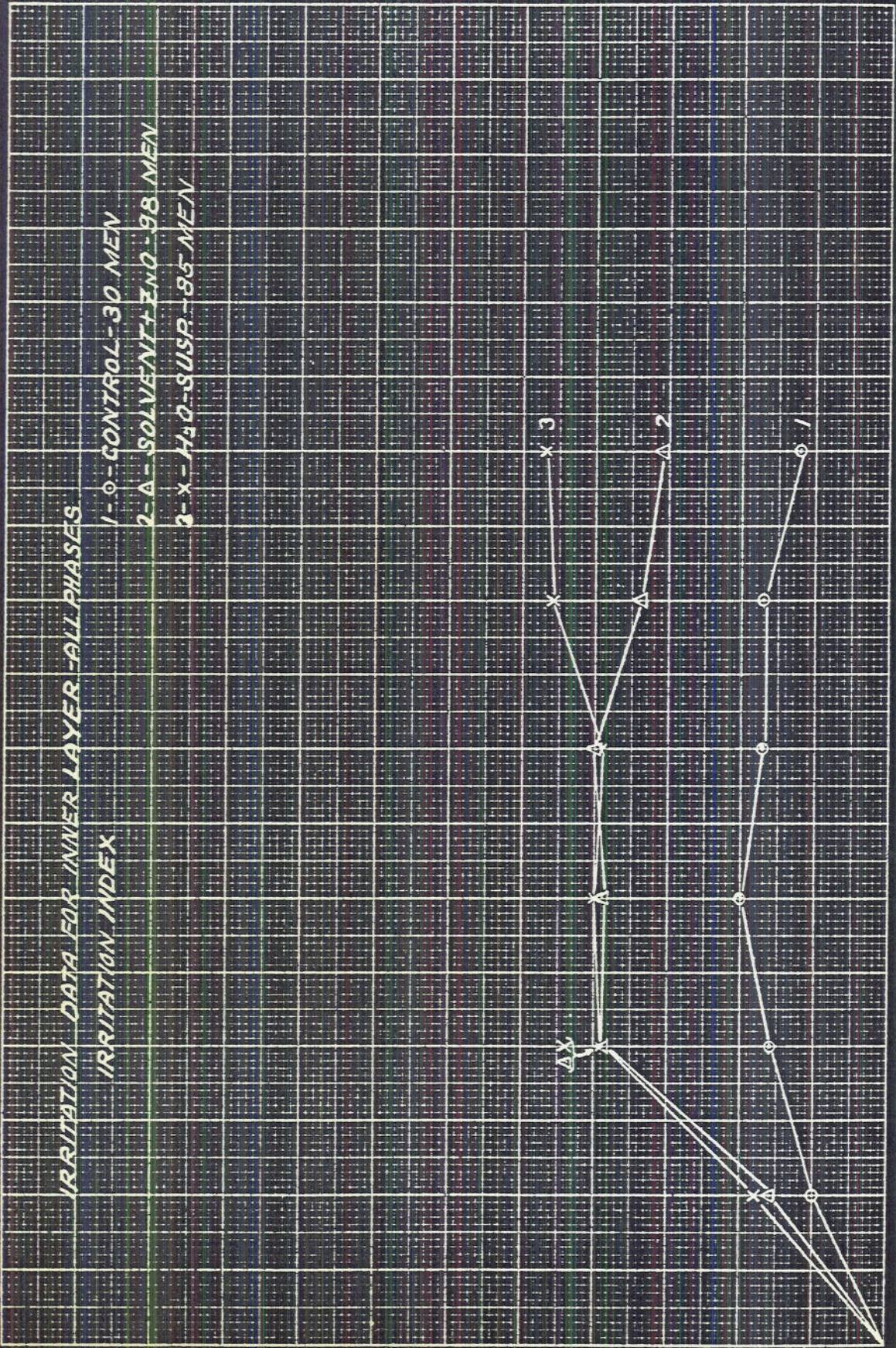
3-A - SOLVENT + ZnO - 64 MEN

4-X - H₂O - SUSP. - 74 MEN



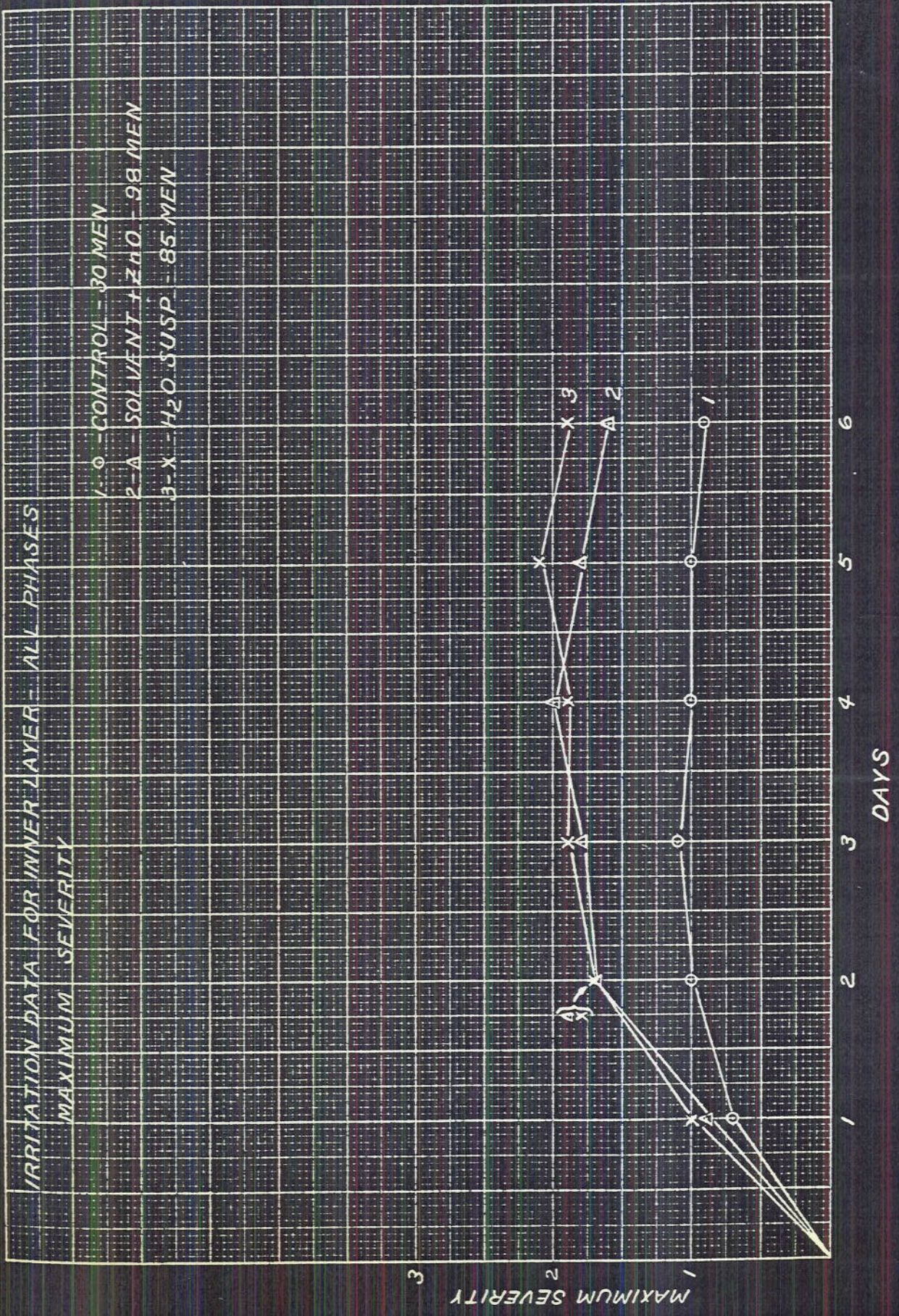
MAXIMUM SEVERITY

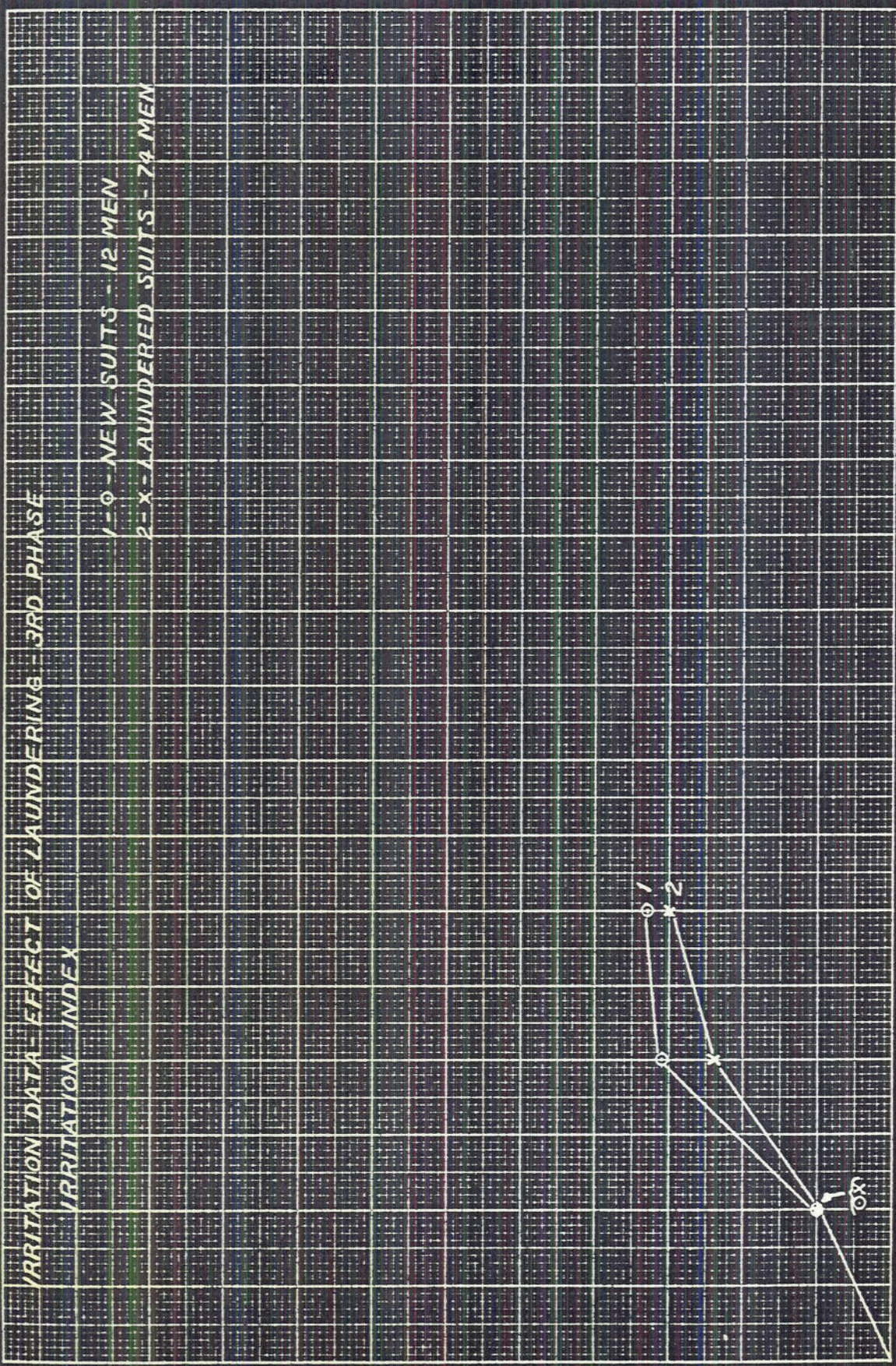
DAYS



DAYS

IRRITATION INDEX

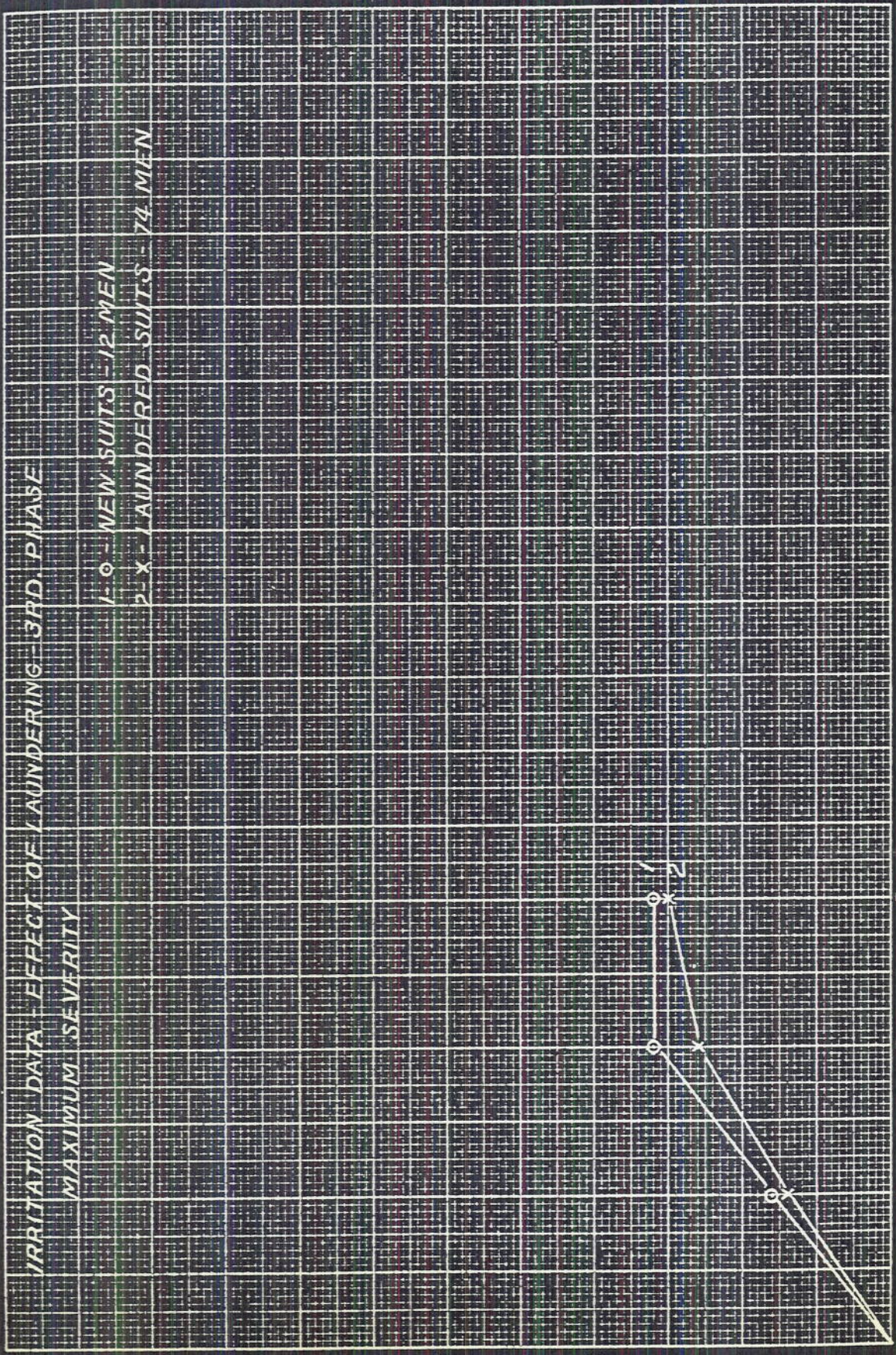




3
2
1
DAYS

IRRITATION INDEX

PLATE 16



IRRITATION DATA - EFFECT OF LAUNDERING - 3RD. PHASE

1-O - NEW SUITS - 12 MEN

2-X - LAUNDERED SUITS - 74 MEN

MAXIMUM SEVERITY

DAYS

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APPENDIX B

Active Chlorine Content and Tensile Strength of Clothing Before and After Wearing Trials

Table XX
Active Chlorine Content of Suits

Phase	Impreg. Type	Treatment	No. of suits Analyzed	Active Chlorine Content (mg./cm. ²)					Per cent Retention			
				shoulder	elbow	armpit	seat	knee		high Ave.	Orig.	
1	Solvent (plain)	soiled	2	.12	.12	.22	.23	.19	.23	.18	.37	49
		washed	3	.12	.12	.23	.26	.14	.16	.17	.37	46
1	Solvent + ZnO	soiled	3	.16	.10	.21	.16	.10	.24	.16	.39	41
		washed	3	.09	.11	.18	.16	.20	.17	.15	.39	38
1	Water-Suspension	soiled	5	.13	.22	.22	.18	.20	.33	.21	.65	32
		washed	6	.16(9)*	.26(9)	.34(9)	.21	.25	.30	.25	.65	38
2	Solvent (plain)	soiled	2	.08	.15	.09	.18	.12	.19	.14	.27	52
		soiled	4	.08	.14	.20	.14	.16(10)	.16	.15	.39	38
2	Water-susp.	soiled	4	.21	.29	.39	.26	.29(10)	.42	.31	.65	48
3	Solvent (plain)	soiled	4	.08	.07	.09	.05	.05(8)	.13	.08	.16	50
		soiled	2				.16	.21	.16	.18	.27	67
3	Solvent+ZnO	soiled	3	.03	.05	.11	.08(4)	.06(8)	.18(4)	.09	.15	69
		soiled	1	.21	.27	.19	.20(2)	.26(2)	.25(2)	.23	.39	59
3	Water-susp.	soiled	4	.08	.13	.15	.12	.11(8)	.27	.14	.25	56
		soiled	2				.27	.42	.47	.39	.65	60

*Numbers in parentheses refer to total number of samples taken.

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Table XXI

Tensile Strength of Suits

Phase	Type	Treatment	No. Tested	Tensile Strength(lbs)				% Retention
				Back	Seat	Ave.	Orig.	
1	Solvent (plain)	soiled	2	169	169	169	170	99
		washed	2	158	160	159	170	94
1	Solvent + ZnO	soiled	2	174	174	174	175	99
		washed	2	159	155	157	175	90
1	Water-suspension	soiled	2	174	169	172	175	98
		washed	2	171	159	165	175	94
2	Solvent (plain)	soiled	2	182	171	176	170	100
2	Solvent + ZnO	soiled	2	165	162	164	175	94
2	Water-suspension	soiled	2	162	162	162	175	93
3	Unimpregnated	soiled	2	165	151	158	160	99
3	Solvent (plain)	soiled	2	175	171	173	159	100
3	Solvent + ZnO	soiled	2	165	162	164	157	100
3	Water-suspension	soiled	2	176	169	173	165	100

Table XXII

Active Chlorine Content of Shorts

Phase	Type	Treatment	No. Analyzed	Mg. Cl ⁺ /cm. ²			% Retention	
				Thigh	Seat	Ave.		
1	Solvent + ZnO	soiled	5	.19	.22	.21	.42	50
		washed	5	.21	.20	.21	.42	50
1	Water-suspension	soiled	2	.37	.28	.33	.61	54
		washed	4	.29	.34	.32	.61	52
2	Solvent (plain)	soiled	5	.05	.03	.04	--	--
2	Solvent + ZnO	soiled	5	.00	.00	.00	--	0
2	Water-suspension	soiled	5	.26	.21	.24	.48	50
3	Solvent + ZnO	soiled	3	.22	.24	.23	.21	100
3	Water-suspension	soiled	4	.20	.16	.18	.32	56

* Original shorts not available for analysis.

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APPENDIX C

Physiological Readings of Men Exposed in Chamber

1. Table XXIII gives the complete physiological readings of the men exposed in the chamber. Readings were taken 24 hours after each exposure, and 48 and 72 hours after the last exposure. The total number of exposures for each man is also given.

The following abbreviations are used:

abd - abdomen	le - legs
ar - arms	ne - neck
ax - axillary folds	NPV - numerous pin-
cf - cubital fossa	point vesicles
d - dorsal	pig - pigmentation
E- - faint to mild	pop - popliteal space
- - erythema	r - right
E ^o - mild to moderate	sc - scapular region
erythema	scr - scrotum
E - moderate to	sh - shoulders
severe erythema	th - thorax
E+ - papular erythema	thi - thighs
el - elbows	v - ventral
kn - knees	V - vesicle
l - left	
lat - lateral	

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Table XXIII

Physiological Readings of Men Exposed in Chamber

Man	Readings 24 hrs. after Exposure No.	3	Readings after Last Exposure	72 hrs.
Suit Type No.	1	2	48 hrs.	
Solvent -- ZnO	1 E ^o sh, vth, ax, ar, cf; E+ sc, dth.		E ^o vth, cf; E sh, ar, ax, dth; E+ so.	Sick-bay.
	2 E ^o vth, ax, ar, rsh, dth; E lsh, sc.		E ^o latth, vth, ar; E rsh, sc, dth; V lsh.	Sick-bay.
	3 E- sh, ar; E ^o cf, ax; E+ latne, sc, dth.		E ^o sh, ar, el; E ne, cf, ax, sc, dth.	E- pop; E ^o ar, sh E cf, sc, dth, ne; V ne.
	4 E- cf; E ^o ne, sc, dth, ar.	E ^o ax, ar, le, pop; E ne, sc, dth	E ax, sh, ar, vth.	E ^o latth, pop, le; E cf, ar, ax, sh, sc, dth, ne.
	5 E- latth, abd; E ^o dth; E ar; E+ sh, sc.		E- latth; E ar, dth; E+ sh, sc; V rsh, rsc.	Sick-bay
Water- suspension	1 E- latne; E ^o sc, ar.	E- ax; E ^o ar; E rsc; E+ lsc.	E- cf; E ^o ar, sh; E sc; NPV lsc.	E- cf, latth, pop, le; E ^o ax; E ar, sh; E+ sc; V lsc.
	2 E ^o sh, ax, ar, sc.	E- ne; E ^o ax, vsh, sc, dth, thi, kn.	E- thi, le, scr; E ^o dth; E cf, ax, sh; E+ sc.	
	3 E- dth; E ^o latth, vth, cf; E ar, sh, sc		E sh, ar, latth E+ th.	E ar, th, sh, sc.

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Table XXIII continued--

Man Suit Type No.	Readings 24 hrs. after Exposure No. 1	2	3	Readings after Last Exposure 48 hrs. 72 hrs.
4	E- latth, E° cf, ar; E vsh, ax, sc, dth			E- thi, kn; E sh, ar, ax, lsc, dth, ol; E+ rsc. E+ rsc.
Control (New Suits) 1	E- sc, ar, sh.	E- sh, cf, th, scr; E° sc.	E- latth, ar; E° cf, sc, th, scr; E sh.	E- latth, sh, cf, ar, scr; E° vth, sc, dth.
2	E- lat ne; E° sh, ar, sc, dth.	E- thi, scr; E° ne, th, ar, sc; E sh, ax.		E- scr; E° ar, sh, vth, ; E° ne, cf, ar, sh, ax, pop, ne; E° sc, dth. E° sc, dth.
3	E- latth, cf, ar, sc, dth; E° ax.	E- sc, dth, ar; E° cf	E- thi, pop, scr; E° ax, ar, sc; E cf.	E- sh, thi, le, pop; E° ax (pig.); E cf.
4	E- sc, ar.	E- cf, sh, le; E° sc, dth.	E- ne, cf, ax; E° dth; E sc.	E- cf, sh, yth, ar, thi, le; E° sc, dth.

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