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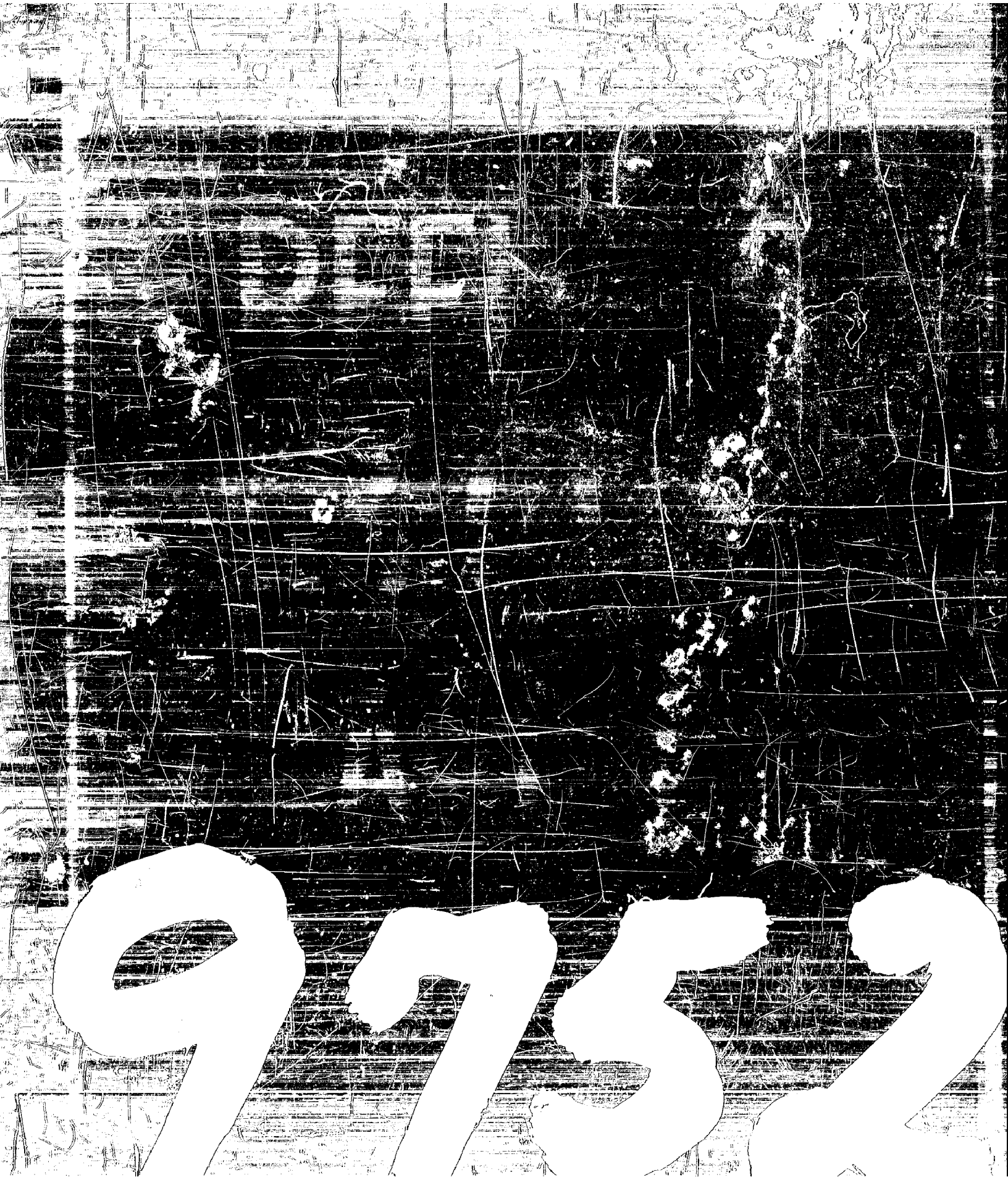

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S.P.C. Report
No. 197.
[illegible] July, 1950.

REPORT

to

ASSOCIATE COMMITTEE ON AVIATION MEDICAL RESEARCH

from

SUBCOMMITTEE ON PROTECTIVE CLOTHING

SUBJECT: Review of the work of the Subcommittee on Protective Clothing (1942-45), Associate Committee on Aviation Medical Research, National Research Council, Canada.

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[1] Working at the Banting and Best Department of Medical Research, University of Toronto, under a grant from the National Research Council of Canada.

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REFERENCE TO REPORTS OF THE ASSOCIATE COMMITTEE ON AVIATION MEDICAL RESEARCH AND OF ITS SUBCOMMITTEE ON PROTECTIVE CLOTHING

REFERENCE TO EXTERNAL LITERATURE 140

S-3039

28 July, 1945.

# REPORT

to

## ASSOCIATE COMMITTEE ON AVIATION MEDICAL RESEARCH

from

## SUBCOMMITTEE ON PROTECTIVE CLOTHING.

Subject: Review of the work of the Subcommittee on Protective Clothing (1942-45), Associate Committee on Aviation Medical Research, National Research Council, Canada.

Authors: J.A. Kitching and B. Fayd.

## SUMMARY


Purpose:

The purpose of this report is to describe concisely and to review the work of the Subcommittee on Protective Clothing, in order that a historical record may be available of the Subcommittee's work, that the scientific contributions of the Subcommittee may be made readily available to military and other national services, to whom the design of special protective clothing is of concern, and that the lessons learnt through the experiences of the Subcommittee as to the organization of this kind of work may not be forgotten.

Scope:

This report covers the origin, organization, and work of the Subcommittee on Protective Clothing, and other work begun shortly before the formation of the Subcommittee.

Conclusions:

(a) Organization: Until the beginning of 1942, work on protective clothing on behalf of the C.A.F. was [illegible] independently at R.C.A.F. Headquarters, the Spring and Best Department of Medical Research of the University of Toronto, and at No. 1 Clinical Investigation Unit, R.C.A.F.

The Subcommittee on Protective Clothing was formed in January, 1942, as a Subcommittee of the Associate Committee on Aviation Medical Research, to coordinate work in this field, and shortly afterwards under its auspices the work was [illegible] to the Ontario Research Foundation [illegible] Research Council Laboratories. The Subcommittee contained civilian and Air Force members, representing the various organizations participating in the work.

During the period 1942 to 1945, the Subcommittee on Protective Clothing undertook investigations of fundamental problems connected with clothing in the sphere of textiles and physiology, it undertook projects at the request of the [illegible] Flying Clothing Committee and Dress and Clothing Committee, for the development of equipment for use in the R.C.A.F. in Canada (both in training and in operational commands), and [illegible] Medical [illegible] at the disposal of the various authorized Scientific Bodies and [illegible].

The Subcommittee on Protective Clothing held thirty meetings during the period in question, in Ottawa and [illegible] Toronto. Guests attended from suitably accredited [illegible] institutions and military services. Minutes were [illegible] in which were specified the actions assigned to [illegible] for the continuation of the work. A high degree [illegible] was established and to this must be [illegible] much of the success that was achieved. Reports submitted to the Subcommittee were considered extremely [illegible], and amended or rejected when necessary, in order that the service committees for which the work was undertaken might be assured of reliable and authoritative advice.

During the course of the work many materials were tested in order that their suitability for incorporation into articles of clothing or other equipment might be determined. These tests were carried out at the National Research Council Laboratories and at the Ontario Research Foundation. A library of fabrics was maintained, in which [illegible] samples of all these fabrics and the results of the [illegible] on them.

The experience of the Subcommittee confirmed the importance of a knowledge of the service requirements and conditions for which an article of equipment was required. Lack of knowledge led to failures and waste of time in certain cases, while proper access to these conditions resulted [illegible] progress in other cases. This matter is of the greatest importance in the development of military equipment.

## (b) Properties of Fabrics and other Materials.

A series of tests was established for the assessment of fabrics. Although most of these were well recognized tests, certain important new tests had to be developed. It was confirmed that for the less dense fabrics the thermal insulation of fabrics is proportional to the thickness. This applies both to a single fabric under various compression loads and in the comparison of various different fabrics provided the bulk density is low. In the transfer of [illegible] through a fabric, the part played by conduction across or along the fibres was shown to be very small, nor was radiation considered a significant factor in view of the very large number of subdivisions of space effected by the fibres.

In view of the conclusion that thermal insulation depends on thickness, an extensive investigation was made of the thickness of pile fabrics and of their ability to retain their thickness under conditions of repeated compression [illegible] was developed by which it was possible to make an estimate of the effective thickness of a pile fabric, due account being taken of the repeated compressions which would be experienced in service. After a comparative examination of many types of pile fabrics made from wool, cotton, rayon and mohair, or mixtures of these, it was concluded that a double pile fabric made of wool was the best, although the possibility remained that the addition of mohair might be beneficial. The wool double pile fabric was improved in respect of lightness and pliability by reduction of the number of threads per inch in the ground to the minimum necessary to hold the pile. A test specially developed for this purpose indicated that the tuft binding power, though reduced, was still adequate.

A test method was developed by which for the first time it was possible to determine in common physical units the permeability of [illegible]. By means of air [illegible] experiments in which the air spaces between the [illegible] and the fabric, and the number of layers of fabric, were each varied in a controlled way, it was found possible to determine independently the resistance offered by the air space below the fabric, the fabric, and the air above the fabric. The results proved important in the design of tropical clothing and of flight exposure suits, and formed a basis for [illegible] the distribution of moisture in clothing. The test method was also applied to leather, and proved valuable in the interpretation of field tests on boots conducted by the Canadian Army.

In view of the loss to the Japanese of sources of Kapok, [illegible] used for life jackets, a study was made of possible substitutes. An attempt to make cotton

or wool buoyant by treatment with a water-repellent substance proved unsuccessful. It was shown that the [illegible] its buoyancy, much more readily on agitation than dry kapok, although under still conditions it gave good results. It was concluded that wool and cotton lack some property necessary for buoyant materials for life jackets. This property is probably the maintenance of rigidity under humid conditions. Milkweed floss was found to maintain excellent buoyancy even when [illegible]. Its optimal packing density was investigated, and its use for life jackets was recommended.

(c) Physiological Aspects of Clothing. In the early part of the war it was expected that protection against cold would be one of the most important problems in the design of clothing. Accordingly, a physiological method was developed by which the thermal insulation of clothing could be estimated from a consideration of the heat production, skin temperature, and loss of body heat of a subject sitting in the clothing in question under cold conditions. The results were corroborated by tests carried out with an 'artificial man' containing an electric heat [illegible] the air inside it. The amount of electricity needed over a given period [illegible] was used to determine the insulation of the clothing worn. [illegible] physiologically convenient [illegible] exchange [illegible] needs of electrical heating under [illegible] the exchange of heat under tropical conditions and under direct solar radiation.

An investigation was made of the distribution of [illegible] from various layers of the subject's clothing [illegible] temperature of the [illegible] and from the [illegible] humidity was estimated, and from this and the temperature the vapour pressure in equilibrium with the [illegible] deduced. The results are in accordance with theoretical expectations.

(d) Equipment Developed. The first project completed for the R.C.A.F. was the recommendation of characteristics of an aircrew suit of battledress style; this proved very satisfactory. A new design of flying glove, having fingers curved in the natural position of the hand at rest, was also accepted without delay and rapidly

produced and issued by the R.C.A.F. This was followed [illegible] suit (also immediately accepted) incorporating the double pile fabrics and constructed with the knees and elbows bent to suit a sitting man. An extensive programme of work for the improvement of this type E flying suit and its components was undertaken. This included the investigation of windbreak covering fabrics, with recommendation of a light material of high quality, the survey of the properties and weaknesses of slide fasteners, with completion of a specification of requirements, the investigation of double pile fabrics of many types, the development of an alternative lining fabric, the improvement of many features of style and construction, and the assessment of the reaction of aircrew to this suit by analysis of the results of a questionnaire.

A [illegible] out for the R.C.A.F. on electrically-heated clothing. This took the form of a lining worn as a separate garment under the flying suit. Two [illegible] numerous thermostats and the other controlled by a single master regulator of novel design placed in the cord. Electrically-heated undergloves and underboots were also specially developed. The second type of suit was accepted by the R.C.A.F. and produced for use by [illegible] crews.

An air heated undersuit was also developed, specially for use in the [illegible] air heating. This article did not receive any great encouragement and was never given service trials by the R.C.A.F., but was [illegible] (for [illegible] in [illegible]) by the [illegible].

The development of a new life jacket was undertaken for the R.C.A.F. [illegible] was obtained as to service requirements. Both an inflatable jacket and a jacket having permanent flotation [illegible] by a [illegible] were [illegible]. The inflatable jacket was found in service trials to be very acceptable to airdrew, and was accepted by the R.C.A.F. Flying Clothing Committee as the general type desired. However, the project was then removed from the Subcommittee by the R.C.A.F. without explanation. It appears that no definite policy as to service requirements was attained. The jacket with permanent flotation was further modified by the R.C.N. and issued by them in large numbers for operational use. The automatically flashing light, completed in cooperation with the R.C.N. and having a brighter flash and longer life than any sucer light of similar size, was also issued in quantity by the R.C.N.

It was purchased in small quantities by the R.C.A.F. but appears never to have been issued. Some of these flights were used (on a limited scale and for a special purpose) by the R.A.F. and are known to have proved valuable.

Development of a new flying boot free of rubber was initiated soon after the loss of rubber-producing areas to the Japanese. Service requirements remained in [illegible] for some time, and the boots eventually produced never received service trials. They would admittedly be expensive to manufacture.

A new flying goggle was developed, having very wide field of vision, with the transparent components all in one position and made of plastic. This goggle was produced and issued by the R.C.A.F., but was [illegible] abandoned in favour of a substantially similar goggle of improved design first produced in the United States.

A type of leather flying helmet was developed which was much more comfortable than the original R.C.A.F. issue, and which, after various modifications, provided as good exclusion of external noise. A mask helmet was also developed of similar style, and this was adopted by the R.C.A.F. and has become the regular helmet used in Canada.

An improved knitted underwear fabric was developed for aircrew use, but was not adopted by the [illegible]. It was clear that flying personnel were reluctant to change their underwear before a flight and would not be comfortable wearing winter underwear in a heated barracks.

The development of a 'flight exposure suit' was undertaken in January, 1944. This suit was intended for continuous wear during flight, and was to be capable of keeping out water from the underlying clothing in the event of immersion such as [illegible] or from bailing out into the sea. It was therefore considered necessary for the suit to exclude water and yet to permit the evaporation of sweat during flight. The first type was designed with a drawstring neck-closure. The upper half of the suit was made of a special fabric (of a type designed in England) which permitted the passage of water vapour while being fairly impermeable to water. Sufficient samples for service trials were available by August, 1944. [illegible] completion of the trials in February, [illegible] improved type of suit, with front closure by means of a slide fastener, was completed within a further month. [illegible] for limited production [illegible] valuable cooperation was received from the U.S. National Research Council throughout this work.

[illegible] 1945 [illegible] articles of tropical [illegible] was undertaken. These included a tropical uniform, cap, and boots. Tests were also carried out on an air conditioning belt fitted with a small blower. Even under [illegible] hot conditions imitative of aircraft parked in the sun, the circulation of environmental air within the clothing proved helpful provided that the shirt was first wetted to provide water for evaporation.

A very extensive programme was carried through for the development of emergency kits for aircrew in case of a forced abandonment of aircraft. A personal kit was developed very rapidly incorporating rations, medical aids, and other special emergency aids, all packed in a bandolier for wear by each member of aircrew. This development was followed by an aircraft kit of much larger size, which would be available in case of a forced landing, and of a sleeping bag kit, containing also extra clothing suitable for use in the bush in winter. Assistance was also given in connection with dinghy kits. All these kits were put into production and issued by the R.C.A.F. in the shortest possible time.

A special casualty bag was developed for the transport of wounded by air. This bag received very favourable comment in service trials, but has so far not been adopted. A solution was also found to the problem of protecting the distilled water in serum administration kits from freezing under cold conditions.

In October, 1943, an urgent request was received for the development of a waterproof ditching suit to be donned on 'ditching' as a protection against immersion and exposure. Prototypes were completed and were given sea trials off Halifax in November, 1943. The R.C.A.F. undertook production of the ditching suit (with certain modifications) and issued it to bomber reconnaissance aircraft on Atlantic patrols.

Research on the physiology of pressurized breathing and on the development of equipment for pressurized breathing for raising the physiological ceiling of fliers was carried out in conjunction with the Subcommittee on Oxygen and Intercommunication Equipment (National Research Council). Completion of the project was carried out by representatives of the National Research Council at the R.A.F. Physiological Laboratory, Farnborough, England. This equipment was accepted by the R.A.F. and was used on high altitude photographic reconnaissance operations over Europe. A film entitled "Boost for Breathing" was produced in which was explained the theory and use of pressurized breathing. This film was shown in England to medical officers and flying personnel concerned.

## ORGANIZATION OF THE SUBCOMMITTEE

### Origin and Terms of Reference

The Subcommittee on Protective Clothing was formed as a Subcommittee of the Associate Committee on Aviation Medical Research of the National Research Council, Ottawa, in February, 1944. The terms of reference (12th Executive Meeting of the Associate Committee on Aviation Medical Research) were as follows:

1. To co-ordinate existing work sponsored by the Associate Committee in relation to clothing;
2. To study the physical characteristics of available materials and all possible substitutes (fabrics, leathers, rubber and plastic goods), and to determine the [illegible] such materials or substitutes in clothing from a physiological and medical point of view;
3. The formation of a fabric library, testing materials according to their proper [illegible] availability;
4. To carry out research, development tests, etc., on all articles of clothing, if requested by the R.C.A.F. Flying Clothing Committee or the Dress and Clothing Committee;
5. To report to the National Research Council and R.C.A.F. on the results obtained in the research, development or testing of protective clothing.

The Subcommittee on Protective Clothing was a means whereby problems of the R.C.A.F. in protective clothing (including a wide range of personal equipment) could be presented as clearly as possible by responsible air force officers to the investigators who were to attempt their solution; whereby the problems and investigations could be discussed and criticized, and whereby the solutions obtained could be made known to the administrative officers concerned. In the Subcommittee, service and civilian research workers and officers from R.C.A.F. Headquarters (Ottawa) whose duty it was to advise the service or to make administrative decisions regarding the provisioning of personal equipment for use in Canada in the light of operational requirements.

The work of the Subcommittee consisted in the investigation of fundamental physiological and textile problems with a view to service application, and in the design and testing of articles of protective personal equipment for the air force. It was the particular function of the Subcommittee to present to the R.C.A.F. in Canada the information and the designs obtained by its efforts in an

[illegible] free from bias and uninfluenced by external pressure, so that executive decisions to be made by the air force regarding personal equipment could be securely founded.

The developments and the results of investigations [illegible] by the Subcommittee were made available to other interested allied services [illegible] in many cases investigations of widespread application were carried out. There was unfortunately no special connection with the R.C.A.F. overseas, except such as might be established temporarily by personal contacts and visits.

Members and Associated Workers

The membership of the Subcommittee is given in Table 1.

TABLE 1.

| Name | Representation and Date of Appointment | Address of Medical Subcommittee |
|---|---|---|
| G. E. Hall, G/C, Chairman | February 1942 - June 1945 | Medical Branch, R.C.A.F. Headquarters, Ottawa |
| H. C. Bazett | Feb. 1942 - July 1945 | Dept. of Medical Res. University of Toronto |
| A.C. Burton | Feb. 1942 - June 1945 | Dept. of Medical Res. University of Toronto. |
| Chairman, Associate Cities on Aviation Med. Research | [illegible] Graham, Mar. 1942 | Dept. of Medicine, University of Toronto. |
| C. E. Coles, S/L | October 1943 - June, 1945. | No. 1 Clinical Investig. Unit, Toronto, RCAF. |
| [illegible] Goodings | March 1942 - June, 1945. | Ontario Research Foundation |
| P. Larose | March 1942 - June, 1945. | National Research Council Laboratories. |
| R.C.A.F. Civilian Service Liaison Officer | P.W. Webb, W/C Feb. 1942 - Jan. 1944. M.L. Fawcett Feb. 1944 - June, 1945. | R.C.A.F. Headquarters Ottawa. |
| [illegible] Ferguson, W/C | October 1943 - June, 1945. | No. 1 Clinical Investigation Unit, Toronto, RCAF. |

[illegible] (Continued)

| Name | Representation and Dates of Membership | Place of work for Subcommittee |
|---|---|---|
| [illegible] Directorate of Aeronautical Engineering | W.J. Cunningham, S/L April 1942 May 1944. | R.C.A.F. Headquarters Ottawa |
| [illegible] Directorate of Aeronautical Engineering Director, Development of Equipment | [illegible], F/L Nov. 1942 - July 1944 N.F. Hoch, S/L Sept. 1944 June 1945. | R.C.A.F. Headquarters, Ottawa |
| [illegible] Directorate of Operational Requirements | M.M. Foss, W/C Oct 1943 - May 1944. G.F. Stevens, S/L July 1944-June 1945 M.J. Rotschild, F/L Nov. 1944-June 1945. G.R. Harland, F/L Feb 1945-June 1945. | R.C.A.F. Headquarters, Ottawa |
| R.C.A.F. No. 1 Clinical Investigation Unit, Medical Officer in Charge | R.C. Coles, W/C June 1942 - April 1944. C.B. Stewart, W/C May 1944 - June 1945. J.K.W. Ferguson, S/C June 1945. | No. 1 Clinical Investigation Unit, Toronto |
| [illegible] | Nov. 1942 Sept. 1944. | Department of Medical Research, University of Toronto. |
| M.O. Whillans, S/L | [illegible] | No. 1 Clinical Investigation Unit, Toronto. [illegible] |
| J.A. Kitching, Secretary | Feb. 1942 - June 1945 | Department of Medical Research, University of Toronto. |

[illegible] were [illegible] same numbers of service and civilian [illegible] cooperation between the two was extremely well [illegible] freely entertained on an equal footing [illegible].

The following were appointed as corresponding members for the period (May, 1944 to January 1945) during [illegible] were posted to the United Kingdom, in order [illegible] results of their observations might be available [illegible].

R. C. Coles, W/C
[illegible], S/L

Both were formerly at No. 1 Clinical Investigation Unit, R.C.A.F., Toronto.

A list of those who have assisted in the investigations of the Subcommittee, together with particulars as [illegible] civil occupations before the war, is given in [illegible] number of the workers were university teachers or research workers, chiefly in textiles [illegible] Nevertheless it is to be emphasized that a training in scientific methods of investigation in general was perhaps even more important than technical knowledge of physiology or textiles, since this enabled the investigators to tackle [illegible] and yet methodically problems which hitherto had [illegible] little scientific attention and which did not appear entirely to fall within the scope of any one particular subdivision of the sciences.

TABLE II

List of Workers Who Have Submitted Reports to the Subcommittee on Protective Clothing

| Name | Occupation before the war |
|---|---|
| Archer, A.C. (F/L) | Broker |
| Barett, H.C. | University teacher and research worker, Physiology. |
| Bentley, A.[illegible] | Research worker, Psychology. |
| [illegible], J.J. (F/L) | Medical Practioner. |
| [illegible], J.L. (F/L) | Medical intern at hospital. |
| [illegible], A.C. | University teacher and research worker, Physiology. |
| [illegible], E. (Miss) | Research worker, Textiles |
| [illegible], C.E. (S/L) | Research worker, textiles. |
| [illegible] (W/C) | Medical practioner. |
| [illegible] Williams, C. | Medical student. |
| [illegible], W.C. (F/L) | Engine [illegible] |
| Cunningham, W.J. (S/L) | Textile [illegible] agent |

| Name | Occupation before the war |
|---|---|
| Davis, R.C. (W/C) | Member in training for commission in R.C.A.F. |
| Duff, [illegible] | University teacher and research worker, Botany. |
| Emery, J.W. (W/O) | Market teacher, Physics. |
| Fennett, [illegible] | Textile manufacturing agent. |
| Ferguson, J.K.M. (W/C) | University teacher and research worker, Pharmacology and Physiology. |
| Fogg, [illegible] (W/C) | Business executive. |
| Fry, F.E.J. (S/L) | University teacher and research worker, Zoology. |
| Goodings, A.C. | Research worker, textiles. |
| Hall, R.M. (S/L) | Research worker, medicine. |
| Hart, J.S. (F/L) | Research worker, Zoology. |
| Hewson, D.T. (F/L) | Research worker, Bacteriology. |
| Hoch, W.P. (S/L) | Engineering [illegible] |
| Jones, [illegible] (F/L) | Industrial chemist. |
| Kark, R. (F/L) | Medical research worker. |
| Kitching, J.A. | University teacher and research worker, Zoology. |
| Kolesar, [illegible] | Student of Engineering. Ex-operational aircrew. |
| Larose, P. | Research worker, textiles. |
| Leibel, B. (F/L) | Medical practitioner. |
| Macdonald, [illegible] | Student in Physiology. |
| Rosaga, [illegible] | University teacher and research worker, [illegible] |
| Pagé, R. | [illegible] |
| Rankin, [illegible] (W/C) | [illegible] |
| Robinson, [illegible] | [illegible] |
| Rogers, [illegible] | [illegible] |
| Shortt, [illegible] | [illegible] |
| Smith, [illegible] | [illegible] |
| Stevens, [illegible] (S/L) | [illegible] |
| Stewart, [illegible] (W/C) | [illegible] |
| Thompson, J.E. | Research associate, Department of Medical Research, R.A.F.O.V. |
| Thomson, F.B. (F/L) | Research worker, Medicine. |
| Tudor, [illegible] | Medical intern at hospital. |
| Waters, E.T. (F/L) | Research worker, textiles. |
| Webb, P.W. (W/C) | University teacher and research worker, Physiology. |
| Williams, [illegible] (F/L) | Business executive. |
| Wrong, [illegible] | Medical (Consultant Embolist) Dermatological Specialist. |

- - - - - - - - - -

The office work of the Subcommittee was carried [illegible] Miss [illegible], while the laundry of fabrics was in charge of Miss [illegible], in the Department of Medical Research of the University of Toronto.

[illegible] the Subcommittee [illegible]

[illegible]ve clothing on behalf of the R.C.A.F. was [illegible] carried out in the Department of Medical Research of the University of Toronto, at No. 1 Clinical Investigation Unit (Toronto) of the R.C.A.F. and at R.C.A.F. Headquarters, Ottawa. Under the auspices of the Subcommittee [illegible] of work was extended to include the textile laboratories of the Ontario Research Foundation, Toronto, and National Research Council Laboratories, Ottawa. [illegible] the properties of textiles, and the [illegible] of textile materials and leathers for use in ar[illegible] of personal equipment, were carried on in the two [illegible] The work done at the Clinical Investigation Unit and in the Department of Medical Research consisted chiefly of the investigation of physiological problems and the design of equipment. The cold room [illegible] (installed by the National [illegible]) are located at No. 1 Clinical Investigation [illegible] work of the Subcommittee's representatives at [illegible] Headquarters was concerned both with the design [illegible] (particularly in the Directorate of Aeronautical Engineering), with the presentation of the Subcommittee's work to the appropriate service authorities, and with the provision of information as to service requirements. However it is not possible to delineate firmly the type of work done in each place, since there was considerable over-lapping. It is also of particular importance to note that, for the solution of any one problem or the development of any one piece of equipment, work was in general contributed by several or all of the institutions mentioned, so that none can claim exclusive [illegible] for a successful outcome. In the same way the [illegible] contributions of fundamental interest which have resulted from the Subcommittee's work are the results of the interplay of ideas. The work of the Subcommittee consists [illegible] of the collaborative effort of the various institutions and workers concerned.

## Meetings, Minutes and Reports

Meetings of the Subcommittee were usually held about once every six weeks, although there was no inflexible rule as to this. Alternate meetings were usually open to [illegible] and closed respectively. Closed meetings were [illegible] for the discussion of matters of local interest [illegible] concern only, while at open meetings it was [illegible] for topics of more general application to be presented. [illegible] meetings of the Subcommittee [illegible] in all [illegible] At the open meetings visitors [illegible] from a [illegible] of [illegible] accredited services [illegible], including the various armed services of

[illegible], the United Kingdom, [illegible]

[illegible] Research [illegible]

[illegible] until

[illegible] problem was followed by the allocation of [illegible] further action to carry [illegible] work towards completion. [illegible] that certain suitably qualified indi- [illegible] responsible to the Subcommittee for carrying [illegible] this procedure was followed through [illegible] the completed development [illegible] been handed over [illegible] all necessary information [illegible] the appropriate [illegible]

[illegible] minutes were prepared [illegible] taken by each [illegible] of [illegible] development [illegible] it the proceedings and discussion, both in order to provide a written record of matters of interest and in order to ensure that all statements presented at the meeting were made responsible by their authors, [illegible] knowledge that they would afterwards be quoted. The minutes (including reports) of each meeting were distributed to members, to authorised visitors, and to certain other services and institutions authorised to receive them by the Associate Committee. Reports were also printed in part or in full in the Minutes of the Associate Committee.

[illegible] reports by the various members of the Subcommittee and by associated workers were discussed very thoroughly and if necessary amended [illegible] with the consent of the authors before acceptance. For this purpose they had to be [illegible] mitted to the Secretary in time to be distributed to members for reading in advance of the meeting. After acceptance by the Subcommittee they were submitted to the Associate Committee in the names of their authors but with the backing [illegible] of the Subcommittee behind them. In practice [illegible] every case possible to reach agreement on reports. [illegible] there was very considerable debate, criticism were offered freely, and reports were not infrequently referred back to the authors for revision or [illegible] this way the accuracy and independence of the reporting of data was maintained, and the R.C.A.F. [illegible] consideration [illegible] persons who had given knowledge [illegible] were supposed to [illegible] investigation.

Relations with other Committees

[illegible] parent Associate Committee [illegible] Subcommittee were addressed [illegible] requirements were received from the R.C.A.F. Flying [illegible]

[illegible] Committee on Protective Equipment was [illegible] investigations were undertaken for the [illegible] committee also. It should be noted that through this last [illegible] carried out in the first [illegible] Subcommittee on Protective Clothing on behalf of the Air Force was applied for the other armed services.

However, it was not necessary for the initiation of a formal request be received from a [illegible] Committee. Actually, as might be expected, the important contributions of the Subcommittee were [illegible] individual members or groups, and only excited [illegible] the Subcommittee after they had reached a [illegible] stage of development. Every effort was made by the Subcommittee to anticipate service requirements, [illegible] when such requirements were made known there was usually little time left for the proper development of an [illegible]

## Relations with Industry

[illegible] in the Subcommittee's [illegible] of work were not suitable for the construction of many types of equipment required to be developed by the [illegible] It was usually necessary that much development work should be undertaken in factories having the [illegible] experienced personnel and equipment. Fortunately [illegible] cooperation was obtained from business [illegible] only limit to what could be achieved was not by the scarcity of man power or facilities resulting from a great quantity of urgent government orders of many kinds. As far as possible the Subcommittee endeavoured to see the work carried out on its behalf, but it is to be [illegible] that the nominal expenses often charged could not in many cases repay the time spent by skilled designers in attempting to solve unconventional problems. In some cases [illegible] declined to accept payment for [illegible] development, even though it was always made clear at the [illegible] the Subcommittee had no authority over the [illegible] which might ensue. It was inevitable [illegible] be collaborated chiefly with firms whose [illegible] were not too far distant from the Subcommittee's [illegible] work. It was in some cases a disadvantage that Canadian companies were associated with much bigger parent companies in the United States, since in these cases the [illegible] industrial research is usually restricted to the [illegible]

[illegible] of many individual employees [illegible] is also greatly to be appreciated.

## Service Requirements

[illegible] most important and yet most difficult requisite for the carrying out of useful work is the provi[illegible] a proper understanding of service requirements and conditions to the investigator. Failure to obtain [illegible] results [illegible] a waste of time in the research laboratory and in the factory, and the good will [illegible] personnel [illegible] be jeopardised. Before [illegible] of the Subcommittee much work was carried out without any knowledge of service requirements. The [illegible] on flying clothing [illegible] was circulated and [illegible] A.F. Flying Clothing Committee early in 1942 did much to clarify the general position. Nevertheless it did not and could not provide complete information as to requirements; nor could the view be accepted [illegible] qualification that what members of aircrew think [illegible] is necessarily what is best for them. It also [illegible] realize (meeting 20) that it must insist on full information as to service requirements before [illegible] an investigation. (This [illegible] history of the work on life jackets and flying boots.) Besides all this, the experiences of [illegible] confirmed the view, held from the [illegible] workers, that it is quite impossible for an administrative officer, however efficient, to set forth [illegible] fully the service requirements for an [illegible] developed. Personal contact with men of operational experience was found to be essential in every [illegible] and in many cases it was necessary for the research [illegible] field conditions for himself. The preliminary [illegible] field conditions of equipment in the course of development [illegible] also found to be important. [illegible] that this equipment might be as complete as possible when [illegible] were accorded. All this, incidentally, was also found to lend a keenness to the progress of investigations which could not have been obtained in any other way. The lack of adequate facilities for this purpose was a severe handicap on the early work of the Subcommittee.

Appointment, in October, 1943, of a representative [illegible] Operational Requirements [illegible] Committee did much to rectify [illegible] and through the fact [illegible] of the Flying [illegible] Committee many visits were made to the field both [illegible] by civilian workers of the Subcommittee. [illegible] Flying Clothing Committee at service trials conducted by that Committee proved to be a most useful means of enabling the investigator to see what im[illegible] experience [illegible] equipment, and incidentally [illegible] experience was afforded by visits of members to [illegible] Air Commands (Canada) [illegible] Cold [illegible] Army Air Force fields in the [illegible] to the [illegible] A.F. [illegible] Physiological [illegible]

[illegible] to the R.C.A.F. in the United [illegible] it should be pointed out that these visits in [illegible] encroached on the essential and most valuable work of those officers whose duty it was to ascertain operation [illegible] requirements, but did enable research workers to study [illegible] equipment [illegible] already been indicated through the more formal channels. The provision of facilities for field visits [illegible] investigators and the close cooperation of the Directorate of Operational Requirements enabled certain important [illegible] of equipment to be developed with a speed which [illegible] could in no way have been approached. In spite of all this, a need for better contact with field conditions [illegible] throughout the Subcommittee's work. It seems in particular undesirable that a special occasion should have [illegible] made of [illegible] the provision of an Anson aircraft to No. 1 Clinical Investigation Unit, [illegible] useful for testing equipment, could in no way replace such visits.

## Prototypes, Service Trials, Specification and Production

On completion of a development, it was customary for the Subcommittee to prepare a small number of prototypes of the article concerned and to submit these to the Flying Clothing Committee or Dress and Clothing Committee of the R.C.A.F., together with a report explaining the construction, methods of use, and performance under laboratory [illegible] the equipment in question. The fact that several members of the Subcommittee also attended the meetings of the R.C.A.F. Flying Clothing or Dress and Clothing Committees enabled the Subcommittee's work to be presented the more easily.

In cases [illegible] requested these were authorized and supervised by the R.C.A.F. Flying Clothing Committee. It was usual for the Subcommittee to [illegible] questionnaires for use at the service trials, and as already stated, it was sometimes deemed desirable by [illegible] Clothing Committee that a member of the Subcommittee should attend the trials. It was found that a member attending in this way was able to assist very materially in ensuring that questionnaires were answered carefully and seriously. The answers to questionnaires were usually sent to the Subcommittee for analysis in order [illegible] could be determined before the specifications were drawn up.

As a result of experience it was found necessary [illegible] individuals who had been most con[illegible] [illegible] heavily in the preparation of the specifications. Accordingly it

[illegible] the practice for draft specifications [illegible] Subcommittee for the two service committees [illegible] The draft specifications [illegible] all the provisions which those responsible for development considered necessary to ensure that the articles in question would be manufactured [illegible] performance of the [illegible] than on the method of manufacture. The draft specifications were then converted to the proper form under [illegible] by those officers knowledgeable in such matters, still in cooperation with the Subcommittee.

Nominally the Subcommittee's responsibility ended with the completion of draft specifications. In the case of the more simple articles, it was possible for the [illegible] to consider their job finished at [illegible] point. More usually, assistance was required for modifications during production and for inspection, and this was [illegible] by the Subcommittee at the request of those branches of [illegible] responsible. In this respect excellent [illegible] Directorate of Aeronautical Inspection, which both assisted the Subcommittee in obtaining services required by it for development and received assistance from it with respect to production and inspection.

In the case of one entirely novel article of equipment it was necessary for the development to be completed in accordance with operational needs in close touch with operational pilots, and finally for this equipment to be introduced [illegible] the officers in charge of operations and the pilots who used it (page 125). In this particular case only a close cooperation between research workers and pilots made the successful completion of the development possible. Finally, the initial production [illegible] Council, [illegible] Aeronautical Inspection [illegible].

A few instances have arisen in which an article did not receive service trials when its development had been completed, because of a lack of immediate need. However, additional prototypes were required long afterwards for trials, because of renewed service interest. It then proved difficult to assemble a sufficient number of prototypes, since materials [illegible] available and the research and factory workers [illegible] in testing of air-heated suits (page [illegible]) [illegible] for the failure of the [illegible] for use in flying clothing to meet service requirements (page 105). In the latter case, difficulties in manufacture of additional prototypes resulted in an inferior product. This situation [illegible] be avoided by the purchase of a reasonable number of prototypes [illegible] development is completed and preliminary testing has shown it to be promising.

## [illegible] OF MATERIALS USED IN CLOTHING

[illegible]

At the first meeting of the Subcommittee it [illegible] that a system of testing of fabrics and [illegible] other materials should be set up, so that the most suitable materials could be selected for the construction of articles of protective clothing. This project was [illegible] especially by those R.C.A.F. Officers who were responsible for the provision of service clothing. In some cases it was [illegible] adopt standard tests [illegible] in others it was necessary to devise new [illegible] Chairman a system of rating was also [illegible] fabric in respect of some particular property could be expressed simply on a decile [illegible] members [illegible] express the results of tests in a manner intelligible [illegible] with [illegible] methods. However, in spite of pressure from members of R.C.A.F. Headquarters, it was also concluded [illegible] it was not possible to combine the [illegible] of different tests carried out on a fabric sample in such a way as to express the serviceability of the fabric by any kind of single comprehensive rating or [illegible] assessing the usefulness of a fabric for a particular purpose, it was necessary to consider the results of each of the appropriate tests independently.

A series of tests for fabrics was compiled [illegible] the validity and usefulness of the latter. [illegible] an index representa[illegible] [illegible] of thickness and [illegible] methods of measurement of [illegible] were investigated and compared (02410). A method [illegible] was [illegible] for the first time for the evaluation in common [illegible] permeability [illegible] fabrics, leather, [illegible] materials. Considerations [illegible] of overall [illegible] under which [illegible] it was concluded that for the [illegible] [illegible] the results of a number of different tests carried [illegible] the [illegible] [illegible] was developed [illegible] for the buoyancy of filling materials for life jackets [illegible]

Figure 1

## FABRIC TESTS

[illegible] to be supplied with sample:

| | |
|---|---|
| MANUFACTURERS: | MANUFACTURERS' NO. [illegible] |
| POSSIBLE USE | FIBRE TYPES COLOR |

[illegible] AND ADDITIONAL INFORMATION

[illegible] (mark appropriate tests)

| | |
|---|---|
| [illegible] RESISTANCE | * CREASE RECOVERY |
| * AIR PERMEABILITY | * EXTENSION AT BREAK |
| * TAKING STRENGTH | * FLAME PROOFNESS |
| * BURSTING STRENGTH | * FLASH RESISTANCE |
| [illegible] | * HYDROSTATIC RESISTANCE |
| [illegible] | [illegible] * PLIABILITY |
| [illegible] | * Laundering * SHRINKAGE |
| [illegible] | 1- On wetting 2- On laundering |
| * [illegible] | * SLIPPERINESS |
| * CONSTRUCTION | * TEAR RESISTANCE |
| Types of fibre | * THERMAL INSULATION |
| [illegible] | * [illegible] |
| Overall | * TUFT BINDING POWER |
| [illegible] | * [illegible] REPELLENCY |
| [illegible] | * [illegible] PERMEABILITY |
| [illegible] | * YARN SLIPPAGE |
| [illegible] | Date received by Secretary: |
| [illegible] | |

The burden of routine testing of fabrics and other materials was divided between the National Research Council Laboratories and the Ontario Research Foundation. Some work on leathers was also done at the Ontario Research Foundation, although no extensive program was carried out on these materials. Since the Sub-committee was rarely concerned with leather articles, work with plastics was for the most part restricted to plastic-coated fabrics.

The submission of fabrics for testing and the recording of results followed an organized routine. Samples of a size sufficient for testing were submitted to the Secretary together with the appropriate form (Figure 1) indicating the proposed use of the fabric and the tests desired. A part of each sample was retained by the Secretary for record purposes, and the remainder was forwarded to the test laboratories (National Research Council Laboratories and/or Ontario Research Foundation) together with copies of the test form. Completion of the tests requested was subject to the discretion of the testing investigator and the Secretary, and unnecessary tests were avoided if a fabric was found in some respect to be hopelessly unsuitable. Copies of the test reports were forwarded by the Secretary to the investigator who had requested the tests. The test results, together with all other data relative to identification of the fabric, were entered on a library card (Figures 2 and 3) on which was also fastened a 6" x 6" sample of the fabric. The library card was prepared in [illegible] copies of the fabric library were maintained in the Secretary's office in the Department of Medical Research, University of Toronto, at No. 1 Clinical Investigation Unit, R.C.A.F. (Toronto), and at R.C.A.F. Headquarters [illegible] under the care of the Civilian-Service Liaison Officer).

During the course of the development of tests, a considerable amount of work of a fundamental nature was done on the properties of fabrics. The relative importance of conduction, convection, and radiation in the transmission of heat through fabrics, and the possibility of obtaining [illegible] of the use of reflecting surfaces were [illegible] (C2461). A fundamental experiment was carried [illegible] relation of thickness and thermal insulation (C2460), [illegible] were also made on the effect of air movement on the thermal insulation of combinations of fabrics (C2411, C2614), the effects of moisture on the thickness and compressibility of pile fabrics (C2498, C2654), and the compressibility of pile fabrics made from various types and [illegible] (C2337, C2406, C2407, C2[illegible]). All these results contributed to the design of the pile linings of [illegible] of water vapour [illegible] (C2555), and [illegible] were applied to the development and evaluation of

[illegible] of vapour permeable fabrics for exposure suits. The work was extended to cover the effect of oil content on the permeability of leather to water vapour (C2724). The rate of drying of fabrics with various initial moisture contents was investigated; it was shown that the type of fibre might be important under certain circumstances (C2[illegible]). An unsuccessful attempt was made to render cotton or wool buoyant by means of water repellents (C2315, C2319, C2445). An extensive investigation followed of the properties required for buoyancy in filling materials for life jackets. It appeared that wool and cotton lack certain properties which a buoyant fibre mass must possess if it is to form a satisfactory filler (C2446). A number of different kinds of animal and vegetable fibres were examined, [illegible] flock was selected as a suitable substitute for kapok (C2490, C2345, C2414, C2752).

## Tests Used for the Evaluation of Fabrics

### Introductory Note

In view of the urgency of military requirements, it was not possible for the Subcommittee to develop a complete range of tests the applicability of which was thoroughly understood and assured. Nor was any opportunity given to the Subcommittee of comparing the evaluation of fabrics based on laboratory tests with the usefulness of fabrics as proven in service use. There is no doubt that many comparisons of this sort will have to be made before the reliability of various laboratory tests can be established and a means of applying them can be thoroughly understood. This point of view has been clearly put forward by Peirce (1937). In particular, it seems clear that the interpretation of tests such as breaking strength, tear resistance, abrasion resistance, etc., such as are now used for the evaluation of coverall fabrics, will remain fraught with uncertainty until a parallel investigation has been made on serviceability in the field and on performance in the laboratory. Therefore, faced with urgency, the Subcommittee took the best tests it could find and invented some new ones when that was necessary. The various tests used are described fully in a special report on the subject (C2419). A list follows:

| Test | Reference to Description |
|---|---|
| Air permeability | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, [illegible], or A.S.T.M. Standards on Textile Materials. |

Fig. 1 left
Fabric library ca
front x 1/2 lore

Fig. 2 (right)
Fabric library ca
back. (x 1/2 lore

| Test | Reference to Description |
| --- | --- |
| Breaking strength grab test | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, or A.S.T.M. Standards on Textile Materials. |
| Bursting strength Mullen Burst Tester | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944. |
| Compressibility | See page 09, also Reports Nos. 02665, C2607. |
| Cuprammonium fluidity | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, and A.S.T.M. Standards on Textile Materials. |
| Colour fastness effect of<br>a. light<br>b. perspiration<br>c. laundering<br>d. salt water<br>e. dry cleaning | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, and U.S. Department of Commerce. Commercial Standard CS 59-41. |
| Extensibility<br>a. grab test for woven fabrics<br>b. Mullen tester for knitted fabrics. | See Report No. C2419 |
| Flameproofness: vertical burning test | See Report No. C2419. Also Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, and A.S.T.M. Standards on Textile Materials |
| Flash Resistance | See pages 34 and 35, also Reports Nos. C2666, C2419. |
| Non-fibrous Materials | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, and A.S.T.M. Standards on Textile Materials. |

| Test | Reference to Description |
|---|---|
| [illegible] | Journal of Research of the National Bureau of Standards, Vol. 10, 1933. |
| [illegible] thick fabric | See Report No. C2419. |
| [illegible] | See Report No. C2419 |
| [illegible] Abrasion Test Meter | See Report No. C2419. |
| [illegible] to Yarn Pulls | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944, and A.S.T.M. Standards on Textile Materials |
| [illegible] on wetting | Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944. |
| [illegible] to laundering fabrics | See Report No. C2419. |
| Slipperiness of lining fabrics | See page 37, also Report No. C2569. |
| Snag Resistance; appraisal | See Report No. C2344. |
| Tear resistance; tongue method | A.S.T.M. Standards on Textile Materials; also Canadian Government Purchasing Standards- Schedule of Methods of Testing Textiles, 4-GP-2-1944. |
| Thermal insulation | See page 17, also Report No. C2410 |
| [illegible] | See Report No. C2[illegible], also page [illegible] |
| [illegible] binding power of [illegible] | See Report No. C2[illegible], also page 31. |
| [illegible] a. hydrostatic test b. drop test | A.S.T.M. Standards on Textile Materials Modification of A.S.T.M. test. See Report No. C2419. |

Tests specially developed or modified by the Subcommittee described in the succeeding sections, and fundamental observations from the testing programme are also discussed

## Thermal Insulation

### Scope and Validity of Measurements

Thermal insulation is the resistance offered to the flow of heat, as for instance the resistance offered by clothing to the escape of heat through it from the [illegible] to the [illegible] unfortunately. In the case of clothing it is not possible to characterize the thermal insulation by a fixed value [illegible] all conditions of wear. It may be affected considerably by such factors as the movement, air spaces between layers of clothing, whether arising from wind or from the movements of the wearer, moisture due for [illegible] to rain [illegible] fabric, such as may [illegible] locally under the seat and [illegible] if the wearer is sitting. However, for the evaluation of certain types of clothing, such as flying suits, to be worn [illegible] conditions it has been possible [illegible] evaluation of the thermal insulation both of whole [illegible] fabrics [illegible] conditions. This section deals with the thermal insulation of fabrics used in clothing; the physiological aspects of the [illegible] insulation [illegible] on pages 43 [illegible]

Measurement of thermal insulation is based [illegible] relation

$$\text{[illegible] insulation} = \frac{\text{Difference of temperature}}{\text{Heat flow per unit area}}$$

[illegible] there is a clear analogy with Ohm's law. Just as in [illegible] it is much more convenient (C2035) [illegible] thermal resistance (insulation) than of conductivity (when a number of layers of insulating material are placed between the source and destination of heat, the retarding effect of [illegible] resistances is additive, just as for electrical resistance impeding the flow of electricity;

$$\text{[illegible] area} = \frac{\text{Difference of temperature}}{I_1 + I_2 + I_3 \text{ etc}}$$

[illegible] thermal resistances [illegible] to forete[illegible] a particular fabric to the thermal [illegible] clothing into which it is to be [illegible] In practical application it is necessary for the thermal insulation of the fabric to be measured [illegible] conditions [illegible] experienced in [illegible] to have information [illegible] conditions [illegible] be [illegible]

[illegible] to penetration by wind [illegible]

[illegible] it has [illegible] fabrics under conditions of [illegible] support of this belief may be [illegible] the results obtained [illegible] with four different pile [illegible] tested on men in [illegible] physiologically, the order of ax- [illegible] linear [illegible] measure. For a detailed analysis of the insulation contributed by each part of the clothing it is necessary to know the thickness of the air spaces between [illegible] since these also add to the thermal insulation. Recent work in the United States [illegible] suggests that [illegible] of the clothing [illegible] fabrics and the air spaces within [illegible] close accordance with those de- [illegible] means.

[illegible]

The thermal insulation of fabrics is normally determined from the rate of flow of heat from a metal plate [illegible] fabric specimen to another overlying plate (or [illegible] and from the difference of [illegible] between the two sides of the fabric. The equipment (for textile materials) (C2410) in use at the National [illegible] ington. The brass plate below [illegible] is heated electrically with known power. The ea- [illegible] from the edges of lower side of this lower plate is prevented by means of corresponding guard plates heated to the same temperature as it. Therefore all the heat lost from the [illegible] passes through [illegible] temperature on the two sides of [illegible] with thermocouples after sufficient time has elapsed for the temperature conditions in the apparatus to have become steady. Both the upper and the lower plates [illegible] avoid reflection since the surface of the [illegible] reflecting [illegible] surfaces would lead to a [illegible] thermal insulation of fabrics [illegible] with the use of a loading [illegible] of the fabric specimen.

Some tests have also been made with another [illegible] apparatus (C2410). In this the flow of heat takes place through a glass plate of known insulating

[illegible] through the test specimen over-lying it [illegible] difference of temperature on the two sides of [illegible] plate [illegible] from [illegible] thermal insulation, [illegible] through the glass plate is determined. This heat flow is assumed to be identical, from the experimental arrangement, with that through the test sample. From this and from the difference of temperature between the two sides of the test sample, the thermal insulation of the latter is then [illegible].

Experience (C2410) resulting from the testing of numerous samples has shown the importance of very thorough precautions to prevent loss of heat by ways other than through the test sample. The second apparatus described above was rather too small (7 inches in diameter, including the guard ring), so that the ratio of edge to central area was high. As a result, a small loss of heat from the sides introduced a serious error in the estimation of the heat flow through the test fabric. Much more satisfactory results were got with the N.R.C. apparatus [illegible] measures 13 inches square, including the guard plate).

The results of [illegible] of thermal insulation may be expressed in British thermal units or in [illegible] In the evaluation of clothing a new unit, [illegible] has been defined (Gagge, Burton and Bazett, [illegible] page 4[illegible]). It has been found convenient to use [illegible] also for the expression of the thermal insulation of fabrics. The thermal insulation of 1 cm. of ideal still air (see below) may also be used as a unit. The following are the conversion factors:

$$1\ \text{Clo} = 0.88\ \frac{\text{A.F.}}{\text{B.T.U./Hr./Sq.Ft.}} = 0.18\ \frac{\text{Cg.}}{\text{Gals/Hr./Sq.F}} =$$

0.5[illegible] cm. of ideal still air.

## [illegible] Plate Method

As already indicated above, for measurement of thermal insulation the fabric sample may either be [illegible] upper plate or left open to the air. The results [illegible] with [illegible] the methods are widely different (C2410). [illegible] (closed) method is [illegible] to the evaluation of flying suit interlinings (such as the pile fabrics), which are used under what amounts [illegible] conditions. On the other hand, the open method might be considered more [illegible] the evaluation of fur as used in fur coats, [illegible] the hair facing outwards. The insulation of an outward-

[illegible] by wind and sometimes [illegible] by convection currents [illegible] the pile (Cross). [illegible] Type B (Tandy Bear) [illegible] coverall) which have a 1/2" pile facing outwards. When these were worn with the pile facing [illegible] thermal insulation (as measured [illegible]) [illegible] Addition of a very light [illegible] pile had a similar beneficial effect.

There is a further important difference between [illegible] when the open method is used, [illegible] temperature is usually measured, not immediately on [illegible] side of the fabric sample, but immediately on the [illegible] in the room air at some distance [illegible] this case the [illegible] immediately overlying the [illegible] contributes to the estimated insulation (C2836). [illegible] it is desired to determine how much of the observed [illegible] a standard [illegible] in the room, [illegible] deducted from the observed total (see page 50). [illegible] this procedure may lead to an appreciable error [illegible] degrees of air movement, since under such conditions [illegible] of air movement results [illegible] of the air.

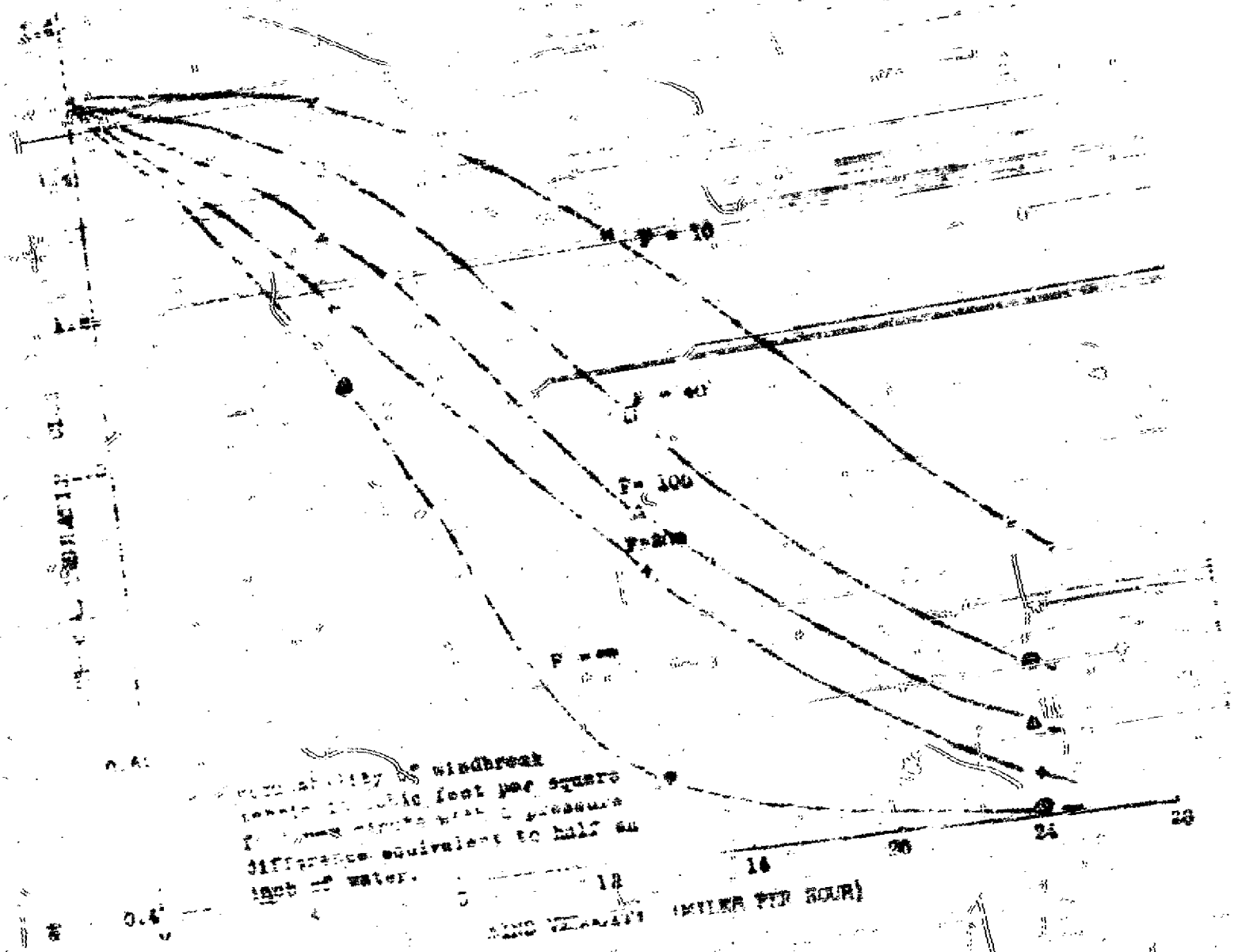
[illegible]

[illegible] above, the thermal insulation [illegible] protecting a clothed man is reduced by air movement. The [illegible] air layer immediately outside the [illegible] that its insulation is impaired, and the insulation of the [illegible] is reduced if the wind penetrates it. [illegible] been carried out (C2811, C2811) on the effect [illegible] air movement on the thermal insulation of pile fabrics [illegible] fabrics of varying permeability to air. These tests were of course done by the open method, and a correction has been made for the thermal insulation of the [illegible] so that the results given below are for the [illegible]. A stream of air was directed [illegible] by means of a fan. The velocity of air movement was controlled with diaphragms [illegible] fan. The velocity of air movement [illegible] measured in three ways [illegible] with a vane anemometer, and [illegible] pressure [illegible] at the fabric surface. Good [illegible] was obtained. The last method seems to be the most convincing in that it represents conditions at the [illegible] and not [illegible] a little distance away.

[illegible] (C2811) got with the wind directed [illegible] the surfaces of the fabrics [illegible]

FIGURE 4

Thermal Insulation of Combination of Coverall Fabric and Double Pile Fabric Beneath it with Various Degrees of Air Movement and Various Permeabilities to Air of Coverall Fabric.




Permeability of windbreak fabric in cubic feet per square foot per minute with a pressure difference equivalent to half an inch of water.

[illegible] very small. It is of little consequence [illegible] the much larger loss in insulation of the overlying air due to air movement. This [illegible] (C2411) has been confirmed by the U.S. War Department's Climatic Research Laboratory. For higher [illegible] velocities there is a much greater advantage in a high degree of impermeability to air. This is illustrated [illegible] the exact figures of which apply of course only to the fabrics used for the tests.

TABLE III

Pile fabric (0.45" thick at 0.1 lb./sq.in.), with overlying coverall fabric having a permeability to air of 10 cu.ft./sq.ft./min. ½" water difference of air pressure

| | "Still" conditions | 8 m.p.h. | 24 m.p.h. |
|---|---|---|---|
| Thermal insulation of fabric (Clo) | 1.60 | 1.43 | 0.80 |
| Thermal insulation [illegible] | [illegible] | [illegible] | [illegible] |
| Total insulation (fabric + outside air) (Clo) | 2.30 | 1.70 | 0.95 |
| [illegible] loss due to wind penetration | - | 2% | 30% |

[illegible] results may be regarded as applicable to other fabrics of approximately the same characteristics. The presence of other fabrics or air spaces (as in clothing) underneath the pile fabric might to some slight extent modify the results. In any case, it must be remembered that in clothing the shape of the exposed surface is different from the flat surface used in laboratory tests, and part of this surface will be on the side sheltered from the wind, so that the effect of air movement may well be less. The loss of insulation due to wind penetration is considerably less when the angle between the direction of the wind and the surface of the fabric is less than 90° (C2631).

Transmission of heat through fabrics

[illegible] of heat through a fabric must [illegible] radiation [illegible] and conduction. An analysis (C2464) has been made of the relative importance of [illegible] in order that the possibilities of improving the design of existing fabrics might be explored.

[illegible] evidence (C2464) to indicate that conduction by the [illegible] plays an insignificant [illegible] of heat through the best insulating fabrics used in clothing. Speakman and Chamberlain (1930) [illegible] for the least dense fabrics, further reduction in density does [illegible] the [illegible] The

[illegible] fabric used for [illegible] suits is extremely [illegible] within the range of densities over which [illegible]. Furthermore, compression of the double pile [illegible] to less than half its original thickness does not [illegible] change its thermal insulation per unit (actual) thickness [illegible]. In all these cases the thermal insulation per unit thickness is the same as that for air space filled with kapok (C2464), which is one of the best insulating materials available. However, for denser fabrics (such as [illegible] material), the thermal insulation per unit thickness is distinctly lower (Spenkman and Chamberlain, 1950). [illegible] be concluded that, in the case of the best insulating materials, such as the double pile fabrics, there is no practical possibility of decreasing heat loss due to conduction by the fibres or yarn, since the ideal of no [illegible] has already been so nearly achieved (C2464) [illegible] represented by the thermal insulation of a very narrow air space [illegible].

The parts played by convection, conduction, and [illegible] the transmission of heat across the air spaces in fabrics have been investigated indirectly (C2464) by measurement of the thermal insulation of air spaces of [illegible] between two plates. From Figure 5, [illegible] be seen that the insulation of an air space increases with thickness, [illegible] until finally (at about 0.7 Clo. the approximate insulation of "still" air) there is no further increase no matter how wide the air space. This falling off is to be ascribed to the development of convection currents. For narrow air spaces the thermal insulation is practically proportional to the thickness, and from the shape of the curve (Figure 5) it is clear that the narrower the air space the more nearly is this true. Therefore it is reasonable to assume that for the extremely small air spaces in fabrics convection has already for all practical purposes been reduced to the minimal attainable value. Therefore no further [illegible] improvement in the insulating power of a fabric is to be expected from a change in the size of the individual [illegible] or pores. (This statement [illegible] of the pores approximates to the mean free path of the molecules in the air, as in the case of Silica aerogel. In this case, the transfer of heat by conduction [illegible] the air spaces is still further reduced. The diameter of the pores under consideration is of the order of one tenth of a micron -- far below the average for textile fabrics.)

Consideration (C2464) has been given to the [illegible] of the thermal insulation of clothing by the suppression of radiation, both within the fabrics and at their surfaces. The part played by radiation in [illegible] of heat across air spaces was investigated by [illegible] tests [illegible] which in some cases the two plates

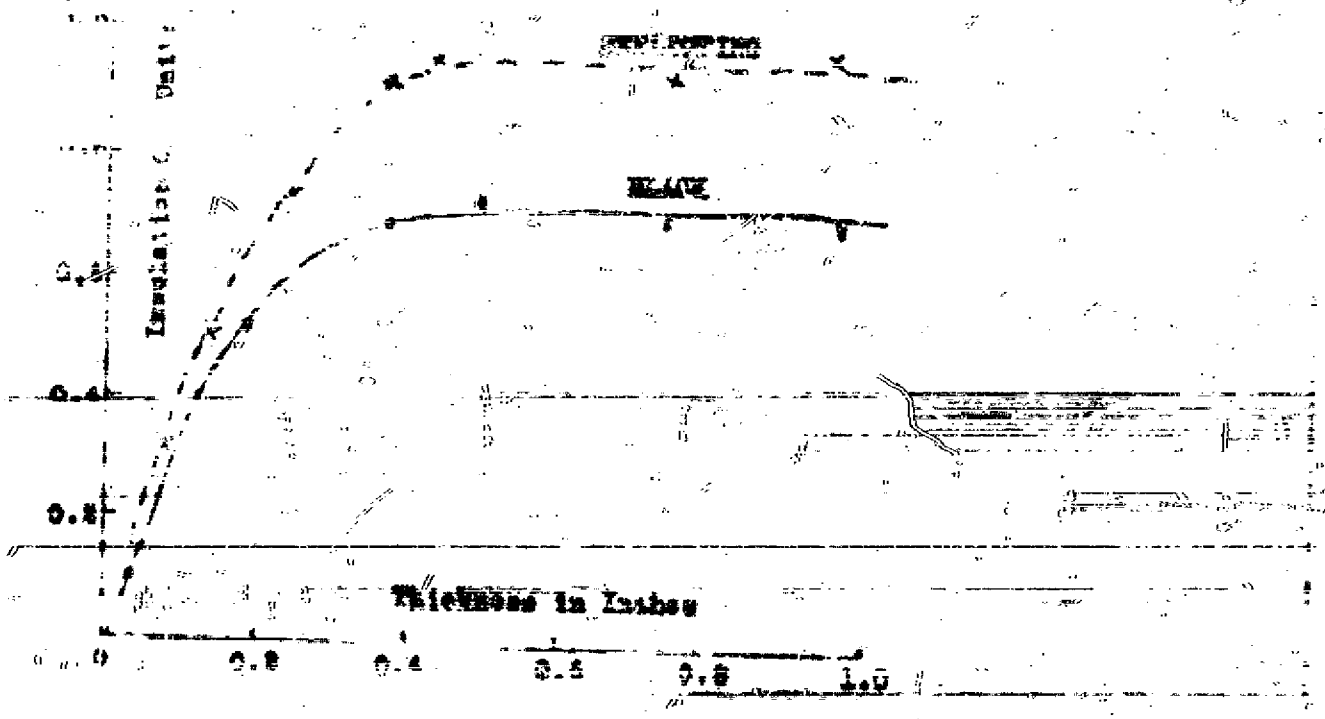



FIGURE 6

Thermal Insulation of an Air Space of Various Thicknesses with the Boundaries Black and Reflecting.

[illegible] as to give the greatest possible radiation, and in other [illegible] were covered with a polished metal surface so that radiation was reduced to a minimal quantity. For air spaces wider than 0.7 inches, the thermal insulation was increased by about 40% by suppression (as far as possible) of radiation. For narrower air spaces the relative importance of radiation became progressively less [illegible] known. The narrower the air space the greater [illegible] (given difference of temperature) is the rate of heat loss by means other than radiation, while radiation is independent of the width of the air space. Suppression of radiation from an air space bounded by plates one [illegible] improved the insulation by about 20%. It was therefore concluded [illegible] that for the most [illegible] air spaces within fabrics the part [illegible] small. Elimination of this radiation, such as it may be, would need textile fibres with [illegible] reflecting surfaces.

From these tests it seems that radiation must play a more important part in the transfer of heat across the wider air spaces that occur between the different layers of clothing and in the loss of heat from the outside surface of the clothing. Other tests were carried out [illegible] by the open method, of the thermal insulation of a pile fabric covered with a layer of paper. The paper was coated with a reflecting aluminum paper (reflecting power probably around 80%) on each side. In some tests one or both sides of the paper were then painted over with a dull black paint (reflecting power around [illegible]). The following results were got:- (Table IV).

TABLE IV

Thermal Insulation of Mohair [illegible] inches thick at C.I. [illegible] per sq. inch. Covered with a Layer of Paper, [illegible] with Overlying Room Air, Measured by the Open Method under Conditions of "Still Air"

| Surfaces of Paper | Thermal Insulation (Cl.) |
|---|---|
| Both surfaces black | 2.0 |
| Upper surface reflecting | 2.3 |
| Lower surface reflecting | 2.2 |
| Both surfaces reflecting | 2.55 |

Thus some additional insulation was gained by reduction of radiant loss between the pile and the paper, and from the [illegible] surrounding room. As regards the latter, the gain in insulation of the outside air (under still condi- [illegible] (C.[illegible]) for the gain in insulation by the use of reflection for all air spaces above about three quarters of

an inch [illegible]. However, under windy conditions a reflecting [illegible] outside of the clothing can make little difference. [illegible] under such conditions the rate of loss [illegible] the surface of the clothing is [illegible] that the [illegible] by radiation is relatively negligible (C2[illegible]).

It is concluded from the above considerations, that there is extremely little scope for the improvement of materials such as the double pile fabric in respect of [illegible]. This statement is based on tests made under conditions of still air, and might not be applicable when there is movement of air within the clothing. Apart [illegible], some slight improvement could be achieved by [illegible] of layers of [illegible] materials within the clothing, but it is very doubtful if the gain in insulation would outweigh the increased weight and difficulties of manufacture.* The usefulness of a heat-reflecting surface on the outside of the clothing, to reduce heat loss, is much impaired by air movement, so that this also is likely to be of very doubtful value. (This statement does not apply to protection against the sun, as in helmets, which is discussed briefly in the next section)

Insulation by Reflection

[illegible] of insulation by reflection, as applied to clothing, have been discussed in the previous section. Some consideration has also been given to the [illegible] required for reflecting surfaces (C2464).

Insulation by reflection may be used (C2464) for two quite different purposes: to reduce heating of the [illegible] by absorption of the sun's radiation at the surface of the clothing, and to reduce cooling of the man by radiant transmission of heat through the clothing from him to the outside. The requirements of reflecting surfaces for these purposes are quite different. To avoid heating by the sun a surface must reflect the sun's radiation, which is spread out over a fairly wide range of wavelengths but which lies mainly in the visible range. Thus the outside of sun helmets, [illegible], tents, etc., cannot both be inconspicuous and remain [illegible] strong sun. On the other hand, for the conservation of heat there must be good reflecting power for long wave (or heat) radiation while reflection [illegible] radiation is of no consequence.

A number of tests were carried out (C2464) with the cooperation of Canadian Industries Limited (Paint and [illegible] Division, Toronto), of the reflecting power of various paints for the sun's radiation. For convenience a carbon arc or gas-filled tungsten filament light was used, the spectral distribution of its radiation being sufficiently similar to that of sunlight. Three identical metal cans

* A suit with reflecting layers was constructed under the auspices of the [illegible] National Research Council. It is understood that this conclusion was supported by their experience.

[illegible] this radiation, [illegible] being dead black [illegible] assumed to be 5%), another polished [illegible] assumed to be [illegible]), and the third [illegible] painted. The percentage [illegible] of the painted can was calculated by comparison of the rise in temperature of the air inside [illegible] the rise in each of the other two. The results [illegible] general the best camouflage gave the greatest heating [illegible] olive drab [illegible] special new [illegible] ordinary olive drab camouflage [illegible] from [illegible] in infra-red absorption, and therefore showed [illegible] in infra-red photographs. This paint was found to have a [illegible] better power of [illegible] sun's radiation than ordinary olive drab, presumably because of its infra-red reflecting properties. Objects [illegible] with this special paint would get slightly less [illegible] in sunlight than if painted with ordinary olive drab [illegible] camouflage is not a [illegible] objects may be [illegible] be more effective than aluminum paint (C2464).

The reflecting power of sateen fabrics (which appear shiny) for the sun's radiation was tested (C2464) because of a report (Gregory, 1930) that it is higher than that of other fabrics. However, it was found that this was not so. Light is strongly reflected from these fabrics at [illegible] angles, very much less so at others, so that the total reflecting power of the shiny side is no greater than that of the dull side.

For the purpose of increasing the [illegible] in [illegible] (see previous section), attempts were made [illegible] to coat a cloth with a heat reflecting layer of metal paint. It was [illegible] that commercially-[illegible] painted cloths had poor reflecting power [illegible] heat radiation. Two conditions must be fulfilled by heat reflecting paints: the medium in which the particles are carried must transmit heat radiation with the least possible absorption, and the particles themselves must [illegible] of a number of lacquers* used for suspending metallic particles showed that these varied widely in their absorption of heat radiation. Vinylite, ethyl acetate, and ethyl cellulose were good (coefficient of absorption small) while a sample of plasticized [illegible] was found to be particularly bad. The [illegible] the aluminum particles used was also found to be [illegible] that particles of average diameter below about [illegible] gave poor reflection [illegible] heat radiation. This was to be expected since [illegible] the reflecting [illegible] individual [illegible] by the particles [illegible]

[illegible] to the wave length of the light to be [illegible] particles which [illegible] may be a poor reflector of long wave (or heat) radiation.

Following the principles outlined above, a cloth* of heat-reflecting power of about 70% was obtained [illegible] Paint [illegible] Division. This was done by spraying with a paint made of fairly uniform large aluminum particles* suspended in a medium consisting of vinylite (VINS) and appropriate solvents and plasticizers. No attempt was actually made to incorporate this fabric in clothing as it was felt that the possible [illegible] was very slight, but the same paint could be used on the inside of huts, tanks, etc., especially under hot [illegible] conditions when it is desired to reduce the inward radiation of heat resulting from the absorption of sunlight.

Effect of thickness on thermal insulation

It follows from the definition of thermal insulation in terms of rate of heat flow and difference of temperature (in which aerial resistances are additive, see page 17) that two layers of the same (uncompressed) fabric have twice the thermal insulation of one layer, and so on. [illegible] the double pile fabric was compressed to various degrees, it was found (C2460) that the thermal insulation was proportional to the actual thickness of the fabric under the conditions of the test (Figure 6). This [illegible] with the general results of Speakman and Chamberlain ([illegible]) already quoted (page 22). For purposes of the design of flying suits, it has therefore been accepted that [illegible] purposes the thermal insulation of a pile fabric is proportional to its effective thickness. The same general principle may be applied, though less rigidly, to the clothing as a whole.

It is considered, in view of the conclusions of earlier sections, that it is not feasible to design a [illegible] insulation for [illegible] thickness [illegible] the best [illegible] fabrics. Accordingly, for [illegible] fabrics [illegible] the linings of flying suits, the [illegible] design a cloth which, under the conditions of use, will have and retain the greatest possible thickness consistent with such other requirements as the [illegible] of the wearer.

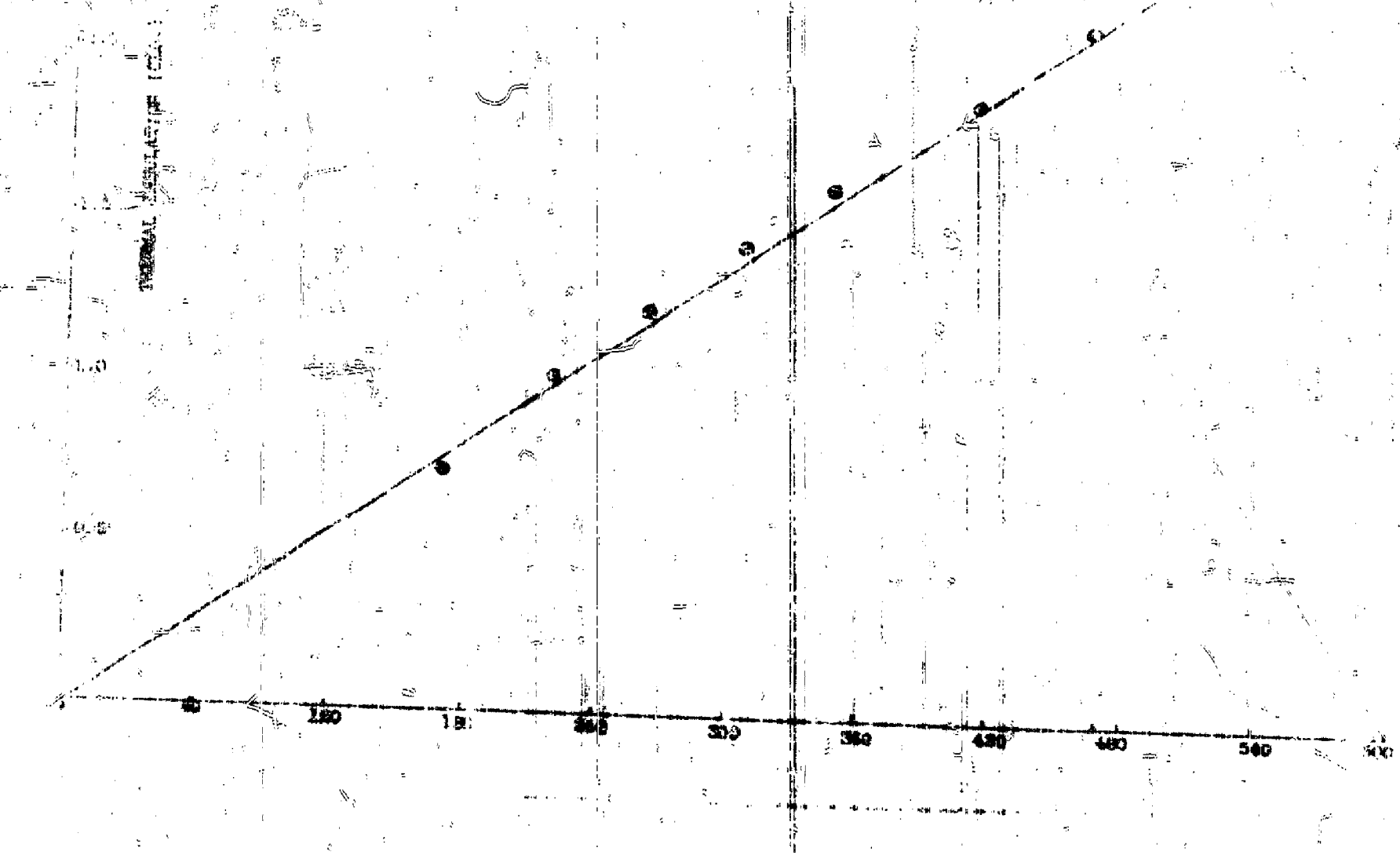
Cloths for the reflection of heat radiation have also been [illegible] Company, [illegible], and by the U.S. [illegible]

* Kindly supplied by Canada Bronze Powder Company.

FIGURE 5

THERMAL INSULATION OF DOWNTUBE FASCIA [illegible]

VARIATION WITH [illegible]



## Thickness of Pile Fabrics

### [illegible] Thickness

It was concluded that the thermal insulation [illegible] pile fabrics is directly proportional to their actual [illegible] that there should [illegible] index of the average thickness [illegible] pile fabric [illegible] when incorporated into [illegible]

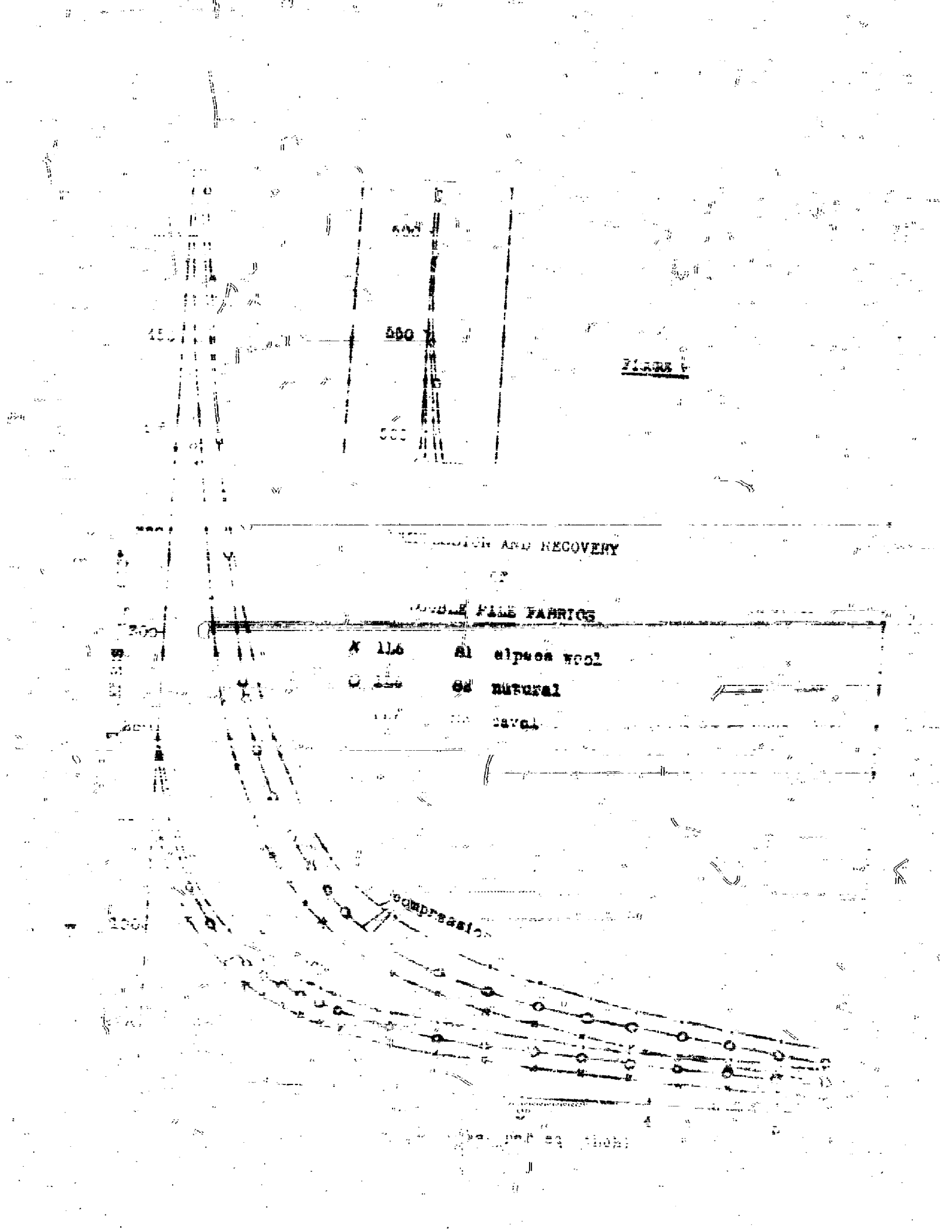
Two methods [illegible] for the experimental [illegible] of pile fabrics. Their thickness may be measured microscopically [illegible] in such a way that [illegible] or it may be measured [illegible] which flattens the outstanding hairs [illegible] in accordance with the pressure which it exerts. The second method seems to conform more [illegible] in flying clothing. [illegible] the work which is described below.

The fabrics incorporated in clothing are [illegible] during use. In the case of the pile linings of flying suits, the compression force over the greater part of [illegible] garment is believed (C2[illegible], C[illegible]) [illegible] amounting to less than 0.1 lbs. per [illegible] harness [illegible] fabric and [illegible] may be caused from [illegible] the wearer and in certain [illegible] may be much greater, as for instance under the seat (see page 57). It is therefore of more [illegible] interest to estimate the thickness which a pile fabric will assume during and after this treatment, rather [illegible]

[illegible] a pile fabric is compressed [illegible] in a compressometer [illegible] a considerable [illegible] pressures are [illegible] off. On [illegible] the original thickness is by no [illegible] Repeated compression [illegible] of thickness [illegible] and the [illegible]

Accordingly, a detailed study (02[illegible]) was made of the thickness of double pile fabric during repeated [illegible] of compression and release from pressure. For this study the compressometer was fitted with a (5 inch diameter) [illegible] feet than usual, in order to minimise the effect of possible local irregularities in the pile of the fabric. Tests were carried out over a wide range of pressures and [illegible] of compression and release. The results of one series of tests are illustrated in Figure 5. Each sample was subjected alternately to low pressure for one minute, then [illegible] pressure for one minute, then low pressure for one [illegible] and so on repeatedly. The thickness was measured at the pressure in question at the end of each minute. From the graphs it will be seen that the thickness of the [illegible] at low pressure (0.1 lbs. per sq.in) [illegible] the previous history, the greater the compres[illegible] the less the thickness to which it recovers. However, in all cases there is a rapid loss of thickness during the first few cycles of compression and recovery, followed by [illegible] gradual decline during the later cycles (02653). [illegible] has been shown to be true for piles of wool, wool [illegible] The rapid [illegible] can be restored by brushing). The subsequent gradual decline, which persis[illegible] a mean after some hundreds of cycles, may [illegible] a progressive matting of the fibres.

Examination of used flying suits (02469) showed that the thickness of their linings varies considerably. [illegible] (when new) is subject to variation. However, the linings of [illegible] had the least thickness. The extent of the decrease, after [illegible] for [illegible] hours, was sufficient to indicate that the rapid initial loss of thickness (as found in the laboratory tests) had been passed, and that the pile had entered on the gradual decline. In the case of double pile fabric from the back of the most used suits, the thickness corresponded to that which was found experimentally after some hundreds of even thousands of compressions at 1 lb. per sq. inch (with release to 0.1 [illegible] per sq.in). As a result of this investigation it was concluded (02687, 02688) that a representative estimate of the thickness of a pile fabric during use could be obtained by measurement at 0.1 lbs. per sq. in. after a sufficient number of cycles of compression and recovery [illegible] to bring the fabric [illegible] the stage of gradual decline. For this purpose five [illegible] of 0.1 lbs. per sq. in., at which [illegible], is reasonably justified by the



550
AND RECOVERY
FILE FABRICS
116
81 alpaca wool
natural
compression

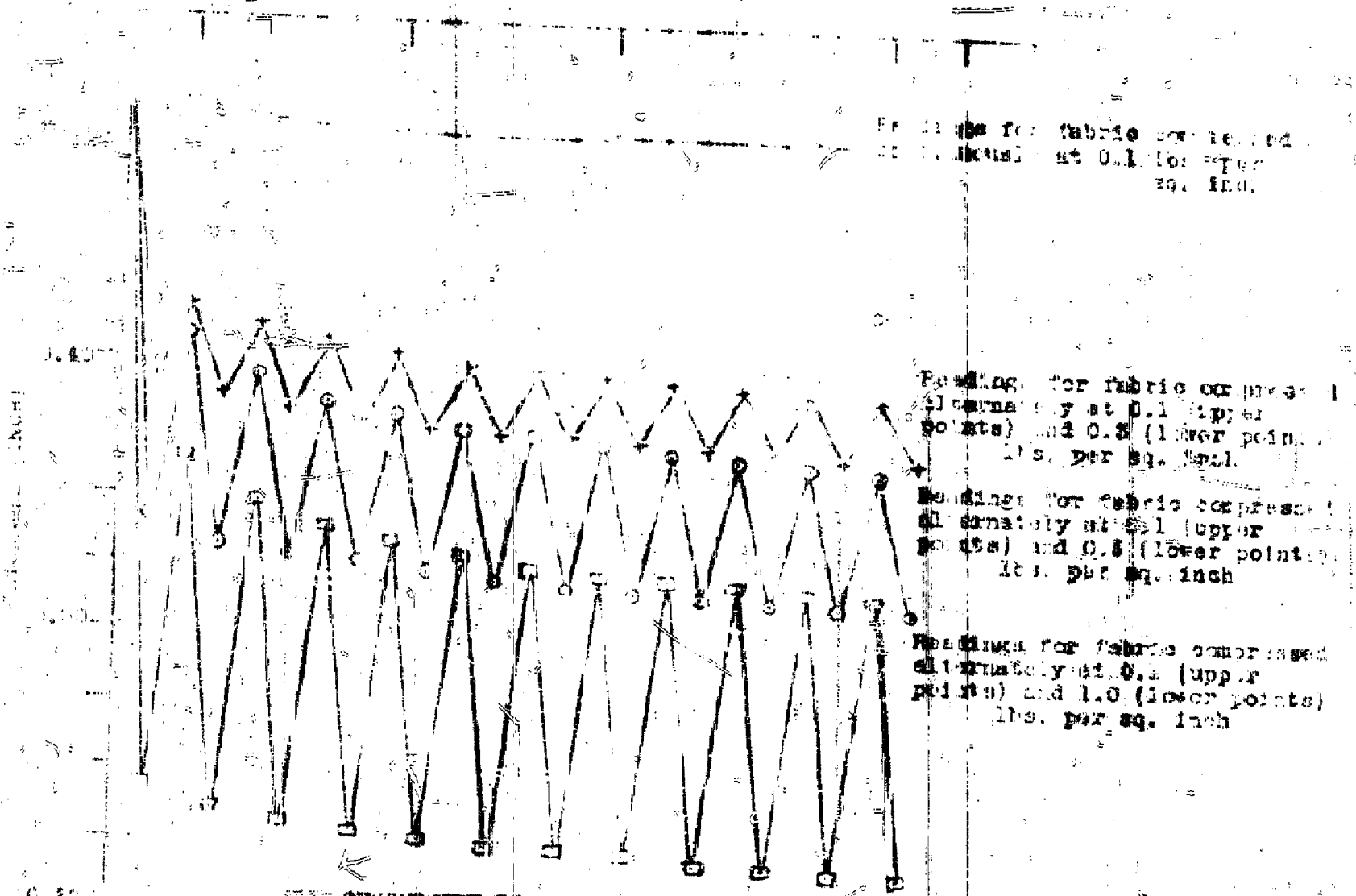



FIGURE [illegible] THICKNESS OF DOUBLE PILE FABRIC ( L 74)
UNDER SUCCESSIVE CASTRES 1[illegible]S

[illegible] index of compressibility was required to [illegible] in thickness of pile fabrics result- [illegible] pression force exceeding the basic value [illegible] per sq. in. [illegible] conditions representative of use in clothing. It was found experimentally (after [illegible] pression and recovery) as pre- viously defined that the thickness [illegible] with the logarithm of the pressure applied [illegible] of this line can therefore be used to [illegible] the fabric when [illegible] with any pressure within the practical [illegible] It is convenient to express the ob- [illegible] in thickness as a percentage of the original [illegible] sq. in.)

Index of compressibility $= \dfrac{t_2 - t_1}{t_0 \times \log_{10} \dfrac{p_2}{p_1}}$

when the reference thickness (say at 0.1 lbs. per sq.in.) [illegible] thickness at pressure $p_1$

[illegible] as 0.1 lbs. per sq.in. and $p_2$ as 1.0 lbs. per sq. in.,

[illegible] $\dfrac{p_2}{p_1} = 1$, and

Index of compressibility = $\dfrac{\text{Thickness at 0.1 lbs./sq.in.} - \text{Thickness at 1.0 lbs./sq.in.}}{\text{Thickness at 0.1 lbs./sq.in.}}$

[illegible] the fractional loss of thickness on compression [illegible] sq.in. These values are, of course, [illegible] of gradual decline has been [illegible] at the pressure in question, as a result (in the case of pressures above 0.1 lbs. per sq.in.) of a series [illegible] of compression [illegible] that pressure [illegible] accuracy can be obtained if determinations of thickness are made at several different pressures, and if the thickness at 0.1 lbs. per sq.in. is then estimated from the best straight line relating thickness with logarithm [illegible] the index of compressibility finally [illegible] describe the behaviour of the fabric over [illegible] of pressures [illegible]. It should be [illegible] index of compressibility

provides a complete description of the compressibility of a particular sample of pile fabric, yet it does not necessarily yield any general information on the compressibility of different types of pile except in well controlled experiments in which all factors are kept constant except the one under investigation.

## Comparison of Different Types of Pile Fabrics, and Effect of Moisture

A comparative study (Cross) was made of the thickness and compressibility of a wide range of different pile fabrics with different contents of regain moisture. The investigation was carried out before the standard system had been developed of measuring thickness and compressibility after a definite number of cycles of compression and release of pressure. Therefore in these experiments the [illegible] was measured directly (without previous compression) [illegible] lbs. per square inch, then at 1.0 lbs. per square inch, and finally at 0.1 lbs. per square inch [illegible] period for recovery. Not much reliance can be placed on small differences, since the previous history of the sample will considerably influence the result when the thickness [illegible] in this way. However, the larger differences can safely be accepted. Little difference was found in the resistance to compression of a range of double pile fabrics with the pile made of wool of qualities ranging from [illegible] to [illegible]. In general, the thickness and recovery [illegible] compression of fabrics with a wool pile was but little [illegible] below 10%, but higher regains had an [illegible]. However, [illegible] was found to lose thickness with increasing moisture content over the range of 0 to 10% regain. With a double pile fabric of wool and rayon the loss of thickness and impairment of recovery was more marked at regains above about 20%, than in the case of double pile fabrics with the pile made of wool only. Very good resistance to compression and recovery from it were found in a wool carpet pile fabric and in sheepling. However these materials are also much heavier for a given thickness than the double pile fabrics under consideration. Excellent results were obtained with a short [illegible] however this was due no doubt partly to the shortness of the pile. A sample of double pile fabric with pile of mohair and wool did not give results any better [illegible] with a pile of wool only. Nevertheless it [illegible] additional samples should be made up with mohair in them. Apart from this, the resistance of [illegible] pile fabric to compression might be improved by [illegible] pile [illegible], but this [illegible] in weight and stiffness.

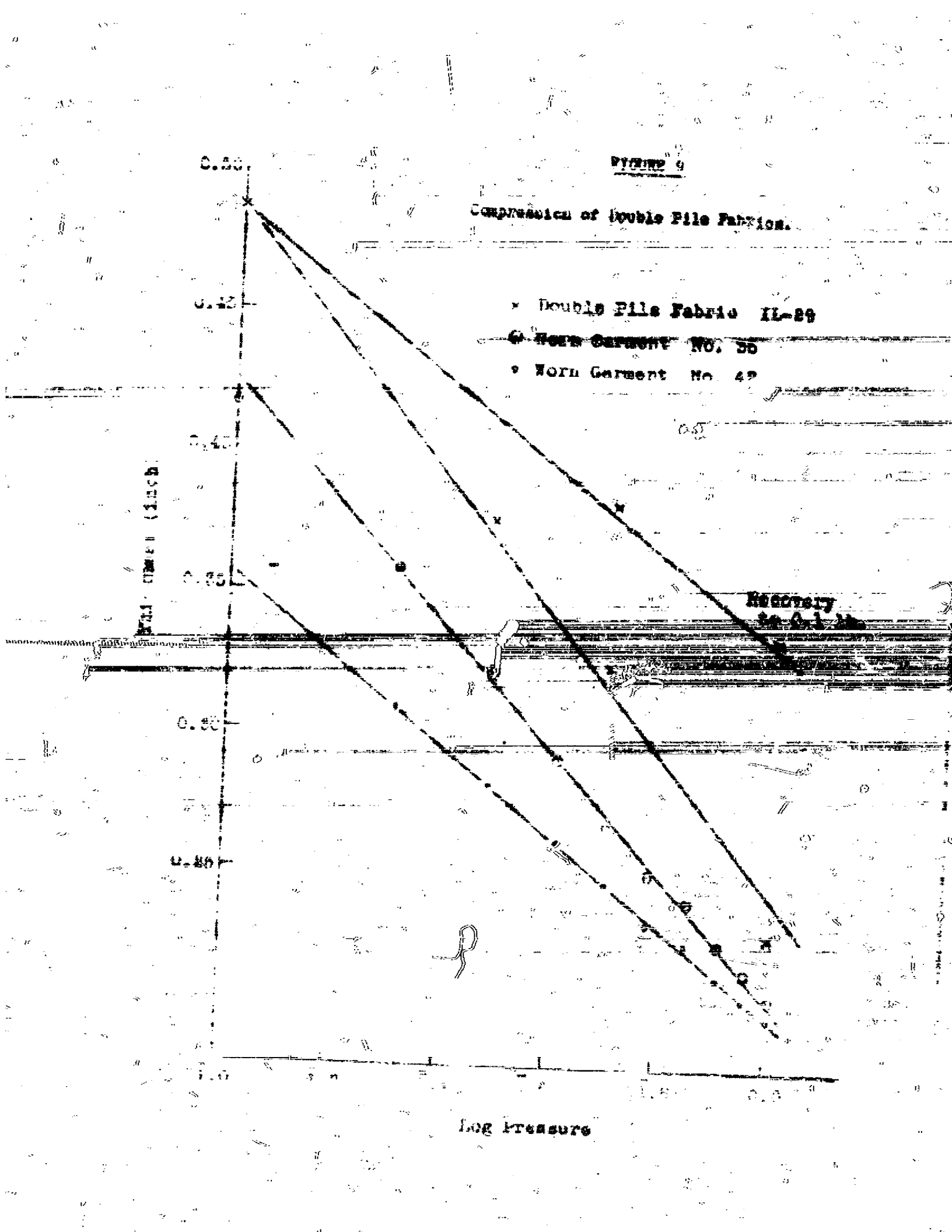


Figure 9
Compression of Double Pile Fabrics.
Double Pile Fabric IL-29
Worn Garment No. 55
Worn Garment No. 42
Recovery to 0.1 lbs.
Log Pressure

## Tuft Binding Power of Pile Fabrics

It was desired to reduce the weight of the ground of the double pile fabric used for the linings of flying suits as much as was possible without serious impairment to the security of the pile tufts. A test was therefore developed for tuft binding power (C2419). In this test an individual tuft of the pile is gripped in the carriage jaw of an inclined plane yarn tester, and [illegible] clamped or securely held the machine is [illegible] allowed to operate until the tuft pulls through. The average load at which this occurs in ten [illegible] is recorded as the tuft binding power. Only tests in which the complete tuft pulls through are accepted, and certain precautions have to be taken (C2419).

[illegible] result of tests carried out by this method, (as well as tests for compressibility and pliability) a reduction in two stages was effected on the ground of the double pile fabric in production for the R.C.A.F. (C2420). Reduction in the weight of the ground also resulted in an increased pliability of the fabric without significant detriment to the effective thickness or resistance to compression. The weight of ground finally achieved (Meeting 19) was the lowest which would permit of the accommodation of the tuft density used with this fabric.

## Permeability of Materials to Water Vapour

### General

In accordance with Fick's Diffusion Law, the mass (M) of water vapour which passes through a homogenous material in a given time (t) is proportional to the area (A) through which the transfer is taking place and to the difference of vapour pressure ($P_a - P_b$) on the two sides of the material and inversely proportional to the thickness (T) of the material. The constant relating these variables may be written as one of direct proportionality, in which case it represents the conductivity, or as one of inverse proportionality (r), in which case it represents the resistivity of the material for water vapour, as in the following equation:

$$\frac{M}{t} = \frac{A(P_a - P_b)}{rT}$$

The constant of resistivity (r) may be combined with the thickness [illegible] of the material to give the resistance (R [illegible]) [illegible] a sample of material under consideration [illegible] constant of resistivity rather than [illegible] conductivity enables the separate effects of a series [illegible] (Gregory 1950) [illegible] of thermal insulation

[illegible]. Thus, if the passage of water vapour through a pile of material is considered

$$\frac{M}{t} = \frac{A(P_a - P_b)}{R_1 + R_2 + R_3 \text{ etc.}}$$

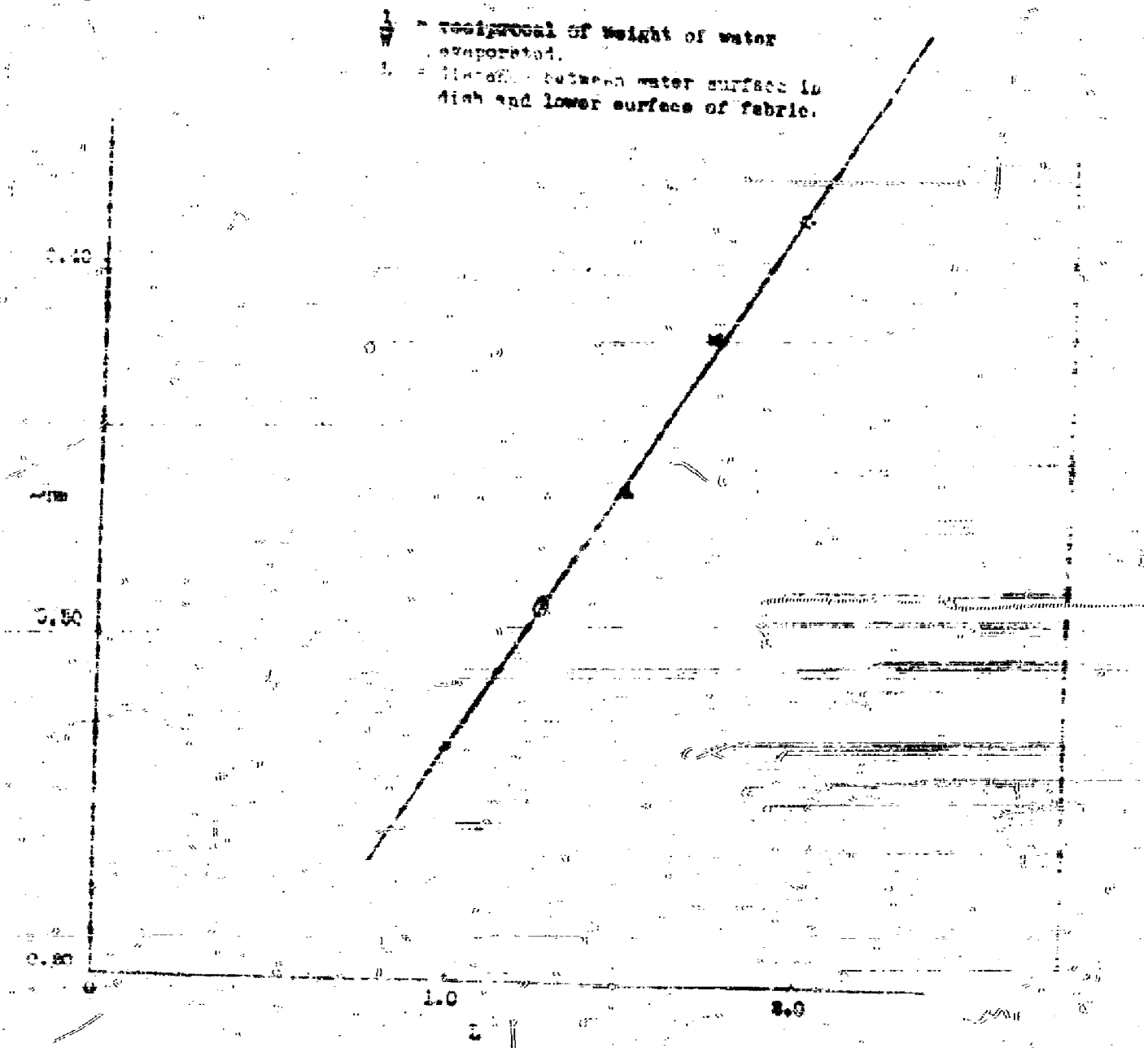
This fact (CBSS) has facilitated the development of a test method for [illegible] and analysis of the distribution of moisture in clothing.

Test Method

It was considered (CBSS) that any method in which the fabric or other material to be tested came into contact either with water or with a dehydrating agent was open to objection, since water may seep into the fabric and a granular dehydrating agent is liable to leave air spaces between itself and the fabric. Accordingly, it was decided to use an experimental arrangement in which the test specimen was mounted over a dish containing water and was separated from the water by an air space of [illegible] thickness. With such an arrangement, resistance to the passage of water vapour is offered by the air [illegible] water and the fabric, by the [illegible] the fabric. By means of simultaneous [illegible] which the thickness of [illegible] the number of layers of fabric were independently varied, it was found possible to assess separately the resistance of each under conditions such that the resistance of the air above the fabric was held constant, so that it could be cancelled out from the calculation.

When the thickness of the air layer between the water and the fabric was varied, one layer of fabric being used in each case, a rectilinear relation was found between the inverse of the rate of water loss and the thickness of the air space (Figure 10) [illegible] expected from Fick's Diffusion Law in accordance with the equation already given (page 31). However, for thicknesses [illegible] 2 or 3 cms., this relation no longer held, no doubt because the air was disturbed by convection.

If now a test [illegible] carried out at the same time with any suitable thickness of air space but with two [illegible] layers of fabric, the resistance of the [illegible] air space which gave the same rate of water loss [illegible] and with the additional layers of fabric. The difference in thickness of air space when one and when more than one fabric layer is used, is equal to the resistance of the additional layers of fabric. The fact that the rate of water loss has been the same in both cases




Graph illustrating method of estimation of resistance to passage of water vapour by diffusion.

Points marked X were obtained in tests with a single layer of fabric.

The [illegible] represents on the straight line the value of $\frac{1}{W}$ obtained with [illegible].

FIGURE 10

ensures that there can have been no difference in the [illegible] the fabric in the two cases, owing to a different [illegible] although further investigation may well show this precaution to [illegible].

In later work it has been found convenient to [illegible] sintered glass disc underneath the fabric to support it. [illegible] procedure, simultaneous tests are carried out with four different thicknesses of air between the water surface and the single sintered glass discs. (The sintered glass discs have all been [illegible] to have an equal resistance to the passage of water vapour). [illegible] fabric is used. At the same [illegible] other tests are carried out, each with any convenient air space, [illegible] fabric over [illegible] the same comparative procedure is applied [illegible] of the resistance of the fabric. The sintered glass discs do not influence the estimation provided they all have an equal resistance. It will be [illegible] that it is possible to obtain the necessary result with only three dishes. However, [illegible] for a check as to accuracy. In all cases it is necessary that the dishes and their samples be left long enough for a steady state to be set up and for the fabric to have reached equilibrium in respect of regain moisture with the surrounding atmosphere.

The validity of this test method has been [illegible] of the diffusion coefficient of water vapour in the air by this means. [illegible] obtained agree closely with standard values.

This test method can be applied not only to fabrics but also to many other materials such as leathers, papers, and sheet plastics. It enables the results to be [illegible] physical units in a manner independent [illegible] of the [illegible] characteristics of the experimental [illegible] of a particular investigator. In [illegible] permeable materials, those characteristics otherwise seriously enter into the result. However, in the case of rather impermeable materials, the resistance [illegible] the air layers below and above the test material becomes relatively small.

## [illegible] of Fabrics to Water Vapour

[illegible] resistance [illegible] variety of fabrics confirm those of Gregory [illegible] in that resistance [illegible] of water vapour is in most cases very [illegible] resistance usually amounts to only [illegible] or [illegible] times [illegible] for glass cloth it was found [illegible] as high as about 9 times that of still air.

[illegible] concluded by Gregory, that in the case of most of the fabrics used in ordinary clothing, much of the water vapour passes through the fibres themselves as well as through the air spaces.

An investigation was made [illegible] of the permeability to water vapour of various kinds of leather with specific reference to fat content. It was concluded that leathers of very high fat content, such as might be regarded as suitable for wet conditions, necessarily have a high resistance to the passage of water vapour. Extraction of the fat from leathers greatly reduces this resistance. Treatment (after extraction) with dubbin increases the resistance, although not necessarily to anywhere near the [illegible] of a test on the upper leather of R.C.A.F. Lumbermen's boots is given in Table V.

TABLE V.

R.C.A.F. Lumbermen's Boots (Type 2) Upper Leather

| | |
|---|---|
| Thickness of leather | 0.28 cms. |
| Fat content of original sample (% by weight) | 18.2 |
| Permeability of original sample | |
| (a) equivalent thickness of ideal still air | 35.0 cms. |
| (b) ratio of resistance to that of air | 125.0 |
| Permeability of extracted leather | |
| (a) equivalent thickness of ideal still air | 0.8 cms. |
| (b) ratio of resistance to that of air | 3.0 |
| Permeability after applying dubbin | |
| (a) equivalent thickness of ideal still air | 4.0 cms. |
| (b) ratio of resistance to that of air | 14.0 |

Flash Resistance

[illegible] for the flash resistance of fabrics (C2306) in order to determine to what extent a fabric would give protection against brief exposure to hot flame. Protection was desired against burns such as might occur to a man escaping from a crashed plane. It was presumed that in such circumstances, if his clothing remained intact, parts of his body of protection would not be burned, but that if his clothing caught fire he would be burned [illegible] the result of crashes

[illegible] been severely [illegible]

[illegible] established on which [illegible] flame. The fabric was [illegible] poop and the latter was caused [illegible]

[illegible] fabric [illegible] to ignite was [illegible]

Little time was available for this work, and it will be [illegible] that considerable refinements could be made to the method. In particular it was desired by the investigators concerned to install a small metal plate and [illegible] the fabric in order that the results might have a closer relation to the raising of temperature [illegible]. This suggestion was made to [illegible] Coordinating Committee on Protective Equipment and was [illegible] with an investigation of [illegible] helmets.

Water Retention and Rate of Drying of Fabrics

An investigation (C2747) was made of the rate of drying of fabrics that had been thoroughly soaked in water. In Figure 11 are illustrated the results got with fabrics [illegible] vertically in relatively still air under controlled conditions of temperature and humidity. The rate of evaporation from different fabrics was the same until the amount of water remaining approached that held as regain moisture; then there was a decrease in the rate of drying. Similar results were got in a wind tunnel at various wind velocities (up to a [illegible] min.), although of course the actual rate was increased. The rate of drying from a thoroughly wet fabric [illegible] was identical with that from a shallow dish of water exposed to similar atmospheric conditions. The [illegible] of the rates of drying of thoroughly wet fabrics [illegible] standard conditions) has already been reported by workers under the [illegible] National Research Council (Foust, Frishman, Sookne and Harris). It may be concluded [illegible] thoroughly wet fabric acts like a sheet of water in respect of drying, and that the time taken to dry depends [illegible] the amount of water held.

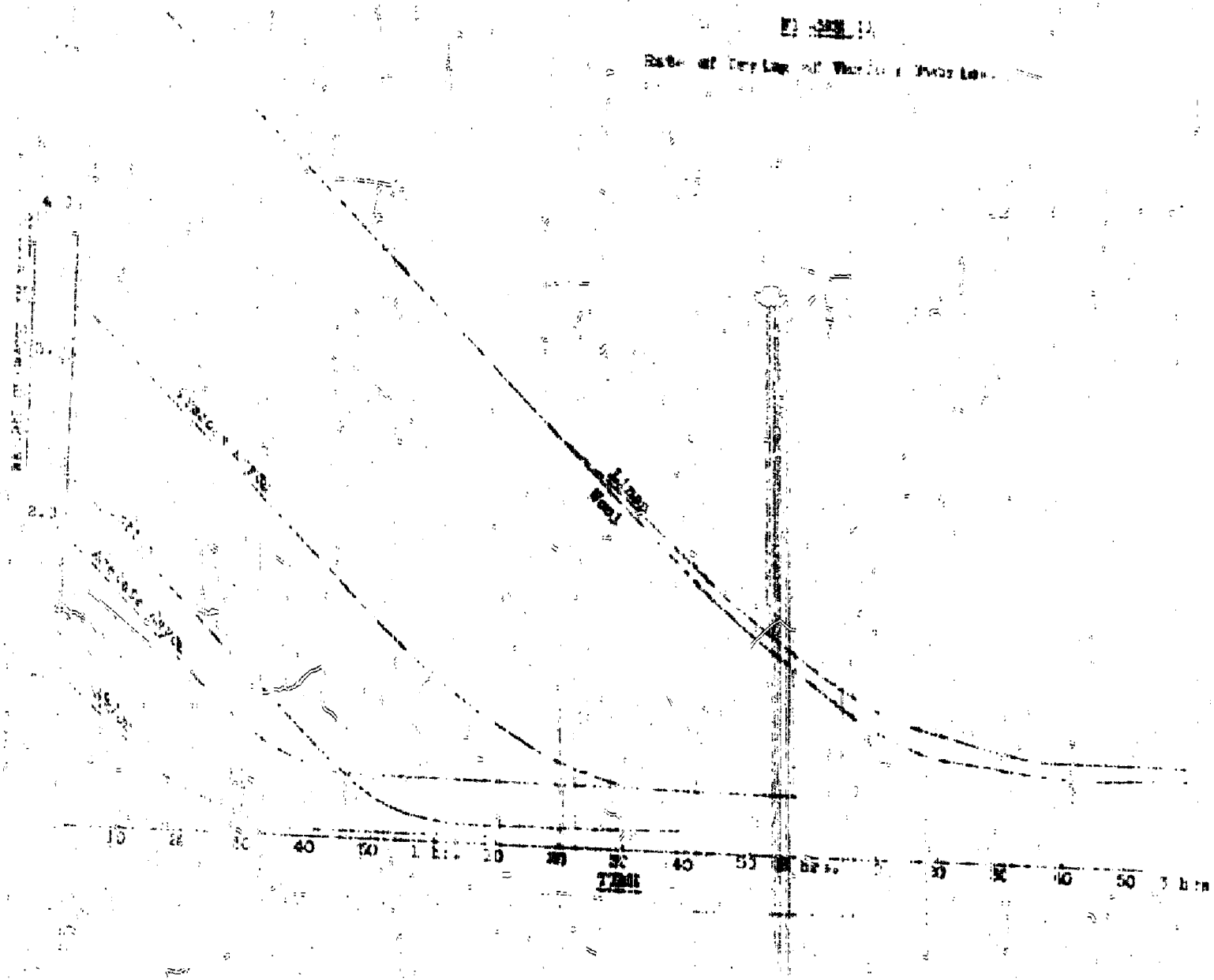
[illegible] carried out (C2747) of the amount of water held by various fabrics with maximal retention [illegible] to remove the water. The maximal water absorption was got by immersion of the sample in water [illegible] wetting agent, followed by suspension for a few

[illegible] reasonable to expect a fairly close correlation [illegible] held and the air space volume [illegible] the volume of the fabric less the [illegible] actually is perfect, since the [illegible] could not be [illegible] purposes of measurement will not equally well represent [illegible] in different types [illegible] correlation is close enough to [illegible] of the maximal water holding capacity of different fabrics.

The results [illegible] for water retention after treatment [illegible] to remove water are quite strikingly different, [illegible] of treatment were tried [illegible] fabrics between absorbent materials under a [illegible] between press [illegible] rollers, and centrifuging. The last method seems the least open to objection. [illegible] correlation was unbiasable either with the dry weight of the fabric [illegible] The amount of water held by glass fabrics and nylon fabric was consistently [illegible] compared with that held by wool, cotton, linen and viscose rayon fabrics. Acetate rayon gave intermediate [illegible] after allowance had been made for regain moisture contained by each fabric, it remains clear that there were differences in the amount of non-regain water held by the various fabrics, and that these differences depended on the type of fabric.

It was reasonable to suppose [illegible] after [illegible] fabric had been centrifuged, most of the remaining water would be associated with the surface of the fibres [illegible] of droplets in the spaces between the fibres or yarn. Accordingly a calculation was made of the fibre surface areas of the various fabrics, and from [illegible] of a water film was computed on the assumption that all the non-regain water was evenly spread over the fibres. The calculated film thicknesses were found to range from 0.6 to about 5μ. However for a given [illegible] the results are as consistent as could be ex[illegible] lowest value is that for glass, with nylon [illegible] followed by acetate rayon, cuprammonium rayon, wool, [illegible] viscose rayon. It is interesting that the results for [illegible] rayon are much lower than those for viscose, in spite of the fact that the two types are chemically identical. The viscose fibre is much less smooth in its surface [illegible] than the cuprammonium rayon fibre, so that the [illegible] surface area of the viscose fibre is too low, [illegible] retention of water [illegible] on the surface may well contribute to the [illegible] of water held by this material.

It


TIME

[illegible] of the [illegible] however the water [illegible] much lower for a sample [illegible] with the water [illegible] similar [illegible] suggest that water retention after treatment tending to [illegible] amount of water adhering [illegible] the surface of the fibres and that the amount is dependent upon both the physical and chemical [illegible] of the surface.

The Slipperiness of Lining Fabrics

[illegible] that linings of [illegible] flying suits should be slippery in order that [illegible] may slide readily over underlying clothing, [illegible] during wear. The procedure (SMSSD) adopted for measurement of slipperiness [illegible] materials on a block and the other to a board capable of being tilted to any angle. The angle of inclination of the board at which sliding of the block would occur at approximately uniform velocity was measured, and the coefficient of friction was obtained from [illegible] the static friction (or the force required for sliding to begin) is slightly higher than the sliding friction, [illegible] both more convenient from the point of view of measurement [illegible] the purposes in question. The [illegible] between the fabrics was approximately [illegible]

An investigation of the sliding angle and coefficient of friction of a number of different appropriate [illegible] considerable differences. In some cases the direction of the weave is important.

[illegible]

[illegible] as the standard [illegible] for [illegible] non-inflatable life jackets for the [illegible] Armed Services. The quality is known to vary. [illegible] existence of considerable stocks of Java Kapok in North America. It was considered necessary [illegible]

[illegible] as is popularly [illegible] of its fibres, it is due

[illegible] entrapped between the fibres [illegible] has been estimated [illegible] in one cubic foot of [illegible] the customary density [illegible] than [illegible] of [illegible] spaces [illegible]

Kapok, even when packed in a fabric container which is not [illegible] [illegible] of [illegible]

[illegible] surface of its fibres repels [illegible] the spaces between [illegible] kapok must be 'fluffy', so that [illegible] spaces are individually [illegible]

[illegible] resistance to [illegible] so that the air entrapped in it is not squeezed out by the [illegible] of waves on a partially [illegible] life jacket [illegible]

[illegible] of Filling Materials

A test method has been developed for the estimation of the usefulness of filling materials for [illegible] (C[illegible]). For this purpose an acceptable measure [illegible] was needed. The buoyant force of a float or life jacket is measured as the weight in water which it will just support without sinking [illegible] of a weight suspended [illegible] spring balance and [illegible] in water. The fall in reading on the spring balance when the float is attached [illegible] weight (both being fully submerged) represents the buoyant [illegible] the float. For a filling material, [illegible] practical consideration is the buoyant force of a given [illegible] bulk (rather than weight) [illegible] of life jackets. [illegible] buoyancy by the weight [illegible] by a given weight of filler is altogether misleading, [illegible] for instance, a life [illegible] support a weight of [illegible] in [illegible] material [illegible] cubic [illegible] with material [illegible] cubic foot. [illegible] with [illegible] weight of filler is therefore misleading for life jackets [illegible] suspect are [illegible]

[illegible]

[illegible]

| [illegible] | [illegible] | [illegible] | Volume [illegible] of material [illegible] to exert [illegible] of 20 lbs. | [illegible] force [illegible] exerted by [illegible] of material |
|---|---|---|---|---|
| [illegible] | 30.2 | 0.64 | 0.33 | 60.3 |
| [illegible] | [illegible] | [illegible] | [illegible] | 59.3 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | 0.35 | 57.3 |
| [illegible] | [illegible] | 2.52 | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | 52.3 |
| [illegible] | [illegible] | [illegible] | 0.42 | 47.3 |

[illegible] buoyancy adopted is the buoyant force [illegible] cubic foot of filling material totally immersed. In [illegible] in volume on cub- [illegible] water [illegible] is equal to [illegible] water (28.5 lbs. per cubic foot) minus the [illegible] filling material.

Since the buoyancy of a filler is to be measured by the buoyant force per unit volume of material, the density [illegible] must be standardized. The amount of filler which will pack into a [illegible] volume depends on the pressure applied [illegible] pressure (0.27 lbs./sq. [illegible] being the pressure required to fill [illegible] amounts to the density of 1 lb. per 1/3 cubic [illegible], as required by the Department of National Defence for Air in filling kapok life jackets. This figure represents a [illegible] extra [illegible] in the [illegible] of pressure. [illegible] buoyancy of a filling material, [illegible] container is filled with the filling material to [illegible] volume at the standard pressure, and the buoyant force exerted by the submerged material is measured after [illegible] intervals over a period of twenty-four hours.

[illegible] above, does not [illegible] as to the possible effect of buffetting [illegible] static [illegible] is rotated for one hour [illegible] partially filled with water, and the buoyancy is [illegible] has proven [illegible]

[illegible] substitutes [illegible]

[illegible] for a substitute for kapok, [illegible] summarized in Table VII.

[illegible] of good quality, Bahamas [illegible] 'superfine' kapok are prac- [illegible]

[illegible] samples from Trinidad [illegible] (apparently from a different species of tree) [illegible] their buoyancy when agitated under water. Unfortunately the supply of Bahamas cottonsilk floss is [illegible] is available commercially.

In view of the powdering (C2336) of the [illegible] kapok in the quilted ('tropal') [illegible] of certain R.C.A.F. flying suits, a comparative investigation (C2345) was made of the fracturing of 'tropal', [illegible] and milkweed floss. Although there is no [illegible] that kapok breaks up in life jackets in [illegible] to lose or redistribute buoyancy, [illegible] desirable that any substitute for kapok in life jackets should not fracture more easily than does kapok. The breaking up of kapok fibres was successfully accelerated in a test in which samples of the kapok were rotated together [illegible] of rubber stoppers in a jar. Fracture and [illegible] into balls was much worse in 'tropal' than in [illegible] untreated kapok, although some occurred in [illegible] materials. The loss of buoyancy in 'tropal' was [illegible] to be noted that in the handling of [illegible] the air may become filled with dust, against [illegible] protection might be needed.

Tests have also been carried out on a variety [illegible] domesticated birds. Of these, goose down was the only type that gave satisfactory results. Admixture [illegible] down, or of fibres of these, led to serious reduction of the buoyancy. Sheep's wool and deer [illegible] also given very unsatisfactory results.

Attempts were made (C2280, C2315) to give buoyancy [illegible] by treatment of these materials with water-[illegible]. Valuable cooperation was received from the [illegible] Technical Associations of Canada. [illegible] materials had considerable buoyancy under still conditions, they lost most of it when agitated [illegible] (C2319, C2343, C2444). The great superiority of kapok and milkweed may be explained by the fact that a mass of these fibres retains its resistance to compression [illegible] a mass of cotton or wool fibres, when [illegible] humidity, loses the [illegible] consequence of the loss of rigidity of [illegible] or wool in a humid environment, the air entrapped [illegible] the

[illegible] squeezed out during agitation; nor does [illegible] with a water-repellent prevent the uptake of [illegible] upon which the change of rigidity [illegible]

**TABLE VII**

Buoyancy of various vegetable, animal, and synthetic fibres

| Item No. | Material | Density of packing (lbs./cu.ft.) | Buoyancy (lbs. of flotation force per cu.ft. of filling material) After 1 hour | After 24 hours | After further hour during which sample was agitated. |
|---|---|---|---|---|---|
| | **Vegetable fibres** | | | | |
| | [illegible] new 'Prime Java' | 3.0 | [illegible] | 57 | 43 |
| 3 | [illegible] new 'Indian Superfine' | 3.0 | [illegible] | 57 | [illegible] |
| 4 | Panels from naval life [illegible] found lacking in [illegible] | 3.0 | 58 | 56 | 43 |
| 5 | [illegible], new high quality | 5.0 | 53 | 46 | 9 |
| | [illegible] new | 2.4 | 60 | 56 | 39 |
| | Cottonsilk from Bahamas new | 4.5 | 57 | 56 | 36 |
| | Cottonsilk from Bahamas, [illegible] in cushion for 5 yrs | 5.0 | 57 | 55 | [illegible] |
| | Cottonsilk from Trinidad, | 3.6 | 57 | 56 | 43 |
| | Cottonsilk from Antigua, new | 3.3 | 55 | 43 | 7 |
| | [illegible] | [illegible] | [illegible] | 32 | 4 |
| | [illegible] | [illegible] | 53 | 44 | 44 |
| 13 | [illegible] down, 60% duck | [illegible] | 56 | 50 | [illegible] |
| 14 | 100% duck feathers | [illegible] | [illegible] | 47 | waterlogged |
| | [illegible] | 5.[illegible] | [illegible] | 19 | test discontinued |
| 15 | [illegible] fractionated | 7.4 | [illegible] | 0 | discontinued |
| 16 | [illegible] chicken feathers | 7.1 | 41 | 22 | discontinued |
| | [illegible] turkey feather | | | | |
| | [illegible] shearling | [illegible] | [illegible] | 52 | 30 |
| | [illegible] with water | | [illegible] | 9 | 0 |
| | [illegible] | | [illegible] | 15 | 5 |
| | [illegible] | [illegible] | [illegible] | 12 | 4 |

| [illegible] | | | After 1 Hour | After 24 hours | After further hour during which sample was agitated |
|---|---|---|---|---|---|
| [illegible] | Bubblefil | 1.6 | 28 | 25 | 25 |
| 22 | Bubblefil | 2.1 | 38 | 36 | 36 |

[illegible] pressure used in packing [illegible] ation in a series of readings taken after various intervals of time.

[illegible] 'Bubblefil', a viscose fibre containing [illegible] of entrapped air, manufactured by E.I. Dupont [illegible] Company, was also tested for buoyancy (08437). Although the buoyancy was practically unaffected by the test procedure, the initial buoyancy was relatively low. (Table VIII).

TABLE VIII

| Material | | Packing density (lbs./cu ft.) | Buoyant force after 1 hour of static immersion (lbs./cu.ft.) |
|---|---|---|---|
| (2) | Kapok | 3.0 | 59.6 |
| (3) | Bubblefil | 1.6 | 27.7 |
| | Bubblefil | 2.1 | 38.2 |

The buoyancy of [illegible] depends entirely on the air within the fibres or bubbles. The air between them becomes replaced with water. At a packing pressure equal to that normally used for kapok, 'Bubblefil' has a buoyancy per unit volume [illegible] of kapok (Table VIII, item 2). With tight packing this can be raised to 60%. (Table VIII, item 3). Unfortunately economy of volume is an important consideration [illegible] design of life jackets. In addition 'bubblefil' was found to break down readily when agitated while dry. Experience with treated kapok in flying suits will indicate the need for caution in the choice of such a material.

[illegible] substitutes for kapok so far [illegible] to be by far the most [illegible] laboratory tests, it [illegible] floss is as good as kapok. Life jackets, some containing kapok and others milkweed floss, have been [illegible] This comparison should go far [illegible] the usefulness of milk- [illegible] a substitute for kapok.

## CLOTHING AS PHYSIOLOGICAL PROTECTION

### Historical [illegible]

In the early days of the Subcommittee and before its formation, the protection of flying personnel against cold was a [illegible] problem. [illegible] of the early work was [illegible] with the evaluation of clothing for this purpose. An extensive analysis was made of the heat exchange through clothing under cold environmental temperatures (C2036). The insulation of clothing was estimated [illegible] consideration of the rate of loss of body heat through it and was expressed in a new physiological unit the "Clo" (C2035). A purely physical method of measuring the thermal insulation of clothing on an 'artificial man' was also developed (C2027). Various flying suits were [illegible] by these two methods and the results [illegible] provided a basis for the choice of a [illegible] double pile fabric for the lining of the N.C.A.F. winter flying suit (Type 2). Both these methods of measuring the thermal insulating of clothing have been used extensively in various laboratories [illegible]. An investigation was also made of the [illegible] in human [illegible] personnel to cold conditions without [illegible]

Results of the N.C.A.F. Flying Clothing Committee's questionnaire on flying clothing had shown the unpopularity of bulky flying clothing. On the other hand it was recognized by the Subcommittee that the thickness of clothing and the thermal insulation are inseparable (see page 26). It was therefore necessary to design clothing having the greatest possible thickness but causing the wearer the least possible sensation of bulkiness. For this purpose it was clear that clothing should be designed in such a way as not to cause any restraint of pressure on the wearer (C2296). Flying gloves were designed with the fingers [illegible] in a natural position of rest (C2216) and the same principle was applied [illegible] success to the knees and elbows of the winter flying suit (C2497). An investigation was also made of the areas of the clothing where pressures were likely to be developed (C2297, C2556). [illegible] reduce the thermal insulation of the clothing by compression the fabrics of pressing out the [illegible] also restrict the peri[illegible] it was found that the [illegible] were in general small, emphasis was [illegible] which would retain [illegible] after such temporary but repeated [illegible] as were likely to be experienced in service use. [illegible] tests on men wearing winter flying clothing as to the areas of the body most liable to a

[illegible] cold (02[illegible]). While it does not [illegible] [illegible] dress would necessarily be helpful, it seems unfortunate that no attempt was made to investigate this possibility.

It was generally recognized by the Subcommittee [illegible] exercise [illegible] very cold conditions [illegible] heat exchange was likely to be greatly affected by the [illegible] moisture could diffuse from the skin to the outside air. The experience of one member of the Subcommittee on the U.S. Army Alaskan Expedition (1942) drew attention to the problem of the accumulation of [illegible] [illegible] out from the skin in the clothing. In experiments in the cold room this was frequently observed when a rubberized coverall was used. Information obtained [illegible] (0[illegible]400) showed that men experienced in outdoor constructional and logging work in very wet con[illegible] had expressed the view that the outer clothing must not be impermeable to water vapour. A similar opinion was received from men working in dry cold conditions on the [illegible] (Edmonton to Whitehorse). In view of these general field observations discussed above, a [illegible] work was undertaken on the exchange of moisture through clothing. The first step was the development of a test method for measuring the vapour permeability (02655). The resistance of a fabric or other material was estimated in terms of the thickness of a layer of still air having an equal resistance. With this [illegible] it was possible to obtain a simple theoretical description of the distribution of water vapour in clothing (after achievement of a steady state) with known exercise and in known external environments. Experimental results are in accord with expectation.

Work on tropical clothing was limited to certain special problems in view of the small number of investigations [illegible]. The theoretical analysis of heat exchange first made in connection with cold conditions was extended to include the effect of the sun's radiation and of evaporation of sweat (02[illegible]). Indices were derived to represent solar heat load and the heat stress on a man under tropical conditions [illegible] various thicknesses of clothing.

## Thermal Insulation of Ambient Air

### General Considerations and Effect of Air Movement

[illegible] already pointed [illegible] the surface of a man's clothing to the outside air (except of course under conditions of extreme heat). In other words, the air surrounding a man has an insulating effect. Loss of heat [illegible] surface of the

clothing (or from the bare skin) takes place partly by [illegible] (see page 28). The portion [illegible] air movement [illegible] independent of air movement, [illegible] function of the emissivity of the surface of the [illegible] the thermal insulation of an air [illegible] when the thickness of the air exceeds [illegible] small value (see p. 22), the thermal [illegible] a certain definite and characteristic value, dependent on the degree of air movement. The results obtained by Winslow, Gagge [illegible] transposed to Clo units [illegible] in Table IX.

TABLE IX.

[illegible] to be used at all Temperatures

| | | | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.85 |
|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.39 | 1.37 | 0.85 | 0.57 | 0.40 | 0.34 |
| Air movement ft./min | 4,500 | 2,000 | 1,030 | 425 | 210 | 120 | 75 | 50 | 35 | 30 |
| [illegible] | 2,280 | 1,015 | [illegible] | 216 | 107 | 61 | 38 | 25 | 18 | 15 |

[illegible] - Insulation of [illegible]

[illegible] is defined [illegible] page 47. These results can also be expressed by the equation $I_A = \frac{1}{0.61 + 0.19\sqrt{V}}$ Clo

where the term 0.61 represents the radiation and the term $0.19\sqrt{V}$ represents the convection which is dependent on the [illegible] (V) here expressed in cms./sec.). [illegible] of the air ranges from [illegible] practically still air down to 0.1 Clo in a wind [illegible]. The change of insulation with change of [illegible] velocities (Table IX) the values given apply to men in a 'semi-reclining' position. The effect of posture on the insulation of the ambient air is not known.

Consideration was given to the question as to [illegible] thermal insulation of the air could justifiably be assigned standard values for different degrees of air [illegible] independent of the temperature. For the range of [illegible] experienced in actual practice this procedure [illegible] to be valid [illegible]. With reduction of air temperature [illegible] given gradient of temperature) by radiation decreases, but loss by convection increases;

[illegible] counterbalance one another [illegible] is [illegible].

[illegible] Curvature of [illegible]

The values given above are applicable to the [illegible] as a whole. However, in the case of the thermal insulation of [illegible] a part of the body having [illegible] as a finger, a correction has to [illegible] because of the curvature of the surface. The effect of [illegible] on the thermal insulation of a surrounding fabric [illegible] has already been analysed by [illegible] Dilla. It [illegible] heat passes from the surface of the cylinder or sphere through a layer of fabric wrapped around it, the surface area across which the heat is passing be[illegible] increasing distance outwards through the [illegible] the passage of heat is facilitated. Obviously, the greater the curvature the greater is the effect. Application [illegible] of this principle to thermal insulation of the outside air, which may be regarded as a layer surrounding the surface of the body, has shown that the correction to be applied becomes significant in the case of parts of the body as small as the finger. This is discussed further under 'gloves' on page 92.

Effect of Altitude

At high altitudes the loss of heat from the [illegible] by convection will be less owing to reduction in the density of the air. The effect can be calculated from the equation already given (page [illegible]) by adjustment of the term [illegible] loss (0.19, becomes 0.19 density of air at altitude / density of air at ground level). [illegible] of air under very still conditions ([illegible] cms./sec.) would be about 1.1 Clo at 34,000 feet although only 0.85 Clo at sea level. For greater degrees of air [illegible] change is less.

[illegible] in Respect to a Clothed Man

For a man wearing an R.C.A.F. winter flying suit [illegible], the insulation of the air [illegible] amounts only to about 15% of the total insulation [illegible] outside the man. Therefore any loss produced by air movement can only amount to quite a small fraction of the total (so long as the wind does not penetrate [illegible] and so influence the insulation of the clothing). On the other hand, the cooling effect of wind on the bare face is very marked, because the whole of the insulation is in the surrounding air, and may drop by [illegible] conditions are intermediate and the [illegible] completely wind proof.

For a man to remain comfortable, the rate of [illegible] production in his body must equal the rate of loss of heat from it; otherwise the temperature of the body will change. Heat loss [illegible] water part by [illegible] convection from the skin, and to a [illegible] from the skin and lungs. (The heat lost through each of these different pathways [illegible] by Winslow, [illegible] and Gagge, [illegible]). [illegible] at which a man can [illegible] comfortable depends on the [illegible] power of the clothing he is wearing and on his state of activity.

[illegible] in the description of the 'warmth' of clothing, a new physiological unit of insulation [illegible] and Gagge, Burton and Nevett, [illegible] such that 1 clo [illegible] necessary to maintain [illegible] a man sitting inactive at sea level in a room at [illegible] is that 1 clo shall be [illegible] insulation of clothing which will maintain in comfort [illegible] change of body temperature) a 'sitting reading' man of [illegible] per square metre of body surface per hour in a 'normally ventilated' room of air movement 20 ft./min. or [illegible] relative humidity of the air less than 50 %. From physiological information it is concluded that this condition will [illegible] fulfilled when 1 clo = 0.18 °C [illegible] Kilocals/Hr Sq Metre [illegible] clo unit is therefore so defined. Many people in Canada and the U.S.A. dress for sitting in a room at [illegible] over [illegible] and so wear slightly under 1 clo.

[illegible] for the use of a unit of thermal resistance [illegible] already [illegible] resistance of the various layers of the clothing may be added together to give the resistance [illegible] of the whole clothing. Thermal insulation could perhaps, for scientific purposes, be [illegible] in terms of some more fundamental physiological unit. However, the clo has in fact proved useful for the simple expression of necessary information to military authorities [illegible] naturally more concerned [illegible] than with scientific [illegible]. Another practical way of expressing [illegible] would be in terms of the equivalent thickness of still air, just as has been done for vapour permeability.

## Insulation Needed for Comfort

[illegible] thermal insulation needed to maintain a [illegible] without change of body [illegible] [illegible] activity and of [illegible] temperature, has been predicted ([illegible]) from [illegible] of the body. These [illegible] have been consistently verified in the work [illegible] in the cold room. For an example of the method of prediction, we may start with the knowledge that a total of 1.[illegible] clo (1.[illegible] clo for the clothing and 0.[illegible] clo [illegible]) is sufficient to keep a sitting [illegible] temperature gradient between the [illegible] room (21° C ) of 12° C. For a [illegible] three times as steep, that is for a [illegible] of [illegible] the total insulation must be [illegible] the man remain [illegible] supplied by the clothing, so that if a flying suit [illegible] worn over R.C.A.F. winter uniform (1.0 clo) under [illegible] thermal comfort have a [illegible] insulation of [illegible]

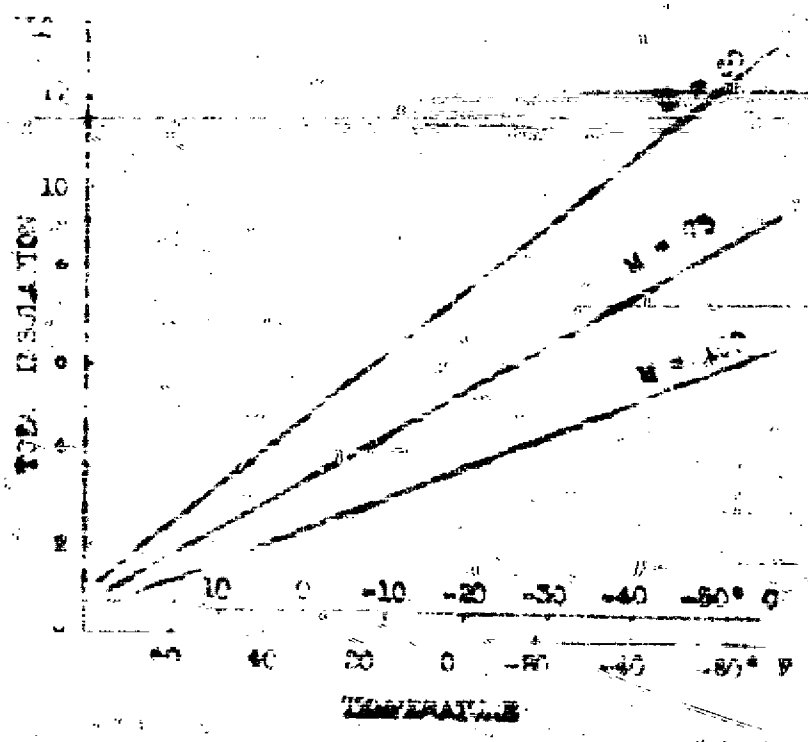
[illegible] showing the total insulation necessary under various conditions of environmental temperature and metabolism, has been derived [illegible] for purposes of calculation. In the fundamental equation of heat balance, shown on page [illegible] the average [illegible] temperature under comfortable conditions has been taken [illegible], the evaporative heat loss as [illegible] of the metabolic heat, and the rates of heat production and heat loss of the body as equal, so that no cooling of the tissues takes place. The following conclusions may be drawn from the [illegible]

[illegible]) The comfortable temperature for a man wearing a heavy flying suit (e.g. R.C.A.F. flying suit, Type [illegible] with coverall, 2.7 clo) is around freezing point.

[illegible] extra heating) to dress [illegible] to enable him to sit [illegible] for prolonged periods at temperatures around 0° F (-17° C) without impossibly bulky [illegible] shown later, for the best [illegible] represented by a thickness of [illegible] to be not less than 1½" thick.

FIGURE 12

TOTAL INSULATION REQUIRED FOR COMFORT
UNDER VARIOUS CONDITIONS OF ACTIVITY
AND OF ENVIRONMENTAL TEMPERATURE.
(THIS INCLUDES THE LAYER OF AIR AS WELL AS OF CLOTHING)



[illegible] clothing is needed; for [illegible] with double the metabolic rate of a [illegible] man, as in walking at 3 m.p.h. the total [illegible]

[illegible] of more. For shorter periods [illegible] possible to remain reasonably comfortable even though the insulation of the clothing is insufficient [illegible]

[illegible] for comfort at any given environment [illegible] in best [illegible] by convection. This is especially [illegible] since a very large part of the transfer of heat through fabrics apparently takes place by convection [illegible] altitude then at ground level, and the insulation of the [illegible] increased (see page 4[illegible]). Clothing [illegible] feet. Although [illegible] have [illegible] prediction [illegible] experimental confirmation has been made [illegible]

[illegible] of the thermal insulation [illegible] of the [illegible] lowest temperature [illegible] any feeling of chill. However [illegible] conveniently with an artificial [illegible] study [illegible]

[illegible] than of component [illegible] the [illegible] of air space [illegible]

However, all this heat is not [illegible]

[illegible]

[illegible] This must be proportional [illegible]

[illegible] as follows:

$$M + e = a = 0.04\ (T_a - T_s)$$

[illegible] and $T_s$ are in [illegible]

[illegible] temperatures

[illegible] units done in this way has [illegible] consistent within 0.3 [illegible] A [illegible] discrepancy is probably due to differences [illegible]

[illegible] to seal the air in an underlying pad

[illegible]

[illegible] air [illegible]

[illegible] shirt, battledress, socks [illegible]

[illegible] as used [illegible]

[illegible] 5.4
[illegible] and seracord cover [illegible]

[illegible] method is by [illegible] man [illegible]. This consists of a hollow model of a man which can be dressed in the flying suit [illegible] late the warmed air [illegible] a thorough circulation of heat. The heater is controlled by a thermostat within the model [illegible] on during a [illegible] period can be measured [illegible] stat has been set to maintain body temperature [illegible]

[illegible] of a clothed man [illegible] this is not essential provided that the temperature difference between the model and the room is large. The total insulation is equal to the temperature difference divided by the metabolic rate per unit area of the model. Since the temperature of the inside of the model is used (and not the skin temperature), the [illegible] insulation includes 'tissue insulation' provided by the [illegible] of the model. Allowance is made for 'tissue' and air insulation in a blank experiment on the naked model.

Results obtained with the artificial man are consistent with those got by the analysis of heat balance [illegible]

[illegible]

If a man sits in flying clothing at a temperature well below the comfort temperature for the clothing [illegible] perature, and later a fall of rectal temperature [illegible]

[illegible] in deep body temperature [illegible]
[illegible] cooling of the deeper tissues [illegible]
[illegible] the surface. Then there is a slow rise
[illegible] which usually [illegible]
[illegible] Throughout this period
[illegible] of warmth and well being

[illegible] to determine
exposure to cold in this way impairs a man's
[illegible] causes of inefficiency in the cold

[illegible] of indifference to duty owing

[illegible] of nervous mechanisms due to reduced
[illegible]
of fingers).

[illegible] were
[illegible] for the hands.
[illegible] coordination and
[illegible] reaction time were
[illegible] Under conditions of extreme
[illegible] the subjects showed some deterioration
[illegible] reaction time. Most marked in the worst cases of
[illegible] could be found with body tem-
[illegible] Closely followed discomfort,
[illegible] that the effects of exposure to cold would be
[illegible] in the performance of a complicated task such
[illegible]

An unknown connection between [illegible]
[illegible] obtained with a urine thermometer (CP042) used on Atlantic
[illegible] considerable exten-
[illegible] conclusions may be drawn.

[illegible] Insulation of Clothing: Warm Conditions

[illegible] under warm conditions and out of doors [illegible]
[illegible] into consideration (CP[illegible]) in the measurement
[illegible]
[illegible] clothing while [illegible]
[illegible] absorption
[illegible] the heat passes inwards to the skin
[illegible] while

[illegible] to the outside air. Similarly [illegible] [illegible] later [illegible] [illegible] skin, and some from the outside [illegible] radiation which passes to [illegible] to that passing to the outside air is [illegible] the ratio of [illegible] [illegible] outside the [illegible] [illegible] [illegible] with [illegible] [illegible] evaporation at some [illegible] [illegible] [illegible] in [illegible] analogous to the [illegible] [illegible] parallel but not [illegible] resistances. Thus, the fraction of the [illegible] [illegible] which affects [illegible] point of absorption $\frac{I_a}{I_o + I_a}$ [illegible] total insulation [illegible] physiological efficiency [illegible] similarly the fraction [illegible] by evaporation within the clothing [illegible] the body

insulation outside point of evaporation

Total insulation

[illegible] heat evaporates directly from the skin and thus water vapour passes out as such to the outside air, then practi- [illegible] the heat absorbed will be drawn from the [illegible] [illegible] which [illegible] evaporates at the skin, condenses to water at a [illegible] within the clothing a little way out, then wicks [illegible] [illegible] clothing and finally [illegible] [illegible] [illegible] is attained in which the rate of evaporation from the outside of the wet layer is equal to the rate of condensation [illegible] from a simple evaluation of the [illegible] condensation, and re-evaporation, [illegible] efficiency of evaporation ($f_E$)

Total insulation

Accordingly the basic equation of heat exchange given on page 50 can be modified to take account of solar radiations and of evaporation of sweat as follows:

$$[illegible] = [illegible] + [illegible] + [illegible] + [illegible] + [illegible]$$

[illegible] heat in Cals/sq.M./Hr.

[illegible] evaporative heat loss from the skin in Cals/sq.M./Hr.

[illegible] from the respiratory tract [illegible] M./Hr.

[illegible]

[illegible]

[illegible] the degree of air movement [illegible]

[illegible] of the clothing in Clo [illegible]

[illegible] which with the [illegible] and [illegible] is [illegible], and with [illegible] is [illegible]

[illegible] on the man, expressed in Kilo- [illegible]

[illegible] per [illegible]

[illegible]

[illegible]

[illegible] of solar radiation on a man can be [illegible] as an increment to the environmental air temperature ([illegible]). This can be demonstrated by rearrangement of the equation given immediately above [illegible]

[illegible]

[illegible] the term [illegible] is additive to [illegible]

[illegible] temperature ([illegible]) this term includes [illegible] solar radiation and the insulation of the air, and is independent of the clothing worn. Values for the [illegible] environmental temperature appropriate to various degrees of solar radiation absorbed at the surface [illegible] the clothing are given in Figure 13. From the figures given by Blum (1945) it appears that for an erect man the [illegible] at the [illegible] of the [illegible] radiation) may be taken as around 150 Kilocalories per square metre of the man's surface per hour with a clear sky and with olive drab clothing having a reflecting power of [illegible] it therefore [illegible] conditions in the sun the appropriate increment to the environmental temperature may even exceed thirty Fahrenheit degrees ([illegible])

[illegible]

[illegible] various criteria have been suggested for the heat stress imposed on a man in given clothing under [illegible]

[illegible] rate which could be [illegible] with a steady state has also been suggested as [illegible] the rate of [illegible]

[illegible] in terms of these various criteria has

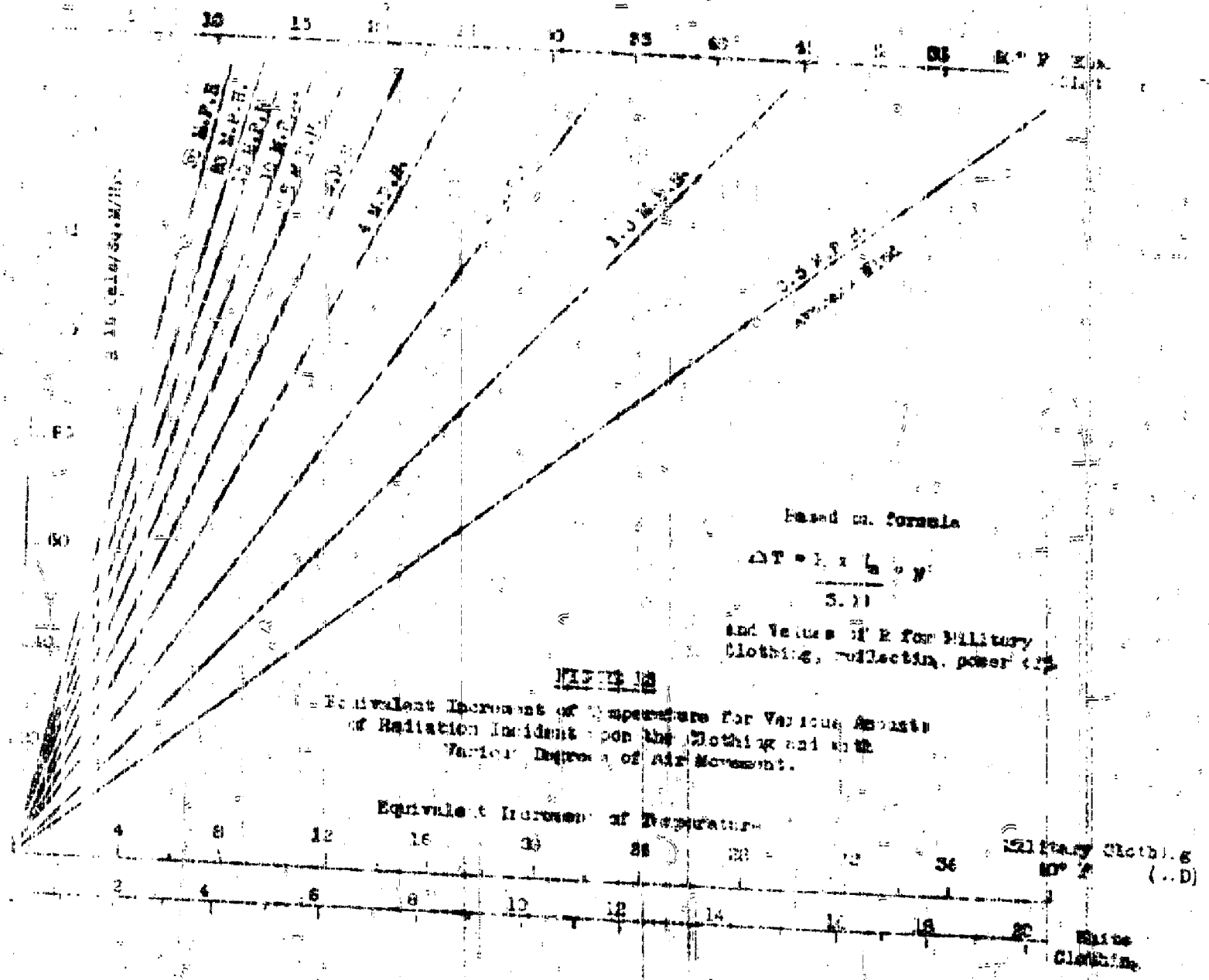



FIGURE 18

Equivalent Increment of Temperature for Various Amounts of Radiation Incident upon the Clothing and with Various Degrees of Air Movement.

[illegible] mental conditions and [illegible] predicted that [illegible] would [illegible] rate or by [illegible] without change in the garments worn would decrease heat stress. This is [illegible] by the evaporative loss necessary to maintain a steady state, the effect of extra clothing will depend on whether the environmental temperature exceeds the critical temperature [illegible] increase of thermal insulation is beneficial above the critical environmental temperature, since it reduces the inflow of heat. At low temperatures the addition of thermal insulation adds to the heat stress.

## Distribution of Moisture in Clothing

[illegible] investigation was made of the distribution of moisture [illegible] of men sitting or [illegible] and [illegible] subjects wore cotton vest, cotton shirt, wool battledress and cotton [illegible] patches of the material were removed after suitable periods from each garment over the shoulder blades. The relative humidity in equilibrium with the patches was [illegible] of the fabrics (approximately [illegible] by means of thermocouples. The vapour pressure in equilibrium with the patches was estimated from the relative humidity and the temperature. [illegible] this procedure can only be used for [illegible] of the relative humidity or vapour pressure at positions within the clothing when [illegible] steady state has been attained in respect to the thermal and vapour gradients.

[illegible] at low temperatures it was possible for the subjects to exercise fairly strenuously without sweating. This of course is in accordance with [illegible] the observations of previous workers. At low temperatures the vapour pressure at the skin was very low; during part of an experiment at 10°C it was around 3 [illegible] This is to be expected [illegible] consideration of the gradient of [illegible] and the outside. The wetted area (W) of the skin was described by Gagge as that [illegible] of the total area of the skin which if completely [illegible] of evaporation [illegible]

[illegible] purposes of the present analysis the skin may [illegible] regarded as a system of [illegible] minute wet points from [illegible] vapour [illegible] At a very short distance [illegible] the diffusion shells emanating from these [illegible] to form a uniform layer the [illegible] which will be determined by the [illegible] ability at skin temperature in pro- [illegible] wetted area, and the actual vapour permeabi- [illegible] in proportion to the non-wetted area of the skin. Thus the vapour permeability [illegible] regarded as a weighted average of that of the [illegible] and of the [illegible] $W)P_0$. [illegible] evaporation [illegible] clothing may be expressed as follows.

$$[illegible] \frac{W)P_0 + P_0}{[illegible]}$$

$$\frac{W(P_{[illegible]} - P_0)}{[illegible]}$$

[illegible] rate of evaporation of water,

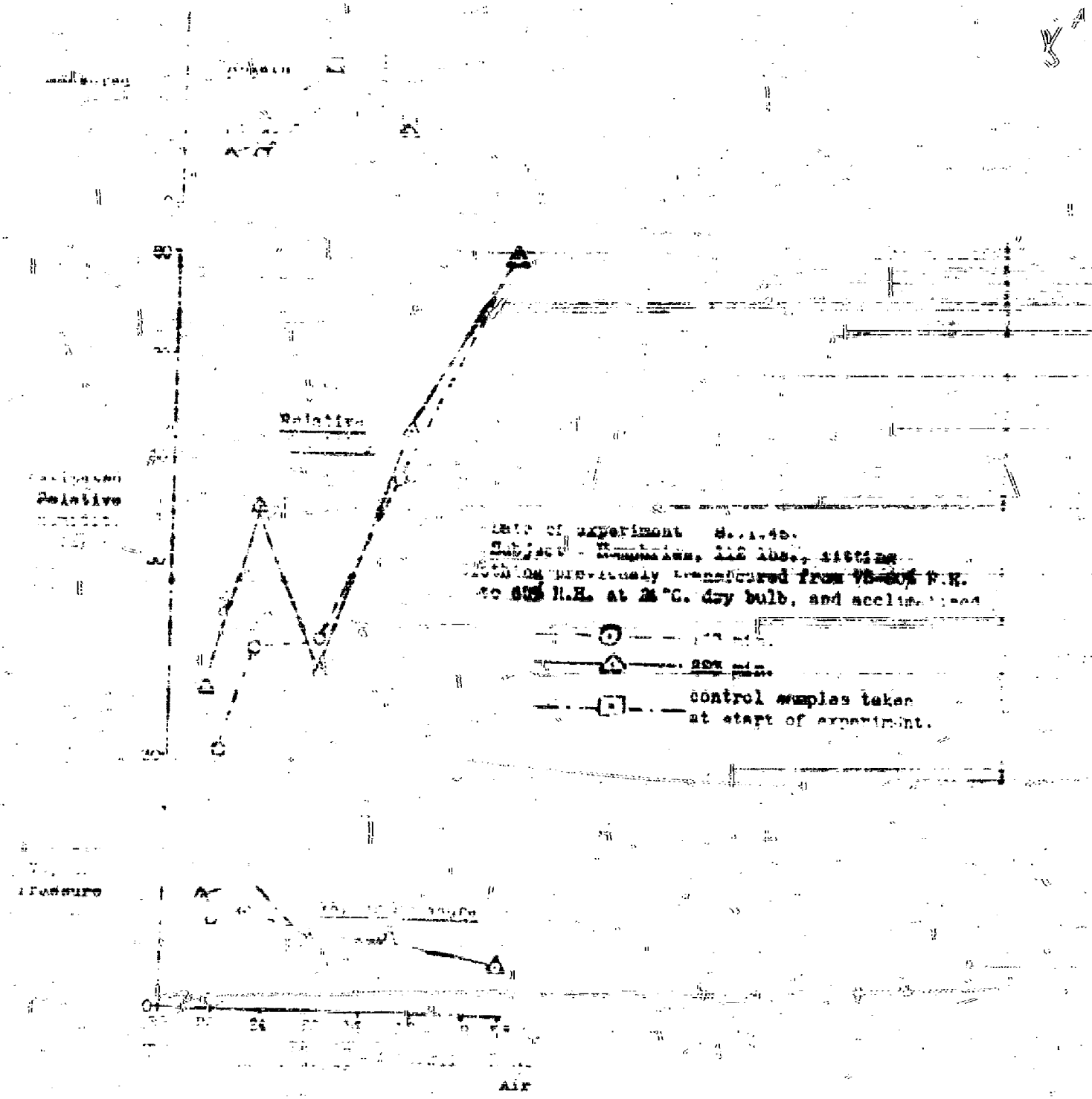
[illegible] the wetted area of the skin

[illegible] the [illegible] vapour pressure at skin temperature

[illegible] the [illegible] environmental at- [illegible]

It has been shown that the thermal insulation [illegible] of fabrics of the density of those used in ordinary clothing, including that used in these experi- [illegible] slightly less than that of still air [illegible] the temperature of the different layers of cloth- [illegible] may be [illegible] of their distribution [illegible] between the skin and [illegible]

[illegible] clothing under consideration was of [illegible] as a very rough approximation the vapour [illegible] conditions of a steady state may be expect- [illegible] from rectilinear. The results (Figures [illegible] and [illegible]) of experiments conform with this expectation. [illegible] some cases it is clear that equilibrium has [illegible] that the physiological state of the [illegible] taken for the [illegible] steady state emphasized the practical [illegible] of the previous history of the clothing that is, what before use the clothing should be well dried




Distribution of Moisture in Clothing.

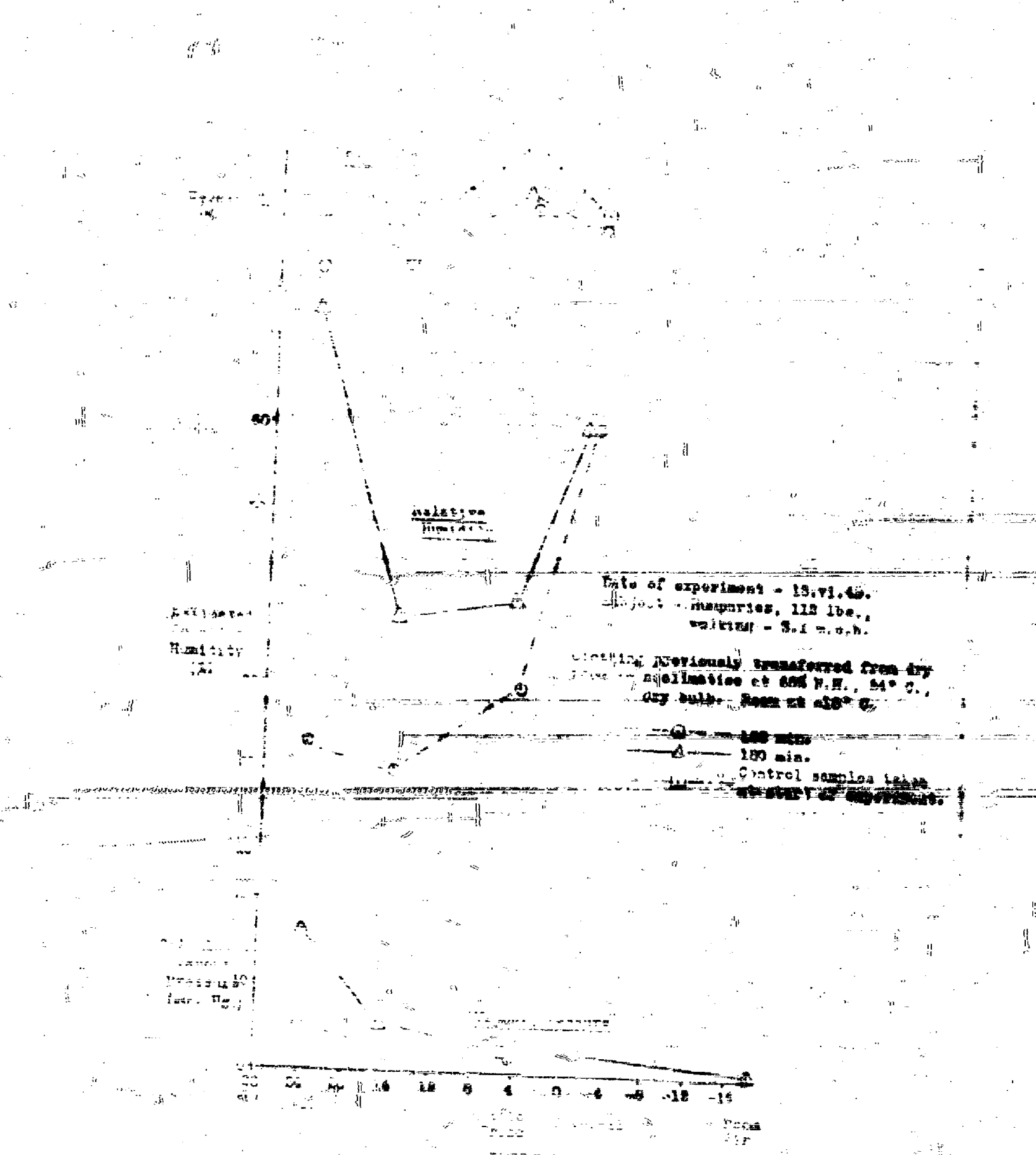
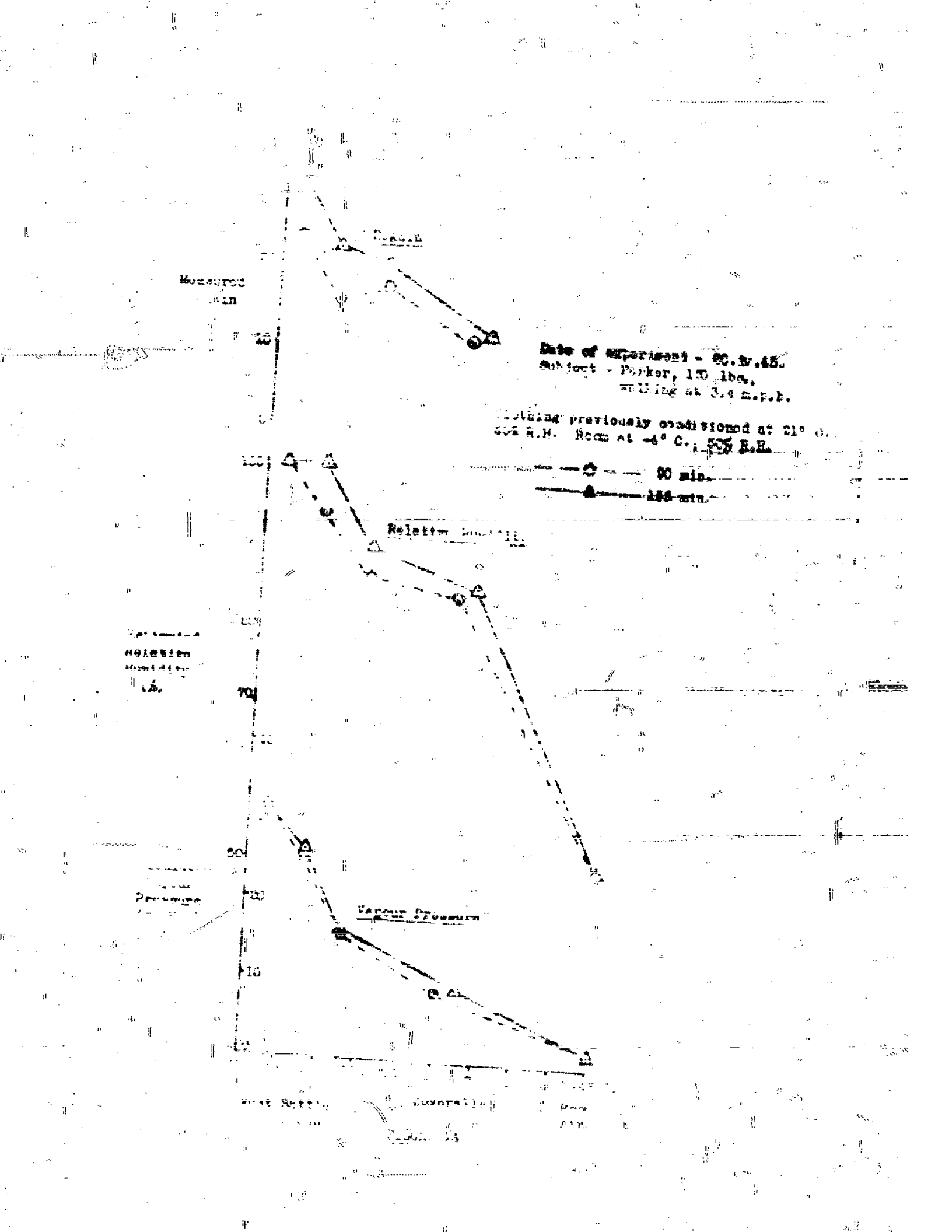



FIGURE 15

[illegible] humidity in clothing.


Date of experiment - 20.iv.45.
Subject - Parker, 150 lbs.,
walking at 3.4 m.p.h.
Clothing previously conditioned at 21° C.
50% R.H. Room at -4° C., 50% R.H.
90 min.
Relative Humidity
Relative Humidity
Pressure
Vapour Pressure
Rest Setting
Overall
Room Air

[illegible] clothing during [illegible] and consequently [illegible]

[illegible] things such as [illegible]

[illegible] compression [illegible] to be measured under [illegible] in service wear.

[illegible] were carried out in which the subject, in full flying clothing, was seated [illegible] aircraft seat with his feet resting on the floor. A small rubber bag [illegible]

[illegible] connected to an air [illegible] recording. At a given air flow [illegible] was recorded until the point was reached at which the bag [illegible] fell off appreciably and the manometric pressure at that point was taken to be that imposed on the bag. In order to determine accurately this point of deflection in rate [illegible] drum was then spun back to the starting [illegible] the second tracing [illegible] the apparatus was carefully [illegible]

[illegible] of two very restricted areas [illegible] the [illegible] but only to 3 lbs. [illegible] pack or pushion. Compression loads on the back [illegible] lbs. [illegible]

[illegible] region and under [illegible] these are holding a pencil or other object [illegible]

[illegible]

[illegible]

[illegible] receivers and the [illegible] These

[illegible] was carried [illegible]

[illegible] development of a new [illegible]

[illegible] the auspices

[illegible] summer flying [illegible] time the development of a [illegible] (Meeting 3) in [illegible] request from the [illegible] The service requirements [illegible] that the [illegible]

[illegible]

[illegible] investigate [illegible] flying conditions [illegible] of the [illegible]

[illegible] made to [illegible] with a [illegible]

[illegible] this [illegible]

[illegible] continued on the [illegible] of an [illegible] helmet [illegible]

[illegible] of 600 airspeed [illegible] head measurements made [illegible]

[illegible] originally [illegible] suitable for fitting all [illegible] The most important feature of the new [illegible]

[illegible] helmets of the series [illegible]

[illegible] in this respect [illegible] attempt was made to improve [illegible] the support

[illegible] increase [illegible] intensity of the [illegible]

[illegible] in a training [illegible]

[illegible] recorded [illegible] ear (C24[illegible])

[illegible] low frequencies, sponge rubber was [illegible] was fair, and [illegible]

[illegible] sponge rubber [illegible]

[illegible] records of [illegible] series of [illegible]

[illegible] results (C2418, C2404) [illegible] marked improvement [illegible] with the Type [illegible]

[illegible] with the [illegible] measurements [illegible]

[illegible] (Type C-7) [illegible]

[illegible] acoustic properties [illegible]

[illegible] service trials in R C A F training stations [illegible] the trials and assisted [illegible] [illegible] for minor improvements were made. It was produced under R C A F [illegible] [illegible] helmets having been recalled.

[illegible] in view of the existence of [illegible] [illegible] their acoustic properties [illegible] ring pads and receiver holders (similar [illegible] mesh helmets) were sewn [illegible] and load loaded rubber shields were [illegible]

Further work on the acoustic properties of [illegible] transferred (meeting 19) to the Subcommittee [illegible] equipment.

Flying Goggles

[illegible] protect the [illegible] interfering with other equip[illegible] they should not cause discomfort during wear. The [illegible] are therefore indicated:

[illegible] contact area.

lifting or slipping off position;
[illegible] [illegible] of [illegible]
[illegible] of [illegible]
Adequate ventilation to prevent [illegible] [illegible] chilling [illegible]

Issue R C A F Goggles (Type A) were not en[illegible] [illegible] and [illegible] [illegible] Clinical Investigation Unit [illegible] the Subcommittee [illegible]

Fig. 17. Flying helmet Type C and flying goggles Type B, together with intercommunication and oxygen installation.

Fig. 18. Mann helmet and Dominion Goggle Company's flying goggles.

[illegible] 1946).

A modified version of the [illegible] Mark [illegible] [illegible] by the development of an entirely [illegible] type of goggle, the first prototype of which was completed [illegible] (C2500). This consist- [illegible] rubber frame of oval shape [illegible] which was [illegible] sheet of optically true transparent [illegible] (cellulose acetate [illegible] changed to ethyl cellulose). A continuous window was thus provided from side to side. An indentation in the lower middle section provided room for the nose and upper part of the oxygen mask. Ventilation was affected by [illegible] holes perforated through the frame in the same place as the window and immediately behind it. The frame was slightly curved and pliable enough to mould to any type of face contour. The amount of curvature imposed on the plastic sheet was not so great, relative to the thickness of the sheet, as to cause any image distortion [illegible] was found [illegible] and was greater than with other goggles tested (H.A.M. Mark [illegible] and issue [illegible] (C2502). Spectacles could be worn with the goggle. It was also noted that goggles offered good [illegible] protection and would have a [illegible] effect in the event [illegible] tests conducted in a wind tunnel showed that the [illegible] was sufficient to maintain the goggles in place in a wind of [illegible] m.p.h. ([illegible]).

Many alterations had to be made before the [illegible] The composition [illegible] was investigated since dermatitis may be caused by certain [illegible] of anti-oxydants [illegible] processed [illegible]. A special technique was developed to carry out tests for rubber dermatitis. It was found that when certain ingredients were left out of the rubber mixture, the incidence of dermatitis [illegible] (C2504). [illegible] was carried out primarily in conjunction with the use of reclaim rubber in oxygen masks.

The method of fastening the plastic window to the frame was improved. The plastic sheet was inserted in a groove [illegible] [illegible] by two rubber lugs situated at the midpoint of [illegible] and lower edges of the frame, respectively, and passing through holes in the plastic [illegible] [illegible] also permit [illegible] [illegible] than [illegible] any distortion of [illegible] of the goggles [illegible] early prototype where the sheet was anchored to the [illegible] by several [illegible]

[illegible] cloth [illegible] [illegible] face.

[illegible] at each side [illegible]

[illegible] experienced with the [illegible] [illegible] of elastic and webbing [illegible] A completely elastic suspension [illegible] finally [illegible] conflicting criticisms on that point [illegible] field testings

[illegible] tests showed the goggles [illegible] fogging better than [illegible] [illegible] at Camp Borden, early in [illegible] that the Type D goggle was [illegible] for [illegible] [illegible] pockets which [illegible] interchangeable receivers [illegible]

The goggles were [illegible] in June, 1943. No [illegible] case was provided although it was agreed that a case would be of value in promoting good care of the goggles and in preventing unnecessary scratching of the [illegible]. An envelope was [illegible], however, to shield extra lenses.

In the summer of 1944, comparative field trials were held of the [illegible] and that manufactured by the Dominion Goggle Company (associated with [illegible] Corp.). The latter goggle is similar [illegible] the face (Figure 16). Airmen preferred it very much to the [illegible] chief complaints of the latter [illegible]

(2) [illegible] fit, [illegible] around nose [illegible]
(3) Poor structural [illegible]
(4) Slippage [illegible] on landing.
[illegible] while landing with hood [illegible]

It was therefore recommended that [illegible] necessary consideration [illegible] goggles for R.C.A.F. become [illegible] to replacing the present [illegible] Dominion Goggle Company's Type 3.0 or [illegible] the R.C.A.F. discontinued production of the Type D goggle and adopted the Dominion [illegible]

[illegible] illustrates a development in which excellent [illegible] was made but in which our further progress [illegible] firm with far greater facilities for

## [illegible] Suits

[illegible]

[illegible] the early [illegible] of the [illegible] types of flying suits were [illegible] a loose fitting one piece [illegible] linen coverall (flying suit, Type B), and a [illegible] kapok ("cropall") garment with [illegible] windproof coverall buttoned onto it [illegible] suit was found [illegible] to deteriorate [illegible] the fireproofed [illegible] of the [illegible] cover in a [illegible] detrimental to the distribution of thermal [illegible]

Current knowledge [illegible] to the expectation that protection against cold would be a serious problem for military aviation. Accordingly, the physiological and physical testing of the thermal insulation of flying suits was [illegible] (see pages 49-51). A number of different types of flying suits were compared and it was shown that none of [illegible] insulation to protect a man indefinitely at the low temperatures prevalent at high altitudes [illegible] suits tested during the [illegible] pile wool fabric [illegible] thermal insulation [illegible]. Accordingly, [illegible] was modified to Type D having a double [illegible] quilted kapok lining, and the suit was [illegible] flying personnel in limited quantities by the [illegible]

The chief [illegible] in fact almost the only, source of [illegible] as to service problems in the early part of [illegible] report on the results of [illegible] flying clothing [illegible] questionnaire [illegible] clothing. Of those [illegible] (including both operational and training personnel) [illegible] quilted kapok suit (Type D) or the [illegible] suit (Type B). The two principal complaints [illegible] neck and [illegible] especially at the [illegible] Accordingly, [illegible] suit (Type D) was [illegible] closed having greater [illegible] previous [illegible] used in [illegible] with [illegible] new tailoring [illegible] sensation of bulk. This work was [illegible] particular with [illegible] of that

The type E flying suit [illegible]

[illegible] are carried by [illegible] overlapping of the [illegible]

[illegible] the opening [illegible] open completely [illegible]

[illegible] incorporating [illegible]

[illegible] front bottom [illegible] suit worn [illegible]

[illegible] bulk, and the [illegible] are designed to fit loosely [illegible]

[illegible] are detached

[illegible] glove [illegible] are tapered

[illegible] by the flying [illegible]

[illegible] places not covered by

[illegible] A parka hood is en-

[illegible]

The type E suit [illegible] outer shell, [illegible] quality cotton [illegible] lined [illegible] slippery material and [illegible] double pile wool fabric also lined [illegible] the body. These [illegible] are held together [illegible] for purposes of drying.

The type E winter [illegible] by the R.C.A.F. [illegible] was commenced in 1942, and the suit was issued to [illegible] operational aircrew as soon as [illegible]

[illegible] development work on winter fly [illegible] consisted in improvement of the type E flying [illegible] particulars of the component fabrics and [illegible] an extensive study was made of windbreak covering materials, with a view to reduction of weight. A survey (02500) was made of the parts of flying suit which showed the most deterioration by wear. It appeared that by application of leather patches at suitable positions the weight of the overall sound safely be reduced considerably. It seems unfortunate that this suggestion did not win more approval. The double pile fabric was [illegible] modified in collaboration with Messrs. Collins and [illegible] of Farnham, Quebec, a lighter [illegible] more flexible [illegible] was introduced by means of a reduction in the number of [illegible] the ground fabric [illegible] fabric had equally good resistance [illegible] compression, and [illegible]

[illegible] kinds of fibres [illegible] but no change [illegible] alternative [illegible] developed (02405) [illegible]

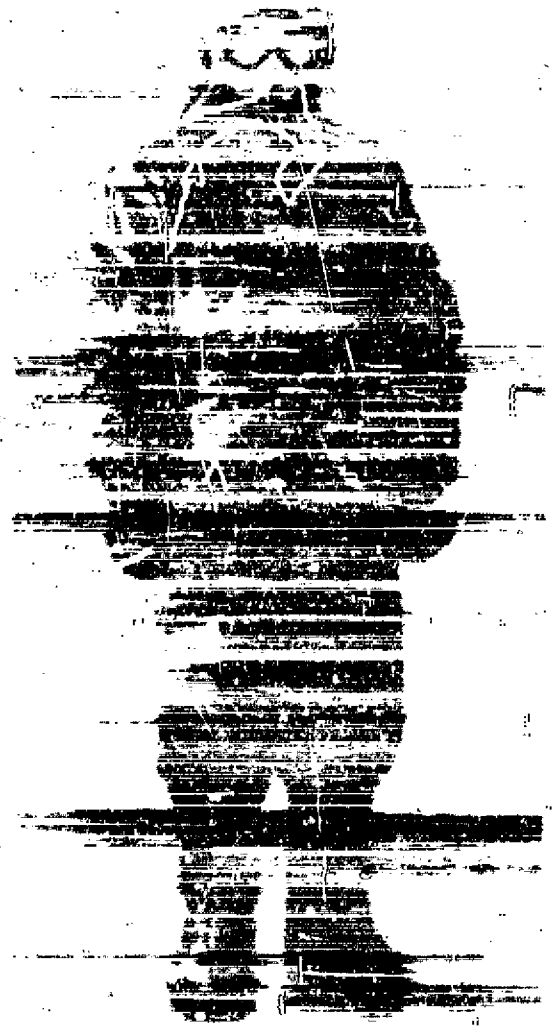


Fig. 19. Winter flying suit, Type B, mesh helmet and Dominion Goggle Company's flying goggles, flying boots Type A, winter flying gloves Type B.

[illegible] flying suits which were [illegible]

The general popularity of the type [illegible] suit is known by the results of a [illegible]

[illegible] offered most [illegible] collar was [illegible] the suit were also criticis[illegible] of men offering the [illegible] the [illegible] feature [illegible] the [illegible] release [illegible] [illegible] of [illegible] crews often but not always [illegible] the [illegible]

[illegible] Winter Flying Suits

An investigation of the [illegible] properties of coverall fabrics was [illegible] [illegible] increase in flexibility [illegible] [illegible] and heaviness caused by [illegible]

A field investigation of the state of wear of flying suits in service was showed that the heavy British cotton coverall fabric known as [illegible] [illegible] [illegible] [illegible] [illegible] information [illegible] [illegible] the rifs of the [illegible] [illegible] flying suit. Such signs of wear [illegible] [illegible] and back [illegible] [illegible] lighter coverall [illegible] at positions of wear. A [illegible] was [illegible] A sample [illegible] was [illegible]

[illegible] pile fabric underlying it (C2611) [illegible] that available covers might [illegible] in such a [illegible] might be

[illegible] in relation to service needs. It [illegible] air permeability below [illegible] for a different of air pressure corresponding to a inch of water was of little benefit [illegible] velocity was low. On the other hand, with [illegible] movement the permeability to air becomes [illegible] low (see page [illegible]). Unfortunately there is no extensive information available as to the air movement at various positions in aircraft used in the [illegible] although a simple instrument is available for [illegible]

[illegible] investigated [illegible] three groups:

(i) Cotton [illegible] twill
(ii) [illegible]
(iii) Rayon warp and cotton weft [illegible] twill [illegible]
[illegible] and [illegible]

[illegible] group is represented by [illegible] Only, the second by a range of fabrics designed by the United States Office of the Quartermaster General, and by a similar British fabric known as 'Canadas'; the third group [illegible] United States [illegible] with [illegible] improvement carried out in collaboration with Grants Limited, St. [illegible]

[illegible] results obtained in the [illegible] of fabrics is given in table [illegible] [illegible] and others not [illegible] [illegible] is calculated [illegible] replacement by fabrics of group (ii) would reduce the weight of the type x flying suit [illegible] (iii) have [illegible] shiny and slippery, so that if one of [illegible] need for a slippery [illegible] would [illegible] a further weight reduction of about 1½ lbs.

TABLE XI

[illegible] Coverall [illegible]

| Trade name | [illegible] | U.S.Q.M.C. Cotton | U.S.Q.M.C. Cotton | Canadian Cotton | English Cotton |
|---|---|---|---|---|---|
| [illegible] | [illegible] | 80 54 | 80 69 | 80 63 | 80 64 |
| [illegible] | [illegible] | Cotton | Cotton | Cotton | Cotton |
| [illegible] | [illegible] | [illegible] oz | 9.3 oz | 9.7 oz | 10.2 oz |
| [illegible] | [illegible] | [illegible] | 115 | 130 | 140 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

| | | Sateen | Sateen | Sateen | Sateen |
|---|---|---|---|---|---|
| | | Sateen | Sateen | Sateen | [illegible] |
| [illegible] | | | | | [illegible] |
| [illegible] | | | | | [illegible] |
| [illegible] | | | | | |
| Strength Weft (lbs) | 248 (9) | 167 (6) | 167 (7) | [illegible] (7) | 203 (9) |
| Tear Warp | 14 (7) | 6½ (4) | 12 (7) | 6½ (5) | 19 (7) |
| [illegible] | 16 (7) | [illegible] | [illegible] (8) | 8 (5) | 19 (9) |
| [illegible] | | | | | |
| [illegible] | [illegible] | [illegible] | (10 & 7) | 30 & 30) | (10 & 10) |
| Air Permeability | 11(8) | 4½ (10) | | 2 (10) | 7½ (9) |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Water Repellency | | | | | |
| [illegible] | | | | | |
| [illegible] | | | | | |
| [illegible] | | | | | |
| [illegible] | | [illegible] oz. | | [illegible] oz. | |
| [illegible] | | [illegible] oz. | | [illegible] oz. | |
| [illegible] | [illegible] | [illegible] | Herringbone Twill | Tackle Twill | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| Composition | Cotton | Cotton | Cotton | Cotton | |
| Wt./Sq.Yd. | 9.2 oz. | [illegible] oz. | 10.0 oz | [illegible] oz. | |
| Ends/Inch | 224 | 230 | 255 | 224 | |
| Picks/Inch | [illegible] | 22 | 30 | 60 | |
| Weave | [illegible] twill | 5-end sateen | 5-end sateen | [illegible] twill | |
| Warp Yarn | [illegible] den | 150 den | 150 den | 150 den | |
| Weft Yarn | [illegible]/42's | [illegible]/42's | [illegible] | [illegible]/42's | |
| [illegible] | | [illegible] | [illegible] | [illegible] | |
| [illegible] | | [illegible] | [illegible] | [illegible] | |
| [illegible] | | [illegible] (10) | [illegible] (9) | 275 (10) | |
| [illegible] | | [illegible] | [illegible] | [illegible] | |
| [illegible] | | | [illegible] | [illegible] | |
| [illegible] | | | | [illegible] | |

[illegible] Aerotwill Aerotwill Tackle Twill

[illegible]

water [illegible] [illegible]

[illegible]

[illegible]

Yarn [illegible]

[illegible] remaining fabrics when both breaking [illegible] to [illegible] by the tongue [illegible] are considered [illegible] The weakening of rayon while moist [illegible] to recommend any fabric containing it accordingly [illegible] was recommended [illegible] for flying [illegible] and parkas.

[illegible] the investigation [illegible] considerable [illegible] of fabrics was carried out [illegible] the appraisal of [illegible] results re- [illegible] has been [illegible] the tests [illegible] likely that field [illegible] some of the more important overall [illegible] would facilitate the general [illegible] laboratory tests.

[illegible] flying suits

[illegible]

(1) Shearling [illegible]
(2) [illegible] in winter flying [illegible]
(3) Double pile fabrics (e.g. in winter flying [illegible]

The relative merits of the best [illegible] of each of these four classes of materials have not been established beyond question. For this purpose a very extensive investigation [illegible] materials [illegible] effective [illegible] and thermal [illegible] be compared in respect of lightness and [illegible], permeability to water vapour, and any other [illegible] in which differences might occur. [illegible] of methods of testing now available, [illegible] investigation could be carried out. It is of no use to compare different types of materials having [illegible] such properties as compressibility [illegible]

[illegible] comparison received consideration in [illegible] solution to protect it from [illegible]. This treatment is [illegible] for it impermeable to water vapour, which is [illegible] may lead to accumulation of moisture in [illegible] the relative merits of those and of pile fabrics remain quite obscure. It is possible that quilted materials will prove to be as good as any other type of [illegible] it appears that the percentage [illegible] in thickness of a pile fabric with pressure is greater the longer is the pile. It is reasonable to expect that a double pile fabric will have a greater resistance to [illegible] and of the same initial thickness. This fact [illegible] the excellence of the double pile fabrics used in the type B suit (and subsequent subtypes).

[illegible] in [illegible] flying suits was made with a pile of [illegible] quality wool. For reasons of supply this was changed to a blend of thin and coarser qualities. There did not appear [illegible] significant disadvantage in the use of lower qualities, although the comparison was not made with the [illegible] The use of cotton [illegible] or rayon in the pile proved disadvantageous. There was [illegible]

[illegible] to hold the pile in (meeting 13). Adequate tuft binding power was [illegible] while the [illegible] flexible than the [illegible]

[illegible] of Kapok in flying suits [illegible] has suggested the possibility [illegible] in the thermal [illegible]

[illegible] the double pile fabric buoyant by means [illegible] [illegible] buoyancy when tested [illegible] [illegible] consequently on buoyant flosses [illegible] [illegible] satisfactory buoyant [illegible] [illegible] be impaired to [illegible] [illegible] of the possibility of obtaining the necessary [illegible] of the double pile fabric [illegible] water [illegible] Since precision had to be made for inter- [illegible] in accordance with change of altitude [illegible] Oxford cloths rather than coated [illegible] the outside cover. The possibility of obtaining adequate buoyancy in this way was demonstrated [illegible] that considerable manufacturing difficulties would arise, and that the resulting [illegible] [illegible] buoyancy is of great importance, so that this system could only be applied to certain limited areas of the suit.

[illegible] proofing of double pile [illegible] [illegible] the methods of cleaning flying suits con- [illegible] [illegible] the thickness of the double pile [illegible] It was considered probable that the enrinkage [illegible] be serious, although no tests were carried out on whole garment.

[illegible] fasteners:

[illegible] jacket and slap pocket [illegible] flying suit are closed by means of [illegible] the jacket must open [illegible] slide fasteners must [illegible] completely so as to be separable. Undoubtedly the slide fasteners in winter flying suits [illegible] [illegible] not surprising that a considerable number of failures have occurred in flying suits and other [illegible] As a result of [illegible] tests of flying suits (C2210), [illegible] [illegible] the suits, it was concluded that proper engagement of the [illegible] of the fasteners [illegible] in the prevention of failures. There is also considerable strain imposed on the tapes in [illegible] the separable ends while these latter [illegible] being engaged, and fouling of the tape in these regions [illegible]

[illegible] these failures, special center [illegible]

[illegible] used in R.C.A.F. clothing.

[illegible] for the fasteners [illegible] facilities [illegible] R.C.A.F. flying clothing. The [illegible] Fastener Company of [illegible] were made [illegible] requirements for the strength of [illegible] and light duty type were [illegible] slide fasteners [illegible] used in R.C.A.F. contracts.

Miscellaneous

Miscellaneous work on flying suits included [illegible] business, based [illegible] internal [illegible] a one-piece worker [illegible] significant [illegible] of this [illegible] of [illegible] was made [illegible] and [illegible] treated was [illegible] treatment was [illegible]

Electrically Heated Clothing

[illegible] the formation [illegible] clinical [illegible] heating over [illegible] was given [illegible] cases) in accelerated cooling of the body. Modifications were suggested [illegible]

[illegible] constant at [illegible] levels in spite of wide [illegible] was also made of the whole [illegible]

[illegible] for the [illegible] were [illegible] Engineering in [illegible] with suggestions [illegible] accepted.

[illegible] of electrically-heated clothing [illegible] with specifications [illegible] the Subcommittee in June 1949 [illegible] clothing [illegible]

[illegible] with radio [illegible]

[illegible] was represented as urgent. [illegible] only possible [illegible] electrically-heated suit already [illegible] of the earlier work already [illegible] agreed meeting at [illegible]

[illegible] underboots, to be worn as [illegible] flying suit [illegible] flying gloves (Type [illegible]) and flying [illegible] that the control of [illegible] the Wolodarsky suit, simplified [illegible] and underboots. Twelve [illegible] were required as soon as possible.

[illegible] elements and thermostats were [illegible] with plugs was [illegible] to the hands [illegible] underglove [illegible] simple automatic [illegible] were designed [illegible] with Mr. Wolodarsky, and samples were tested in the cold chamber and found satisfactory (02412, [illegible]). Mr. Wolodarsky [illegible]

[illegible] half [illegible]

[illegible]

[illegible] in England has caused [illegible] was later [illegible]). Since no flight trials [illegible] likely to be carried out in Canada, and [illegible] understood that thermostats of the type used [illegible] R.C.A.F. engineers, it was [illegible] to work alternative [illegible] to the smallest [illegible] which could not be [illegible]. It was under- stood that it was now possible for [illegible] the electrically-heated [illegible] to be produced in Canada. Therefore it was [illegible] [illegible] with minor modifications [illegible] the distribution of heat, with the power consumption [illegible] regulation of [illegible]

[illegible] proved unreliable. However, an [illegible] was designed [illegible] in the cord of the undersuit. This regulator eliminated [illegible]

[illegible] in the design of the [illegible] from the [illegible] with Mr. Reginald Hinchey (of [illegible]). [illegible] during subsequent production.

Each [illegible] of R.C.A.F. electrically-heated [illegible] following [illegible]

[illegible] (large, medium or small, complete with [illegible] socket) [illegible] pair undergloves [illegible] gas regulator) [illegible] medium, small).

[illegible] that the [illegible] not represent the [illegible] could produce [illegible] Representative [illegible]

[illegible] was able to produce with limited time for fundamental investigation and while limited [illegible] immediately available on a restricted market.

[illegible] experiences in the development [illegible] electrically-heated clothing was put at the disposal of the Canadian General Electric Company [illegible] April, [illegible]. Representatives of that Company's parent [illegible] brought electrically-heated [illegible] Armed Services to [illegible] Consultations. It is believed that this con- [illegible] experience [illegible] the U.S. National [illegible]

[illegible] follows of the general principles [illegible] electrically-heated clothing, as evolved by [illegible] experience and of the various component articles of electrically-heated clothing developed.

[illegible]

[illegible] general [illegible] for electrically- [illegible] as a result of the [illegible] experience in the field. They are summarized as follows (not in any order of merit):-

[illegible] in service. The use of any component liable to failure is to be avoided - elements and connections should be resistant to [illegible] arising from repeated [illegible]. There [illegible] circuits arising either from [illegible] interconnections or from [illegible] insulation over elements. Wires should not cross if this can be avoided. Heating should [illegible] parallel circuits, not [illegible] or two circuits interruption of which would cause extreme failure of the suit.

[illegible] of testing and servicing at [illegible] experience has made clear the importance of testing electrically-heated clothing before and after each flight.

[illegible] aircraft equipment. [illegible] communication [illegible] consumption of power must be within [illegible] aircraft [illegible].

Convenience [illegible] of the suit should make it convenient to put [illegible] flight, and take off [illegible] [illegible] shortened

[illegible]

[illegible] the level of activity of the wearer [illegible] ... [illegible] of auxiliary heating [illegible] ... [illegible] be such as to maintain the normal [illegible] body (Q213b).

[illegible]

[illegible] a reasonable measure of protection under the conditions of [illegible] in case [illegible] failure of [illegible]

[illegible]

[illegible] is [illegible]

[illegible] single [illegible] attain [illegible] of testing and ease of production [illegible] require simplicity of design; whereas the [illegible] requirement of heat [illegible] complex electrical system. However it has been found [illegible] which (as in the present [illegible] electrically-heated [illegible]) the physiological [illegible] design [illegible]

[illegible]

The amount and distribution of [illegible] heating [illegible] such as to maintain the skin and deep body temperatures at [illegible] loss of heat [illegible] sitting man. The wearer of electrically-heated clothing [illegible]

[illegible] by an ex[illegible]

[illegible] of clothing described on page 47 [illegible] are provided in the clothing [illegible] the clothing (of insulation $I_1$) is between the [illegible]

[illegible] flow must be considered [illegible] the skin (at temperature $T_1$) and the heating elements (at temperature $T$) across insulation $I_1$ [illegible] elements (at temperature $T$) and the outside air [illegible] insulation $I_2$ [illegible] of the air).

In the first system, body heat ($M + S - E$) [illegible] the level of the [illegible] equation [illegible]

$$M + S - E = \frac{0.87\,(T_s - T)}{I_1}$$

In the second system, body heat and heat provided electrically ($H$) are passing from the level of the heating elements to the outside air. This heat is described as follows:

$$M + S - E + H = \frac{0.87\,(T_s - T)}{I_2 + I_a}$$

By [illegible] of these two equations the unknown temperature [illegible] we have

$$H = \frac{0.87\,(T_s - T_a) - (M + S - E)\,(I_1 + I_2 + I_a)}{I_2 + I_a}$$

It is obvious that a given amount of electrical heating is more effective if applied near the skin than if near the outside of the clothing. Electrical heating [illegible] the same effect on the skin temperature as would an equal amount of metabolic [illegible] This may be regarded as representing 100% efficiency. [illegible] of electrical heating may then be defined by [illegible] extra metabolic heating which would be required to keep a man in a thermal steady state (i.e., the amount which would just prevent a decline of body [illegible] given same conditions to the electrical [illegible] required to produce the same effect when applied as [illegible] By an extension of the treat- [illegible]

$$100 \times \frac{\text{total insulation outside heating elements}}{\text{total insulation surrounding the man}} = 100 \times \frac{I_2 + I_a}{[illegible]}$$

[illegible] heating needed for a range of [illegible] degrees of acti-
vity of the man, and for different values of thermal
[illegible] outside the heating elements.
[illegible] the nomogram (Figure [illegible]) constructed by
Mr. [illegible]
[illegible] from the [illegible]

[illegible] best distribution of heat will be [illegible]
[illegible] restrict the rate of heat loss from the various
surfaces [illegible]
[illegible] In this
[illegible]
[illegible]
ed for each part of the body [illegible]
of heat loss [illegible]

[illegible]

[illegible] conditions this [illegible] loss will be practically
[illegible] area, except at certain
[illegible]

[illegible] should be distributed evenly except at
[illegible]
will be relatively larger for a given area, since the
[illegible]
[illegible] than that of
the flying suit. Nevertheless [illegible] of the body
[illegible]
[illegible] of the total
total heat should be allocated to each extremity (C2[illegible])
if too much heat is applied [illegible]
[illegible] in spite of the fact that the body
as a whole is losing more heat than it is producing (C3040)
[illegible]
[illegible] do. The following distribution has
been recommended (C2401) for electrically-heated clothing
to fit under flying clothing such as that used by the
R.C.A.F.

| | |
|---|---|
| [illegible] | [illegible] |
| Sleeves (together) | [illegible] |
| [illegible] | [illegible] |
| [illegible] (together) | [illegible] |

The distribution of heating required for the hands and
[illegible]
[illegible] The greatest
[illegible] the fingers, toes,
and heels. Suggested [illegible]
[illegible]
[illegible] the best distribution for all parts of the body.

[illegible] temperature, and that the dis-
[illegible] are practical [illegible].

[illegible] Heating

[illegible] control of heating in distr[illegible]
[illegible] first suggested to the Subcommittee [illegible]
[illegible]

[illegible] object of [illegible] control is to maintain the
[illegible] at the same levels as would be
[illegible] not too [illegible]
[illegible] may be done perfectly by a
[illegible] of circuits controlled by thermostats
[illegible] the whole [illegible]

[illegible] temperature [illegible] less [illegible] control
[illegible]

[illegible] of thermostats [illegible]
[illegible] in a [illegible] from the [illegible]

[illegible]

[illegible] control of heating [illegible] heating of the suit [illegible]
[illegible] from the suit [illegible]

[illegible] with the
[illegible] heating [illegible]
[illegible] also be different [illegible] of the
control [illegible] from what it is around the man

[illegible] in accordance with Mr. Wolodarsky's
widely distributed thermostats. These thermostats are set
to close [illegible] so that they
[illegible] the same part of the
[illegible] a single thermostat usually
[illegible] the current, [illegible]
[illegible] the cold room showed that the thermostats operate
[illegible]

[illegible] are [illegible] it is clear that
[illegible] control
[illegible] as already stated [illegible] the tem-
[illegible] temperatures [illegible] be adjusted
[illegible] which are [illegible] satisfac-
[illegible]

[illegible] because it is
[illegible] because it is more

[illegible]

REQUIREMENTS FOR ELECTRICALLY HEATED CLOTHING

[illegible]

[illegible]

All figures apply to back
except the [illegible] indicated for the palm.

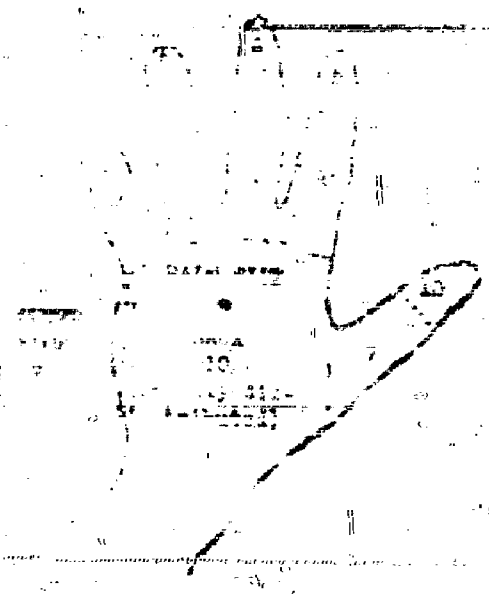


FIGURE [illegible]

[illegible]

[illegible]

because it makes use of slow-acting [illegible]

[illegible]

It is questionable whether it is necessary [illegible] at all to make [illegible] closely regulated [illegible] darsky suit (C2316). For [illegible] provided by the Soloroom the wearers of electrically [illegible] suits in the cold [illegible] power was turned off or on, even when the duration of a single cycle [illegible] amounted to fifteen minutes or more [illegible] [illegible] subcommittee as to whether [illegible] exposed to special [illegible] shielding [illegible] protection [illegible] the Solodarsky system. [illegible] would no [illegible] system were made. As regards the [illegible] have been [illegible] tests were [illegible] interference. This was reduced to a negligible [illegible] the introduction [illegible] the suit (meeting 13). Tests [illegible] carried out [illegible] of the [illegible] of the [illegible] After 12,000 cycles some of the thermostats tested showed a change of setting amounting [illegible] and there was a tendency towards pitting of the contacts. [illegible] thermostats were also [illegible] position (Duchaste, 1942). The amount of radio interference caused by thermostats which had been used for some [illegible] the thermostats was not sufficiently [illegible] the stability of respect. [illegible] ensured. In this [illegible] the use of [illegible] thermostats was not without foundation [illegible] engineers to [illegible]

[illegible] slow-acting [illegible] then obtainable [illegible] of the system [illegible] This opposition led to [illegible] device [illegible] principle of established [illegible]

[illegible] attempt was made to control the heat [illegible]

[illegible] the suit [illegible] such a [illegible] relay or [illegible] of a larger and [illegible] slow-acting variety [illegible] would [illegible] periods the thermostat [illegible] by the heat [illegible]

[illegible] the heating elements in its neighbourhood; and the thermostat would be affected so as to give an average [illegible]

[illegible] extremely [illegible] was this surpris- [illegible] in the flying suit [illegible] of the wearing of extra clothing underneath it, would affect it.

[illegible] that the thermostat would [illegible] placed outside and away from the flying suit, and heated [illegible] the body (in relation to which its [illegible] practice constant) but by a small independent [illegible] artificial source of heat under its control. The [illegible] of controlling electrical heating [illegible] external mechanism had already been suggested (C2[illegible]). The problem of constructing a small and very simple external heat regulator, suitable for placing in the cord of the electrical [illegible] in the following way (C2219). A thermostatic switch, controlling the [illegible] to the flying suit, was installed in a [illegible] box or housing. A short length of resistance wire, [illegible] cable cylinder, was fixed close to [illegible] switch, and also placed under its control so as to be 'on' when the suit was 'on' and 'off' when the suit [illegible]. The heat regulator was adjusted to operate in accordance with the requirements [illegible] which it was to be used [illegible] temperature above which no auxiliary heating at all was [illegible] the containing mechanism was not unduly greater than it would be in [illegible] a man [illegible] resistance of the heater be- [illegible] at and above which the full heating [illegible] temperature the [illegible] of time 'on' [illegible] the average power consumption of the suit [illegible] to the external temperature, with slight [illegible] response to air movement [illegible] were got in tests carried [illegible] at various temperatures with a model heat regulator made up in this way (C2219).

[illegible] of a heat regulator constructed [illegible] were produced commercially [illegible] were tested [illegible] and were [illegible]

[illegible] a more suitable type [illegible] switch, and the modified regulator [illegible] was used with a later production lot of electrically-heated clothing. A type for installation [illegible] in aircraft was also designed [illegible] [illegible] modification [illegible] [illegible] vane which [illegible] the thermal [illegible] of the regulator (meeting 49). It is not known to what [illegible] cooling conditions at places in the aircraft [illegible] might be [illegible] representative of those [illegible] crew members.

A heat regulator of the general design outlined above can be used to control the [illegible] electrically-heated suit without thermostats. Detailed instructions have been [illegible] (C2427). The use of [illegible] enables an electrically heated [illegible] to be used [illegible] under these conditions. [illegible] also gives complete protection from overheating due to short circuiting as well as [illegible] compensation for [illegible] voltage of the aircraft (C2427). The thermostatic switch [illegible] of a [illegible] the load imposed [illegible], so that no significant deterioration is expected during a long period. Provision is made for short circuiting the thermostatic switch so that even when this is open the suit can be tested for purposes of inspection or at stations. On the other hand a heat regulator does not compensate for [illegible] [illegible] activity of the man.

[illegible]

Undersuits of [illegible] types were provided for test [illegible] by the [illegible]. These undersuits are for wear [illegible] [illegible] the winter flying suit [illegible] [illegible] was designed by Mr. [illegible] [illegible] comfortable [illegible] to meet the [illegible] of the [illegible]. It contained heating elements consisting of [illegible] conductors on a glass core with a braided glass [illegible]. [illegible] [illegible] an elaborate [illegible] [illegible] [illegible] distribution of temperature [illegible] (see page 70). This suit [illegible] [illegible] [illegible] on the [illegible] side [illegible] [illegible] in the setting of the [illegible] by the R.C.A.F. to any equipment [illegible] slow-acting thermostats led to the abandonment

of this type of suit

The second type of undersuit (type B) (Figure 24) [illegible] slightly from that used by the [illegible] (Beacon Bros. Limited) in [illegible] requirements as to distribution and amount of heating. The heating elements [illegible] in the taylor [illegible] The heating elements consist of a steel and constantan [illegible] enclosed in a flame-proofed wrapping of fabric which is stitched into the suit [illegible] of parallel [illegible] side of the [illegible] in the first production [illegible] as in the [illegible] the two [illegible] circuits [illegible] used with a [illegible] of 24 volt supply [illegible] the belt pad was [illegible] already occurred in the R.A.F. [illegible] dup-shaped insulation [illegible] washer was [illegible] and [illegible] connection to the [illegible]

Electrically-heated [illegible]

Electrically-heated gloves [illegible] to meet certain [illegible] in [illegible]. The standard [illegible] consists of three separate parts, a rayon in- [illegible] a wool middle part, and a leather outer part. It has proposed that the electrically-heated [illegible] the inner glove in this three-part combination [illegible] of this arrangement is that the electrically-heated glove, like the [illegible] inner glove, could be re- [illegible] removed in order to permit the wearer [illegible] carry out tasks [illegible] manipulation skill.

[illegible] part should be [illegible] necessary to [illegible] the arrangement increases the [illegible] the thickness [illegible] heating elements [illegible] distribution of heating is critical [illegible]

[illegible] test was carried [illegible] It is [illegible] precision that a [illegible] was not [illegible] time available to check the [illegible] greatest [illegible] of the fingers; hardly any was needed on the palm. For the lowest temperatures (40 to [illegible] F.) it was considered [illegible] at more moderate temperatures it was sufficient [illegible] Accordingly it was decided as a practical compromise to use heating on the back of the hand only.

Experimental undergloves were constructed with [illegible] to place a single thermostat in the palm of the back of the hand in order to control the heating in accordance with the requirements for the palm mental temperature. Instead of heating by a single thermostat [illegible] at any moment the current must go either [illegible] or totally off. Control of the average power con[illegible] greater by variation in the proportion of time during which the current is on. It is necessary for the [illegible] to be sufficient for the palm but to [illegible] the average power consumption below that appropriate to the environmental temperature, it was found [illegible] should not exceed 10 [illegible] seconds with these particular gloves. It is to be noted that this result is only applicable to a glove in which the elements are close to the skin. Accordingly the [illegible] the length of the wire and the setting of the thermostat were adjusted so as to obtain the required cycling time and control of average power consumption. Gloves constructed in this way [illegible] Molotarsky gave satisfactory protection against cold in [illegible] lasting up to 5 hours at low temperatures ranging [illegible] 20 to [illegible] F. under [illegible] still conditions [illegible]

As a result of objections [illegible]

[illegible] half or full heating could be obtained [illegible]

[illegible] by the [illegible]

The [illegible] electrically-heated under[illegible] [illegible] is made of a [illegible] rayon fabric the same as that used for the [illegible] part of the [illegible] flying glove type [illegible] [illegible] the thickness of the rayon fabric on the palm side; on the back there are [illegible] together to form channels for the heating elements. The heating elements and the method of incorporating them in the glove are those [illegible] [illegible] Mr. [illegible] [illegible] glove make electrical connection to [illegible] the [illegible] of the underwear, giving half or full [illegible] is required. The supply of current to [illegible] is independent of the heat regulator of the underwear.

[illegible] heated underboots

[illegible] underboot (Type 20) took place together with that of [illegible] glove, [illegible] same conditions of urgency. It was [illegible] [illegible] (Type 4) and over one or more pairs of [illegible]. Regulation of heating was to be by means of a [illegible] thermostat, but this was later eliminated.

[illegible] was made [illegible] [illegible] [illegible] and reasonable skin temperature [illegible] an experimental underboot was used with [illegible] heating in seven different regions of the foot. [illegible] concluded that 12 watts would protect the foot at [illegible] ranging down to [illegible], under still conditions. [illegible] it is likely that a rather higher [illegible] [illegible] distribution of heating is shown in Figure 22. It will be noted that the greatest concentration of heating is over the toes and [illegible]. None is needed over the [illegible] and upper part of the foot (except at the toes). There was no time to investigate [illegible] permissible.

[illegible] underboots [illegible] [illegible] were designed in collaboration with Dr. [illegible] and along general principles of construction [illegible] by him. The original underboots contained [illegible] the inner side just behind the ankle

[illegible]

[illegible] electrically-heated socks [illegible] equally good results in [illegible] the foot is long [illegible], and there is undoubtedly a reasonable latitude in the amount of [illegible]

[illegible] is made of four layers of material, two layers of [illegible] two layers of cotton flannel cloth which are seamed to form [illegible] the heating elements. The heating elements and the [illegible] of incorporating them are those already [illegible] Two dome fasteners on each [illegible] to the tape on the [illegible] is [illegible] the heat regulator

[illegible] carried [illegible] the 50 underboot and on the Taylor type electrically-heated slipper (made by Deacon Brothers), (one of each [illegible] the same subjects under [illegible] tests amounted to up to 40 miles of [illegible] in the 25 underboots some breaks occurred [illegible] Deacon-Taylor slippers were practically or completely broken in all cases at the heel. From measurements of resistance which were made periodically during [illegible] that the damage began [illegible] It is understood that [illegible] been modified [illegible] used by the [illegible]

Air-heated underboots

[illegible]

Work on the [illegible]

[illegible] would be particularly [illegible] in an aircraft in which hot air heating was already installed but in which this form of heating was [illegible] in turrets owing to the rapid [illegible] heat supplied [illegible] in the [illegible] in the early [illegible] reached a [illegible] the time of the origin of [illegible]

[illegible] as in [illegible]

[illegible]

[illegible] ... [illegible]. There was [illegible]

[illegible] ... tests carried out on [illegible]

[illegible]

[illegible] air [illegible]

[illegible] a series of conducting [illegible] and [illegible]

[illegible] clothing over the [illegible]

[illegible] in this [illegible]

[illegible]

found to give reasonable [illegible] at altitude. [illegible] was

period at temperatures as low as [illegible] for this

temperature [illegible] and by measurements of [illegible]

[illegible] two suits [illegible] was found to provide

It was however necessary for [illegible]

[illegible] flow of [illegible] source of supply [illegible]

[illegible] was [illegible] blower [illegible]

[illegible]

[illegible]

[illegible] the [illegible] and to develop the suit.

The light-weight flying suit (Figure [illegible]) [illegible] a one piece [illegible] fitted [illegible] simplicity of [illegible] has been stressed because instruc- [illegible] their flying suits [illegible] by a [illegible] of quilted wool permanently sewn into the cover. There is a fur collar and knitted wool storm cuffs are fitted at the wrists and ankles.

[illegible] were been prepared with coverings of cotton sateen ('Canadac' - SC 84). 'tackle twill' [illegible] comparative tests may reveal something of the relative capacity of these materials to withstand service wear.

[illegible]

The first project [illegible] and consisted by [illegible] the design of an aircrew suit. In [illegible] of 1942, immediately on the initiation of this [illegible] was given to the Canadian Army battledress, the Royal Norwegian [illegible] (similar to the Canadian Army battledress) [illegible] crew suit. Desirable features of each were selected (C2284) [illegible] be similar to [illegible] of the R.C.A.F. uniform.

[illegible] consideration of records of issue of [illegible] to the R.C.A.F. an approximate [illegible] for the aircrew suit. Subsequently representatives of the [illegible] at No. 1 Initial [illegible] R.C.A.F. [illegible] found that the range of sizes of aircrew suits was satisfactory (C2112).

[illegible] was also given to the style and materials of a summer aircrew suit [illegible] action was [illegible] to produce this.

[illegible]

[illegible] winter underwear is in a [illegible] 40%

[illegible]

[illegible] relative [illegible] as smooth as those made with [illegible] plotted over rayon [illegible]

[illegible] against the skin, but which was [illegible] experiments in [illegible] fabric was recommended [illegible]:

[illegible] Spring-needle machine [illegible] cloth to be lightly napped on [illegible] inside.

[illegible] system would still be considerably superior to the present W.C. & F. underwear but not so expensive as the fabric described above.

In Table XIII is shown a comparison of the skin winter underwear [illegible] underwear.

TABLE XIII

| | W.C. Winter Underwear | R.A.F. Winter Underwear | Proposed New Winter Underwear |
|---|---|---|---|
| | [illegible] wool | Wool plotted on acetate rayon | 60% wool, 40% rayon |
| [illegible] | woollen | worsted and filament rayon | [illegible] |
| | | [illegible] | [illegible] |
| | [illegible] | [illegible] | 44 |

Fig. 29 [illegible]. High [illegible] flying [illegible], [illegible] [illegible] [illegible] Goggle [illegible] [illegible] [illegible], winter flying [illegible] [illegible].

Fig. 30 [illegible]. [illegible] Emergency kit, [illegible] [illegible] and mesh helmet.

[illegible] were long and on [illegible] of two-piece under- [illegible] to be little to choose from [illegible] between good samples of [illegible] types [illegible]. It was considered that the sleeves [illegible] of wind [illegible] should be long, since [illegible] [illegible] on the double covering of the small of the [illegible] the abdomen by two-piece underwear. On the other [illegible] must be [illegible] and must stay together. [illegible] of [illegible] [illegible] and discomfort at the crotch. Perhaps the most convincing argument was that [illegible] practical for general issue, since one half may wear out first and can be replaced [illegible]

[illegible] from [illegible] by the Subcommittee [illegible] and Eastern (Meeting 15) Air Commands, it seems unlikely that [illegible] [illegible] before a [illegible] and it is [illegible]

[illegible]

A brief investigation (C2977) was made of the effect of wearing a 'Brynje' vest on the rate of water loss from the skin and on the [illegible] of the water through [illegible] winter flying clothing. There was a smaller accumulation of moisture in the inner clothing when a Brynje vest was worn instead of an ordinary winter underwear in two subjects sitting or walking for periods of [illegible] minutes. It was considered that the Brynje vest might have value to aircrew having to wait at readiness under [illegible] for cold at high altitudes. No further work was undertaken. It is doubtful if the condition [illegible] operationally, in view of [illegible] of most fighter aircraft.

## FLYING GLOVES

[illegible] carried out (C2977) in [illegible] on subjects sitting in the cold chamber at [illegible] Investigation Unit, of the protection against [illegible] types of flying glove available [illegible] investigation [illegible] glove [illegible] will [illegible] from cold during an

[illegible] at [illegible]

Abandoned experience during an investigation [illegible]

[illegible] under the [illegible]

[illegible] type of flying gloves [illegible] of a sheepskin [illegible] shell with lining of [illegible] or pile [illegible] [illegible] was also attached. [illegible] the fingers [illegible] tight, there was no consistency in the sizes, [illegible] sizes were not available, some of the gloves [illegible] made, [illegible] at the base of [illegible] they were clumsy and stiff because the outer [illegible] have [illegible] side of the hand

[illegible] as to [illegible] the initiative of the investigation [illegible] by unofficial [illegible] there did not exist [illegible] official [illegible] for the purpose

[illegible] that the R.A.F. flying glove, made [illegible] and leather [illegible] particularly adaptable to the various needs of flying personnel. It was there [illegible] to adapt this general style [illegible] protection against cold [illegible] It had [illegible] need.

[illegible] flying glove was designed in collaboration with the Julius Keyser Company, Sherbrooke, [illegible] under the special supervision of [illegible] a [illegible] rayon material was selected, after consideration [illegible] instead of the silk (no longer [illegible] after consideration of a [illegible] of wool gloves from the point of view of [illegible] and after an investigation of the [illegible] (02298), a suitable [illegible] sign of glove was chosen. For [illegible] was given to various [illegible] with several [illegible] a high grade of horsehide [illegible]

[illegible] the [illegible]

[illegible] Company of Kitchener, Ontario

[illegible] fingers was a serious [illegible]

[illegible] in [illegible]

[illegible] gloves. Accordingly Mr. Harris was [illegible]

ed to make gloves with the fingers in the natural position

of rest [illegible]

[illegible] help in establishing con-

tacts with the glove industry and guidance [illegible]

[illegible]

[illegible]

[illegible] three and

the three sizes were checked on the hands of a hundred air-

[illegible] a card

[illegible] to require. A simple instruction

[illegible] prepared, giving information as to the uses,

[illegible] and limitations of the new flying gloves.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] and outer gloves, but may

[illegible]

[illegible]

[illegible]

[illegible] Printed nylon [illegible]

[illegible] gloves, it was found [illegible] increase in thickness [illegible]

[illegible] extended with [illegible]

down for treatment of [illegible]

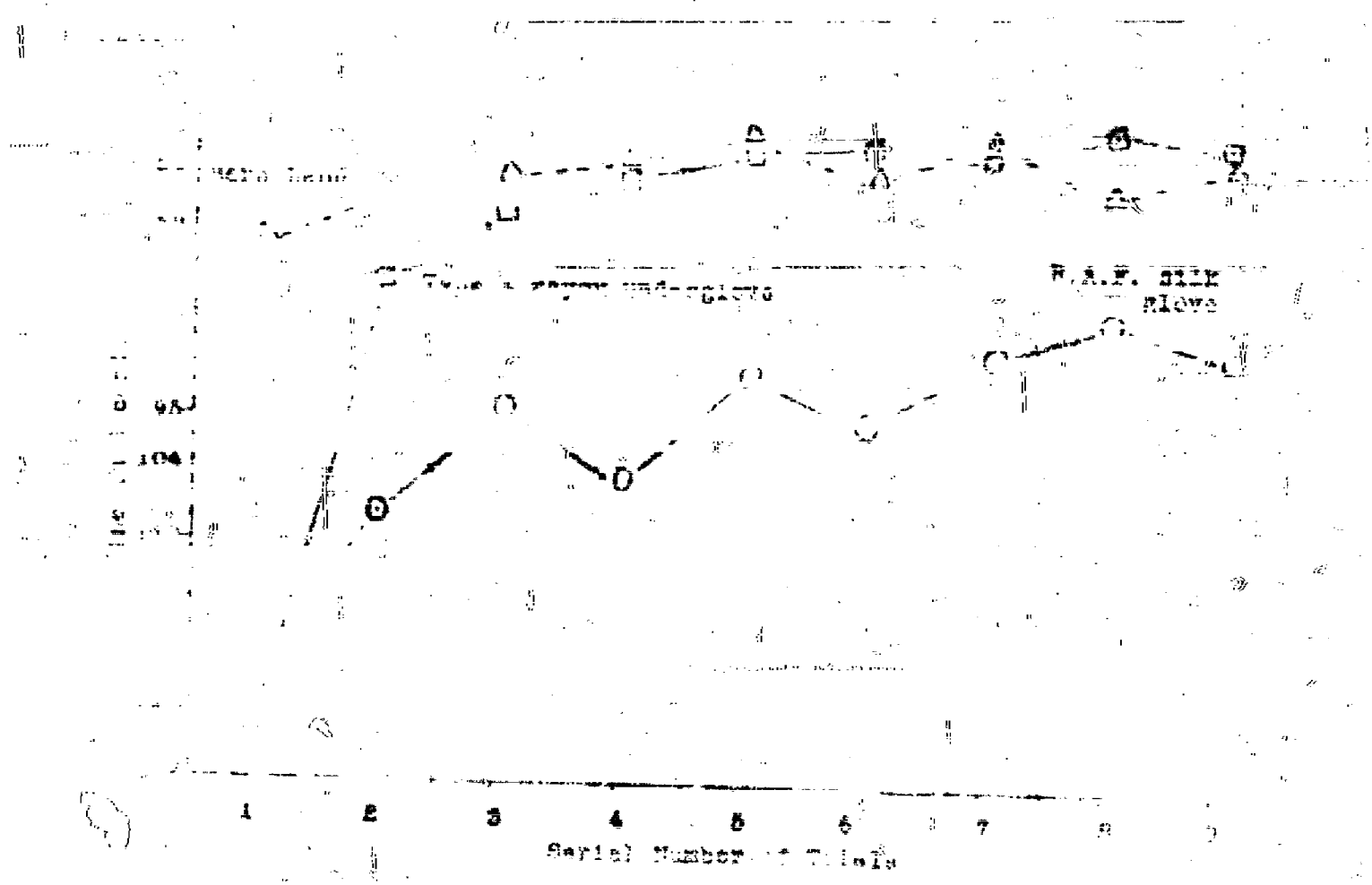
[illegible] was considered stiffer and more [illegible]

[illegible] the arms of the flying suit. [illegible]

[illegible] glove are made [illegible]

[illegible] gloves are removed [illegible] stay inside [illegible] easily be put on to [illegible]

[illegible] have [illegible]




[illegible] pages of the Air [illegible] by

Fig. 3[illegible]. [illegible]ner winter flying glove, Type E, (r[illegible]). (Dark patches [illegible] thumb and forefinger are [illegible] sprayed with latex for better grip.

Fig. 3[illegible]. (Kidd[illegible]) Wool winter flying glove Type E.

[illegible] Boots

[illegible] with rubber sole and [illegible] It is [illegible] walking shoes and high enough to overlap the legs of [illegible] but is not closely shaped to the [illegible] is designed more as a very warm [illegible] being universally [illegible]

[illegible] the first meeting of the [illegible] owing to [illegible] practically all sources of [illegible] natural rubber, it was considered that an alternative design [illegible] no rubber [illegible] understood that [illegible] the [illegible]

[illegible] several unwanted types of boot. Prototypes of flying boots were eventually produced with leather soles, [illegible] 35). The feet were [illegible] or with [illegible] highly [illegible] the [illegible] overlapping [illegible] were not [illegible] since it had been shown that lining [illegible] not necessary, the [illegible] already well [illegible] this area. Various types of [illegible] were incorporated. These new flying boots were designed to fit over two pairs of [illegible] socks [illegible] walking [illegible] the foot, so that they were themselves suitable for walking should the necessity arise. They were approximately [illegible]

[illegible] new flying [illegible] never received service trials [illegible] it was [illegible] that there were adequate supplies of the [illegible] flying boot [illegible] type would make these unacceptable. Neverthe-less [illegible] served a useful purpose in that it [illegible] further used under conditions of acute scarcity of rubber [illegible] substitutes.

## LIFE JACKETS

[illegible]

[illegible] development of a [illegible] jacket for use with a flying suit lacking buoyancy was accepted as a project in April, 1942. (Meeting 4) at the request of the Flying Committee. The requirements given were:

(a) avoidance of use of rubber [illegible]

[illegible]

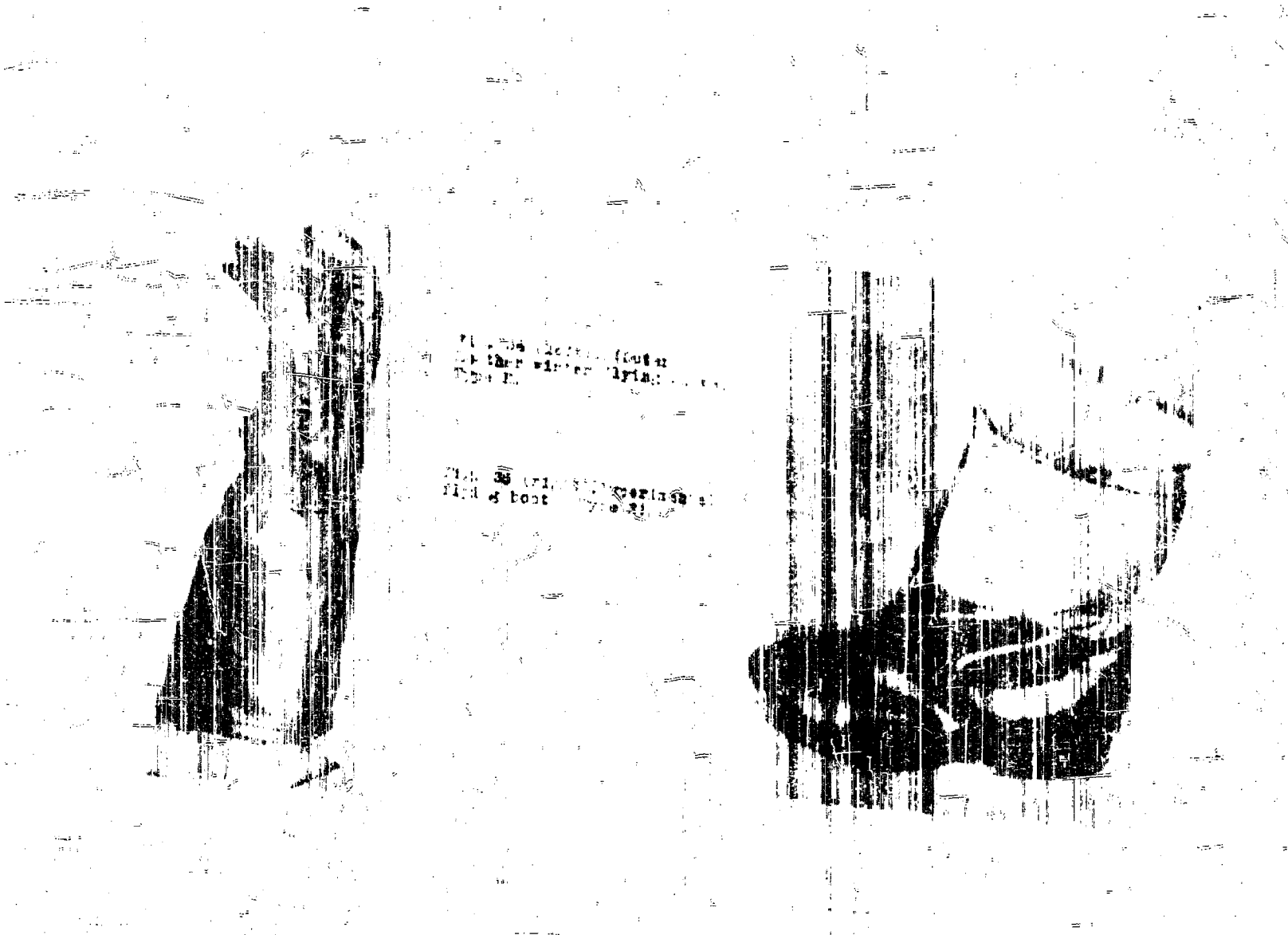
(b) incorporation of an automatic light (with [illegible] control)

The flotation jacket [illegible] A.F. was a 'Mae West' essentially similar to early R.A.F. [illegible] [illegible] in the collar [illegible]

[illegible] of existing life jackets [illegible] by [illegible] in the [illegible] A [illegible] training school, R.C.A.F., [illegible] the [illegible] features [illegible] [illegible] of a new life jacket [illegible] [illegible] all the [illegible] [illegible] in permanent form by use [illegible] filling [illegible] type [illegible] provided by inflation. It was [illegible] the type with all-permanent flotation might be used in spacious aircraft under conditions where the extra thermal insulation would be advantageous, and [illegible] inflatable type under conditions where [illegible] great disadvantage, as for instance in fight- [illegible] The development of an improved [illegible] [illegible] awaiting rescue was [illegible] immediately.

[illegible] of design of the new types of life jacket were determined by October, 1942 (02493, 02540). Throughout the development there was a lack of [illegible] information as to [illegible] February, 1943, (Meeting 13) further work on life jackets was abandoned until such time as the necessary information should be provided. This lack of knowledge extended both [illegible] as the type of flotation desired [illegible] as to the fitting of straps, rings, buckles, and so forth, in respect of which a great many changes and [illegible] were [illegible] demanded. In the attempt [illegible] [illegible] in this sphere.

[illegible] were [illegible] [illegible] the two types of life jacket developed by the [illegible] [illegible] type of modified R.A.F. Mae West



[illegible] the jackets [illegible] preferred the [illegible] inflatable [illegible]. The other two types were considered inadvisable on account of their bulk, while the [illegible] type was [illegible] aircraft and in turrets. Certain [illegible]

[illegible] was received from the [illegible] the service trials [illegible]

[illegible] all-inflatable [illegible] certain [illegible]

[illegible] discussion at the [illegible] that there had been no emergency equipment [illegible] the inflatable life jacket during the service [illegible]

[illegible] side the [illegible] for wear [illegible] and [illegible] for wearing inside, [illegible] that it should be worn [illegible] the matter remained obscure [illegible]

[illegible] by the [illegible] since the present inflatable jacket [illegible] equipment, it was further added in the same [illegible] there was no need for the pockets or the contents of the [illegible] to be noted that the pockets and emergency [illegible] the [illegible] Clothing Committee. Thus terminated work [illegible] jacket. However, the [illegible] incorporated in the pressure jacket [illegible]

[illegible] of this project must be [illegible] entirely [illegible] of consistent information as to service [illegible] It must also be pointed out that the [illegible] of an inflatable jacket without permanent [illegible] was a purely service matter and did not enter [illegible] the purpose of the [illegible] regarded with enthusiasm by various members.

Meanwhile the Subcommittee's jacket with permanent flotation was submitted to the [illegible]

[illegible] of a con-
[illegible] The
[illegible] service in

[illegible] on life
[illegible] packs and emergency lights, [illegible] first
type of emergency light was developed in collaboration
with the Canadian National Carbon Company under the super-
vision of [illegible] Lipple. It was [illegible] to be at
[illegible]
automatically [illegible] tablet, so that the [illegible]
[illegible] tablet.
[illegible] Air Force showed
[illegible] information obtained on a visit to
[illegible] of great importance, so that [illegible] of bright-
attempt to [illegible]
[illegible]
the [illegible] to introduce a thermostatic contact close to
[illegible] to [illegible] clients.
[illegible]
[illegible] of the [illegible]
[illegible] light to
[illegible] of the bulb to
[illegible] battery [illegible] development of a service-
[illegible] holder was carried [illegible]
[illegible]
[illegible] with the
[illegible] the [illegible] very co-
[illegible] the design of the light [illegible] in adapting
[illegible] table for production.
[illegible]
The [illegible]
[illegible]
[illegible] early summer of
[illegible] by the R.C.A.F. [illegible]
[illegible]
[illegible] in service [illegible] jackets and were found very
[illegible] emergency light [illegible]
[illegible] the R.C.M. [illegible]
[illegible] flotation. It is
[illegible]

[illegible] information was received that there was not enough [illegible] A.F.

[illegible] was [illegible]

[illegible] floes, and appropriate [illegible] to the R.C.A.F.

[illegible] in June, 1940, a new type of inflatable life [illegible] produced by the Subcommittee as a result of [illegible] particularly for tropical use, since the area covered by the jacket is minimal. Valuable advice was received from Lt.-Cdr. Cowan.

Inflatable life [illegible]

[illegible] inflatable life [illegible] was intended to occupy as little [illegible] possible when not inflated. The possibility of [illegible] inflation when slightly [illegible]

[illegible] jacket is made of a sandwich material [illegible] of two layers of cotton cloth laminated with [illegible] is done by means of liquid latex, this [illegible] point of view of airtightness and [illegible] the time when the jacket was first developed [illegible] and it [illegible] be pointed [illegible] flotation must have [illegible] reliable seams [illegible] permanent flotation, [illegible] considerable difficulty was experienced [illegible] the same design of jacket could [illegible] been made [illegible]

[illegible] compartments in the [illegible] front and upper back on both [illegible] body, the other extending over the whole [illegible] the general distribution of buoyancy remains [illegible] even if the compartment [illegible] torn, and either [illegible] buoyancy to keep a man [illegible]. Inflation can be effected by discharge of $CO_2$

[illegible] on either side [illegible] comfortably in the water. [illegible] allows [illegible] adversely [illegible] natural [illegible].

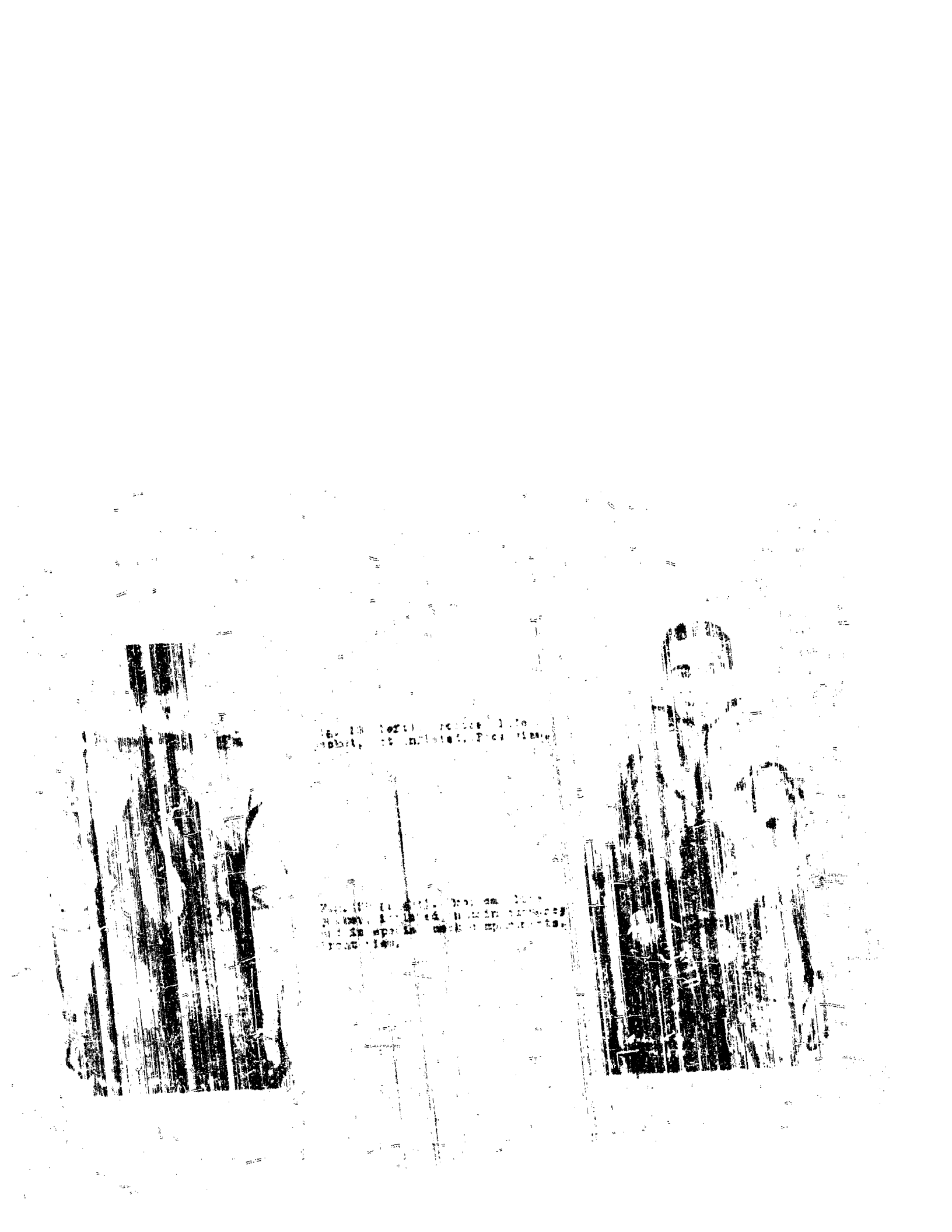
[illegible] the back of the wearer is not covered except by [illegible] (figure [illegible]). The [illegible] inflatable bags of [illegible] is closed in front with a [illegible] designed to [illegible] of the bags does not cause pressure [illegible] upper front of the chest [illegible] collar in front [illegible] hold the head firmly out [illegible] alone will maintain [illegible] position in the water, [illegible] required has to bring him into that position. [illegible] would enable him to climb into his dinghy without danger of sinking.

A system of continuous webbing, covering the [illegible] connecting with the crotch strap, and forming loops [illegible] man out of the water. The buckles of the crotch strap are essentially [illegible] designed by Lt.-Cdr. Cowan. The components of this system will withstand a pull of 500 lbs. A man may be [illegible] safely [illegible] front loops or from either should [illegible].

The jacket weighs [illegible] lbs. [illegible] emergency [illegible].

[illegible] with permanent flotation only

The jacket with permanent flotation only (U2495) [illegible] originally on a [illegible] life [illegible] It was considered that



[illegible]

[illegible] when [illegible] small, and 0.4 oz. when [illegible] [illegible]

[illegible]

[illegible] jacket [illegible] as [illegible]. Air valves are provided to allow [illegible] of pressure with change of altitude. [illegible] used [illegible] but this was [illegible] in favour [illegible] and flaps. The jacket is partially sub[illegible] [illegible]

[illegible]. A crotch strap and collar are [illegible] that can be attached [illegible] fasteners [illegible] the jacket [illegible] comfortably.

[illegible] material itself [illegible], it is [illegible] more bulky than [illegible]

[illegible] negligible for aircrew, and the pad [illegible]

[illegible] pads filled with milkweed floss [illegible] that the optimum density [illegible]. The pads were subjected to [illegible] agitation while in water, and the loss of [illegible] was [illegible] loose, [illegible]

[illegible]

[illegible] milkweed [illegible] of [illegible] to [illegible] was considered suitable (Meeting 24).

[illegible] consists of a battery, [illegible] cord, and bulb with [illegible]

A [illegible] automatically flashing bulb has been [illegible] the flow of current. [illegible] The flashing [illegible] is itself likely to attract atten[illegible]

[illegible] the right way up by reason of its construction and because of the air contained in it, without the need for any [illegible]

[illegible] by a small [illegible], so that it can be [illegible] water; this extends by one mile the horiz[illegible]

[illegible] to economy [illegible] number of cells in the battery from two to three [illegible]

[illegible] life in [illegible] the battery [illegible]

[illegible] even when the hand was numb, but this was [illegible]

## PART [illegible]

[illegible] and [illegible] of Visibility [illegible] of the [illegible] (R.C.A.F. Type [illegible]) and Old [illegible] (R.C.A.F. Type [illegible])

| [illegible] | Intensity of New [illegible] relative to intensity of [illegible] | Calculated range of visibility in miles [illegible] | [illegible] |
|---|---|---|---|
| [illegible] | 5.7 | 7.2 | 5.0 |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | 35 | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | 1.5 |

[illegible] of the new type of light, as regards [illegible]

[illegible] lower than that [illegible] from the air [illegible]

[illegible]

[illegible] development of the [illegible] suit, [illegible] proceed with the development of an exposure suit for wear in flight (Meeting [illegible]) [illegible] waterrightness during immersion. [illegible] and appropriate thermal insulation [illegible] is dependent upon the ready [illegible] of body moisture. For this reason, [illegible] impermeable to water vapour are not likely to be satisfactory during flights of long duration. An impermeable [illegible] development since 1942 for [illegible] 1942) could [illegible] to the existing form. This [illegible] plastic-laminated cotton. Water- [illegible] the suit [illegible] the [illegible]

[illegible] by the R.A.F. [illegible] normally permeable to [illegible]

[illegible] in a horizontal position, it [illegible] in a very appreciable amount of water from the knees [illegible] when one is floating in the vertical position. It [illegible] desirable for Canadian requirements to limit the use of the [illegible] width to the upper part of the suit, provided that this reduction in vapor permeability did not cause undue discomfort.

[illegible] therefore conducted to [illegible] a water [illegible] were need [illegible] retention [illegible] under various conditions [illegible] temperature but at low relative humidities. It was [illegible] permeable suit was practically as comfortable as the entirely permeable one. In both cases, [illegible] the [illegible] suit. The [illegible] [illegible] the disposal of moisture.

[illegible] suit, [illegible]

[illegible] was [illegible] of the [illegible] suit, [illegible] [illegible] first [illegible] [illegible] [illegible] opening. The extra folds of fabric around the neck were then [illegible] [illegible] and closed by a slide [illegible]. First closure was by means of an elastic band [illegible] consisted in a [illegible] opening to which was cemented [illegible] of laminated nylon. Closure was effected by [illegible] the [illegible] and [illegible] it with a string. [illegible] the [illegible] consisted of two plies of cotton [illegible] socks made of butyl-laminated [illegible] experienced with [illegible]

[illegible] August, 1944. [illegible] [illegible] the suit afforded a large measure [illegible] wetting (about 15 minutes immer- [illegible] [illegible] the protection afford-

Fig. 48. Flight pressure suit, type A. (Drawstrings around neck not drawn tight).

[illegible] trials were then conducted in fight- [illegible] the results were made available in February, [illegible]. No serious complaints were made regarding the accumulation of sweat within the clothing, and [illegible] vapour from [illegible] because of the [illegible] of risk of entanglement of [illegible] that [illegible] slide fasteners be used for closing the fly and front of the suit. Several other suggestions were made and [illegible] was [illegible] for further development.

Flight Exposure Suit, Type A

Meanwhile, further work on the development [illegible] was carried on in anticipation of criticisms which might arise from the flight trials [illegible] Research Council, representatives of [illegible] extended the demonstration of a new style [illegible] Flight Exposure Suit designed by the Goodrich Rubber [illegible] a [illegible] slide fastener [illegible] was formed around the [illegible] [illegible] suit also had a fly opening [illegible] fastener, [illegible] Subcommittee's Type A Flight Exposure Suit.

In February, [illegible] information was received from the Flying Clothing Committee that as a result of [illegible] of the Type A suit a further prototype should be made up incorporating the features described above. Certain other minor modifications were requested. [illegible] the resulting Type A Flight Exposure Suit [illegible] within three weeks. The whole development [illegible] in the water were carried out within ten month requested by the [illegible]

[illegible] (Figure 5a) was made with impermeable [illegible] reasonably [illegible]

[illegible] courtesy of the U.S. Q.M.C., in the upper half [illegible] the case of the Type A Flight Exposure Suit.

Further improvements in the style of the [illegible] suit might well be affected. [illegible] slide fastener from shoulder [illegible] a small aperture [illegible] a dressing. A suit of this type

[illegible] (meeting 50) by [illegible]

[illegible] experienced [illegible]

[illegible] to suggest that [illegible] upper half just its [illegible] this was [illegible] repeated wetting and [illegible] respects the suit was found [illegible] of little consequence [illegible] was subsequently examined by [illegible] at Hoarcliffe and favourable opinions were received.

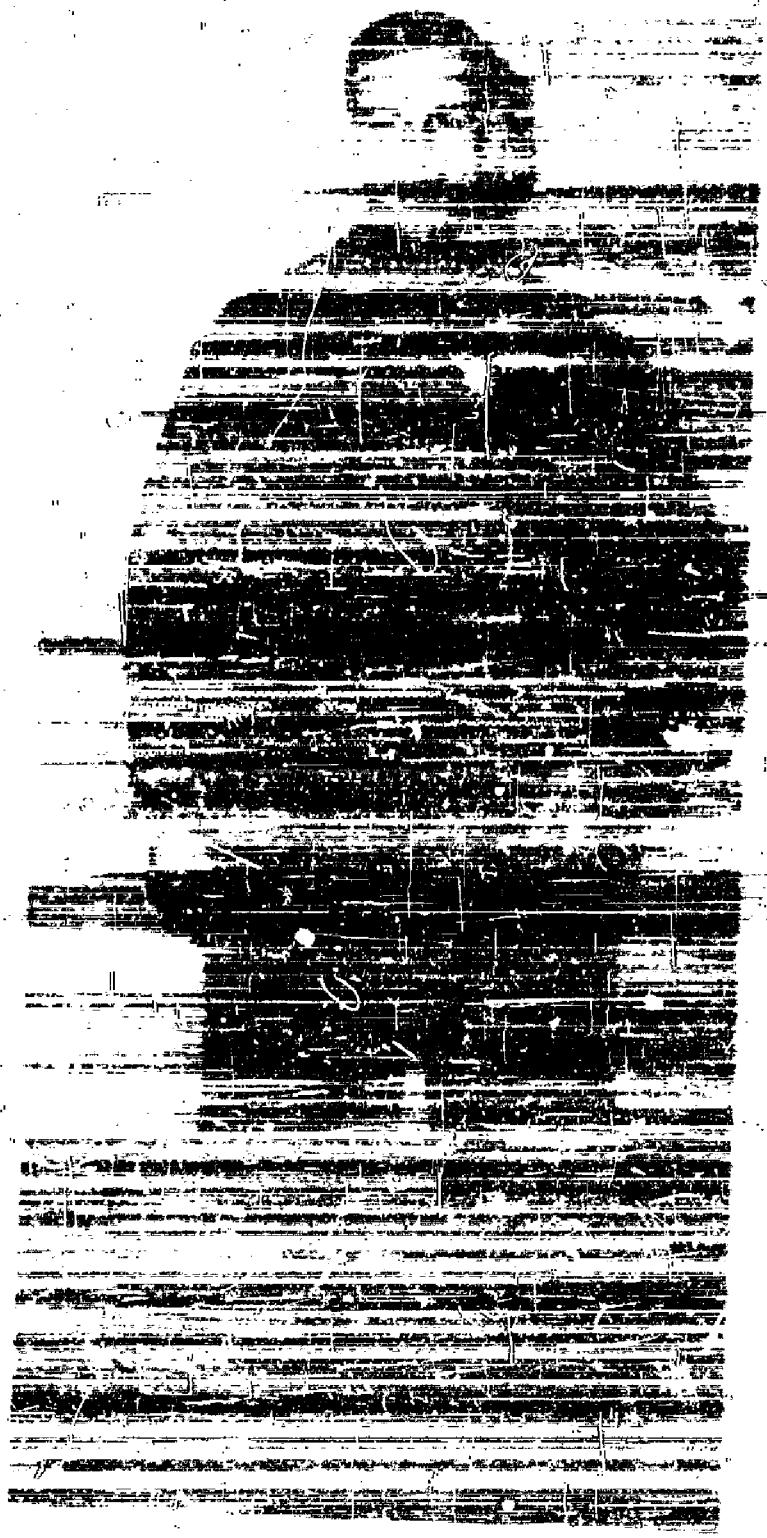
[illegible]

[illegible] the development of a plastic-coated [illegible] permanently [illegible] was initiated [illegible] Quadron Leader [illegible] of his [illegible] by the [illegible] company

[illegible] produced by the chemicals [illegible] was found to [illegible] (OSTEA) [illegible] environ- [illegible] to water [illegible] not [illegible] to avoid the slow accumulation of [illegible] within [illegible] periodically). Tests [illegible] suspicion of [illegible] made [illegible]

[illegible] outcome of the [illegible]

[illegible] where it was [illegible] with a resistance [illegible]



[illegible] exposure suits are [illegible]

[illegible]

[illegible] with ordinary [illegible]

[illegible] A non-return valve [illegible]

[illegible] to the [illegible]

[illegible] internal pressure then [illegible]

[illegible] flight tests of 3 hours' duration were carried [illegible]

[illegible]

[illegible] units for shipment to England where flight [illegible]

[illegible]

[illegible]

[illegible] protector made from the [illegible] the chaplets were found [illegible]

[illegible] Tropic Treated [illegible] to a [illegible] was tested under a [illegible] and was found [illegible] lumberman's cloth- [illegible]

## [illegible] Crew Clothing

[illegible] investigation was carried out at [illegible] of the protective clothing required [illegible] It was concluded that, in addi- [illegible]

[illegible] equipment recommended for this purpose [illegible] athletic [illegible]

[illegible] was request [illegible] develop [illegible] for the [illegible] A thorough [illegible] report [illegible] on an [illegible] of clothing available [illegible] recommended that abdominal belts of a non [illegible] and that the [illegible]

[illegible] of [illegible] were found to be [illegible]

[illegible]

Recommended Scale of [illegible]

| | | | | |
|---|---|---|---|---|
| [illegible] | | | | |
| [illegible] | 1 | 1 | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | | [illegible] | [illegible] | [illegible] |
| [illegible] coarse knitted | | | 8 | 2 |
| [illegible] | | | | |
| [illegible] | | | [illegible] | [illegible] |
| [illegible] | | | [illegible] | [illegible] |
| [illegible] | | | [illegible] | 2 |
| [illegible] | | | [illegible] | [illegible] |
| [illegible] Sperry type of Chevron | | | [illegible] | [illegible] |
| [illegible] | | | [illegible] | [illegible] |
| [illegible] | | | [illegible] | [illegible] |
| [illegible] | | | [illegible] | [illegible] |

[illegible]

Emergency equipment is needed by aircrews who have [illegible] in isolated land regions. It must [illegible]

other means of increasing their chances of survival [illegible] have made their way [illegible] to inhabited areas.

It is clear that only a limited amount of equipment can be carried [illegible] in aircraft for this purpose. A very careful selection of articles to be inclusion in a personal kit [illegible] a good possibility [illegible] after ocean landings of parachute descents).

It can [illegible] that the personal kit, being limited to [illegible] and essential articles, could be of the same [illegible] crews flying over land or over the [illegible] are larger and can include a greater [illegible] will naturally differ in their content depending on whether they are to be used on land [illegible]

[illegible] of the [illegible] the R.C.A.F. [illegible] as follows:

a) [illegible] mosquito [illegible]

b) Medical Kit: [illegible] of spirit of [illegible] iodine, [illegible] tablets, tannic acid jelly, opthalmic ointment (yellow oxide of [illegible] plaster.

c) Aircraft Kit: For occupant of aircraft; one [illegible] kit, for three occupants of aircraft [illegible] one carrying bag; one [illegible] one hand [illegible] one medical service kit; one [illegible] one shotgun [illegible] feet of [illegible]

[illegible] were considered to be unsatisfactory [illegible] because they were not standardized as to [illegible] nor were they packed in [illegible] As a result, they were not carried in the [illegible]

[illegible]

[illegible] action was taken

[illegible]

[illegible] ying over land

[illegible] agreed that as the occasion [illegible] the [illegible] assist the H.C.A.F. in the development [illegible] the dinghy kit.

It was then noted that this reorganization of [illegible] should be [illegible]

[illegible] that [illegible] of [illegible] country. Provision was [illegible]

[illegible] were found to be in [illegible]

[illegible]

Items [illegible] Quant[illegible]

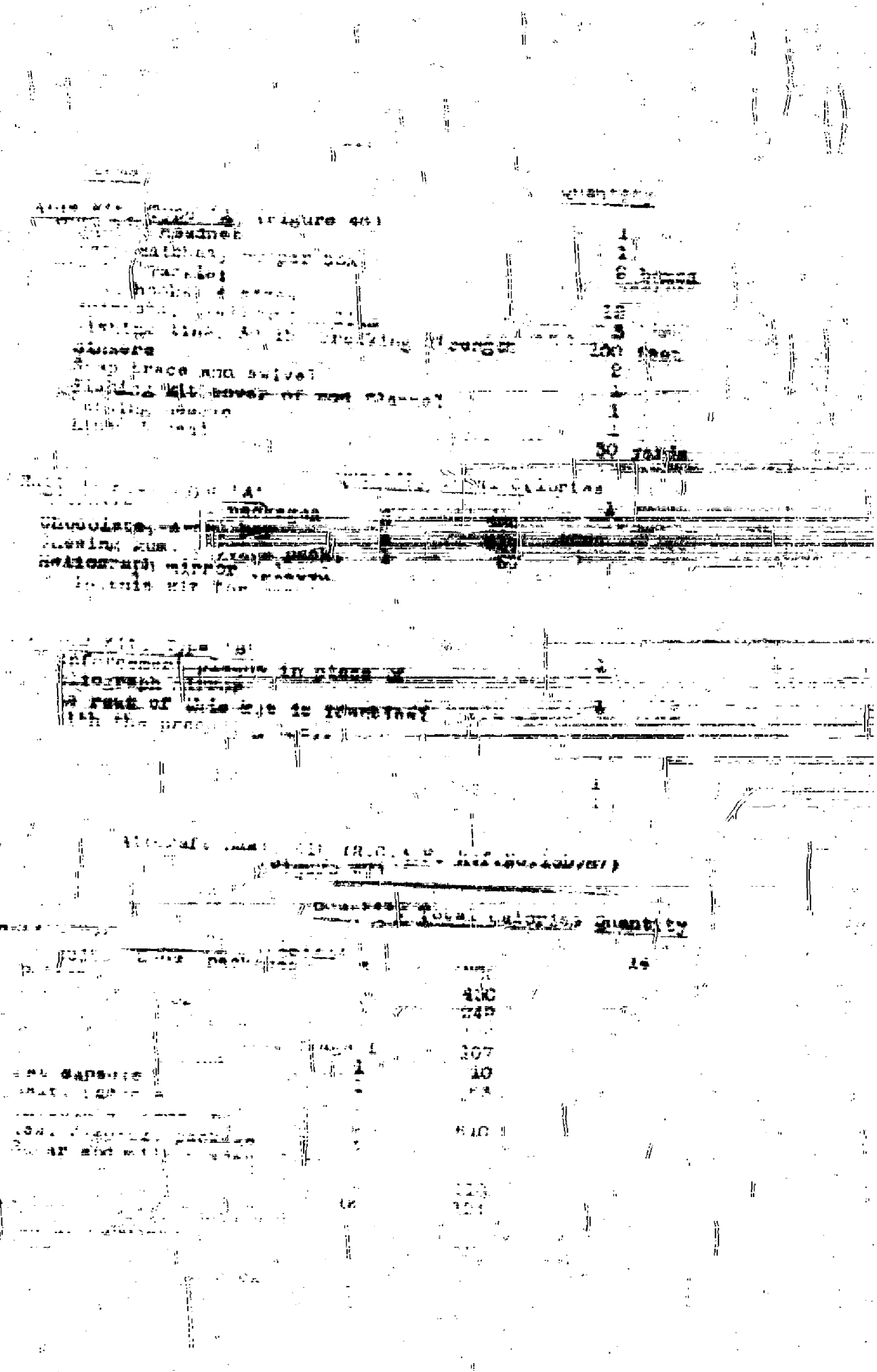
[illegible]

Compressed gauze bandage 3 inches x 5 yards [illegible]

[illegible]

[illegible] of sulphur

[illegible]



| | Quantity |
|---|---|
| [illegible] (Figure 4a) | |
| [illegible] headnet | 1 |
| [illegible] matches, [illegible] box | 1 |
| [illegible] | 6 boxes |
| [illegible] | |
| [illegible] | 12 |
| [illegible] line, [illegible] | 3 |
| [illegible] | 100 feet |
| [illegible] brace and swivel | 2 |
| [illegible] kit cover of [illegible] | 1 |
| [illegible] | 1 |
| [illegible] | 1 |
| | 30 yards |

| [illegible] 'A' | [illegible] Calories | |
|---|---|---|
| [illegible] | [illegible] | 1 |
| Chocolate, [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] |
| Heliograph mirror [illegible] | [illegible] | [illegible] |
| [illegible] | | |

| [illegible] 'B' | |
|---|---|
| [illegible] in place of | 1 |
| [illegible] | |
| [illegible] of this [illegible] | 1 |
| [illegible] | |
| | 1 |
| | 1 |

| [illegible] | Total Calories | Quantity |
|---|---|---|
| [illegible] | | 14 |
| | | 430 |
| | | 249 |
| | | 107 |
| [illegible] | 1 | 10 |
| [illegible] | | [illegible] |
| [illegible] | | 510 |
| [illegible] | | |
| | | [illegible] |
| | | [illegible] |

Quantity

[illegible] type 'A'

[illegible] tablets
[illegible] tape, [illegible] inches x 5 yards

[illegible]

[illegible] axe
[illegible]

[illegible] paper, package
[illegible] 2000, packages

[illegible], package of 100
[illegible], package of 10

[illegible] 11 and 12 — 2 pairs

1 pair

Snow shoes (if indicated) — 1

The personal kit is carried in a yellow [illegible] worn around the chest as shown in Figure 27. Each individual kit [illegible] enclosed in a plastic-coated pouch which [illegible]. The pockets of the [illegible] snap fasteners and are further [illegible] thread. A tab at this end [illegible] slipping out of the throat. The bandolier was tested [illegible] flight and was found satisfactory.

[illegible] aircraft [illegible] kits, of which there are [illegible] aircrafts, are enclosed in a [illegible] waterproofed by an outer plastic [illegible] kit is contained in an [illegible]

[illegible] pea soup and cheese [illegible]

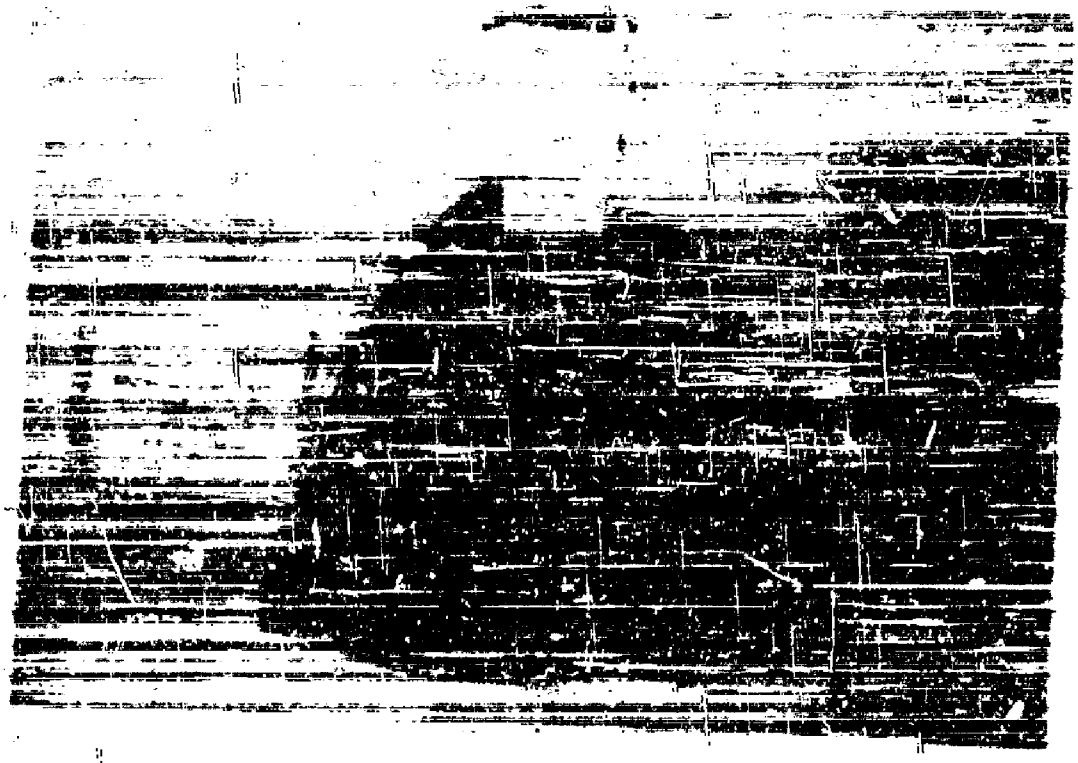


FIG. 46 [illegible] Emergency Kit - Emergency Area, Type A.

FIG. 47 [illegible] Emergency Kit - Urgent Care.

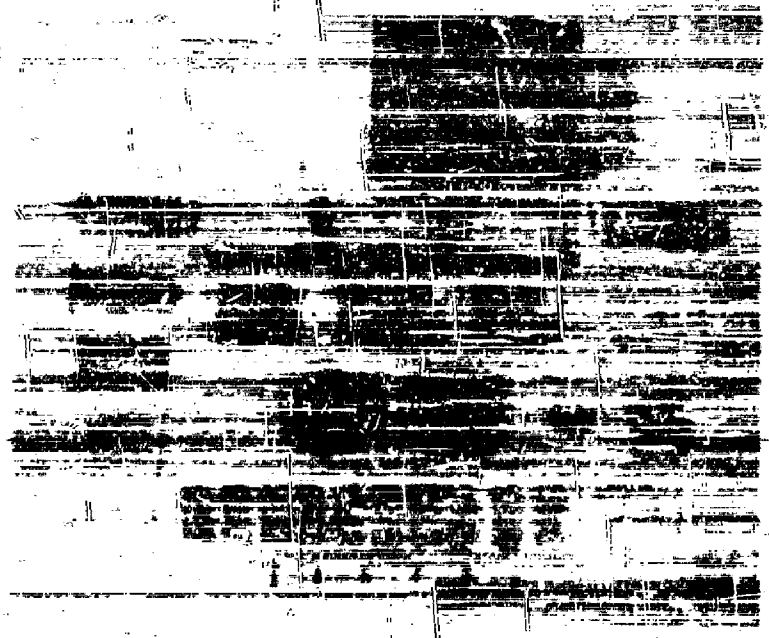


Fig. 40 (above), Emergency kits : rations

Fig. 40 (below), Emergency kits : sleeping bag kits

[illegible] weather field trials [illegible] proved [illegible] to be satisfactory.

[illegible] mally included in the [illegible] the adoption of a plastic [illegible]. This [illegible] keeping [illegible] with [illegible] revealed the [illegible] danger of carbon monoxide poisoning in addition to the [illegible] caused by the accumulation and condensation of [illegible] in agreement with the previous ones [illegible] (Schulzinger and [illegible] 1947). The [illegible] series of [illegible] test material [illegible] that the green material would be slightly [illegible] difference would not be expected to be [illegible] by [illegible] could be improved [illegible], especially if a [illegible]

[illegible] and cold [illegible] more satisfactory than the [illegible]

[illegible] The first [illegible]

[illegible]

Completion of these developments was not [illegible] for all [illegible]. Highest priority was given to the development of the [illegible] kit, which went into [illegible] being issued by August. [illegible] produced did not meet the performance requirements of the specifications laid down by the [illegible]

[illegible] aircraft [illegible] were completed and [illegible]

[illegible] in [illegible]

A [illegible] "Survival" was [illegible] under summer and winter conditions and illustrating vividly some consequences of [illegible]

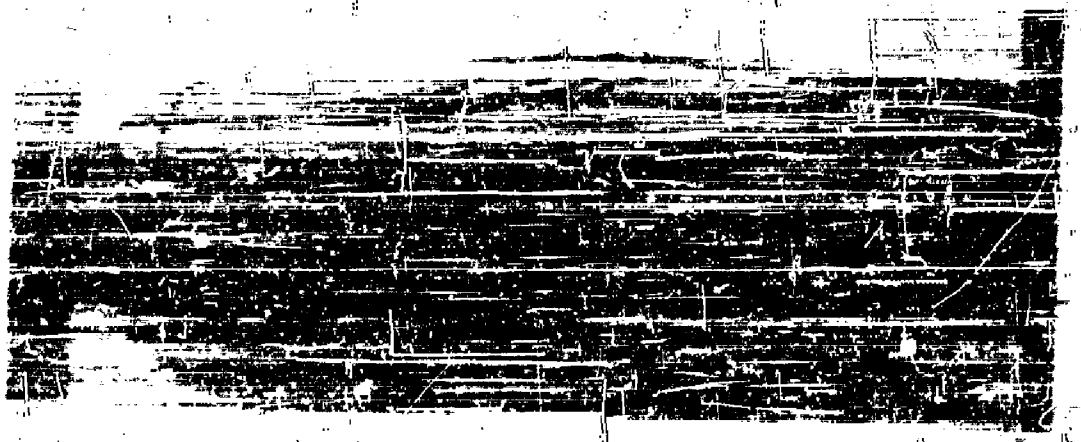
[illegible] and [illegible] was the [illegible] background. Later reports from the same source stated that 'moon red' (a magenta shade) had been shown by further research to be much more visible at sea than the colour previously adopted for the purpose of sea-rescue and signalling. Since these tests [illegible] the colour of the sea [illegible] the actual conditions [illegible] Air Command. Fluorescent colours were also tested in respect of their fading properties [illegible].

[illegible] (1947) [illegible] initially the fluorescent colours [illegible] distance (2 to 3 nautical [illegible] fluorescent colour, but after [illegible] exposure to [illegible] they had no advantage. There was very little to choose between 'arc yellow' and [illegible] the non-fluorescent [illegible] was better than yellow or red. [illegible] for [illegible] [illegible] and [illegible] was [illegible] [illegible] of [illegible] and other [illegible]

[illegible] fading of fluorescent [illegible] water samples of fluorescent fabrics [illegible]

The day [illegible] a casualty bag for the [illegible] Headquarters to No. 1 Clinical Investigation Unit. The [illegible] four or five [illegible] diagonals weighing four pounds each; [illegible] of a [illegible] body with a minimum of exposure to the [illegible] a bar as possible.

[illegible] by the [illegible]



[illegible] fastener having two sliders. When [illegible] the latter is [illegible]tely closed. When they are at the same end, the fastener is completely open. In other words, the fastener [illegible] from [illegible] end. It will [illegible] fastener, [illegible] used as a thermally insulating lining. [illegible] would [illegible] [illegible] flying suits where repeated flexing [illegible] in [illegible].

[illegible] room tests have [illegible] [illegible] weighs 14 pounds.

[illegible] were held in the winter months [illegible] flights of [illegible] to [illegible] duration were made at [illegible] [illegible] superior to blankets from the [illegible] of [illegible] weight, [illegible] of the patient for treatment [illegible]. As a result of these [illegible] improvement [illegible] made to the hood and to [illegible] the slide fasteners.

[illegible] production of these [illegible] for the R.C.A.F.

[illegible] Suits

Introduction

[illegible] immersion in water is well known. It is estimated from field reports that immersion in [illegible] during the winter months, will cause death [illegible] on life rafts [illegible] heavy winter flying clothing [illegible] summer nights [illegible] January to July, 1945, U.S. Emergency Rescue [illegible] whether the body is chilled [illegible] by direct contact with cold water [illegible] body temperature is gradually [illegible] by evaporative cooling [illegible] in the case of men [illegible] exposure is a serious hazard and

[illegible] immersion in cold water [illegible] [illegible] clothing and reach the

[illegible] suit, [illegible] the Norwegian Merchantile [illegible] protective watertight suit) is imperse- [illegible] the insulation of his clothing is [illegible] than a naked man in air of the [illegible] the air surrounding him.

[illegible] watertight suits, there- fore, is to prevent water from destroying the insulation of the clothing during immersion. Some loss in insulation will nevertheless occur for two reasons: the layer of air inside the clothing will be displaced, and the hydrostatic pressure will decrease the effective thickness of the clothing. This latter factor is very appreciable when one is floating in a vertical position, less so in a horizontal [illegible] position. The other factors, however, tend to [illegible] In the first place, the watertight [illegible] air in [illegible] between it and the outer garment [illegible] by evaporation [illegible] the permeable [illegible] Therefore it seems likely that [illegible] clothing is nearly [illegible] If a man wears wearing one same clothing, [illegible] the water- tight suit, in an air environment. In other words, a man wearing a watertight suit over winter flying clothing in [illegible] as he would be if wear- [illegible] at 0° C. It is clear that the protection afforded by a [illegible] the thermal insulation of the dry clothing underneath it.

Because it cuts down evaporative cooling, a [illegible] if the clothing in an air environment, [illegible] lothing to a life raft. One may therefore expect suits impervious to liquid water and [illegible] be of benefit during immersion and [illegible] worn over dry or wet clothing. It is obvious that the [illegible] ful if worn over dry clothing.

These assumptions have been confirmed by tests carried out by Dr. L.F. Newburgh of the U.S. National Research Council at the Naval Medical Research Institute. [illegible] clothing [illegible] immersed in [illegible] water [illegible] 1943) It was shown in these tests [illegible] watertight suits were beneficial for men wearing wet [illegible] temperature [illegible] wet bulb [illegible]

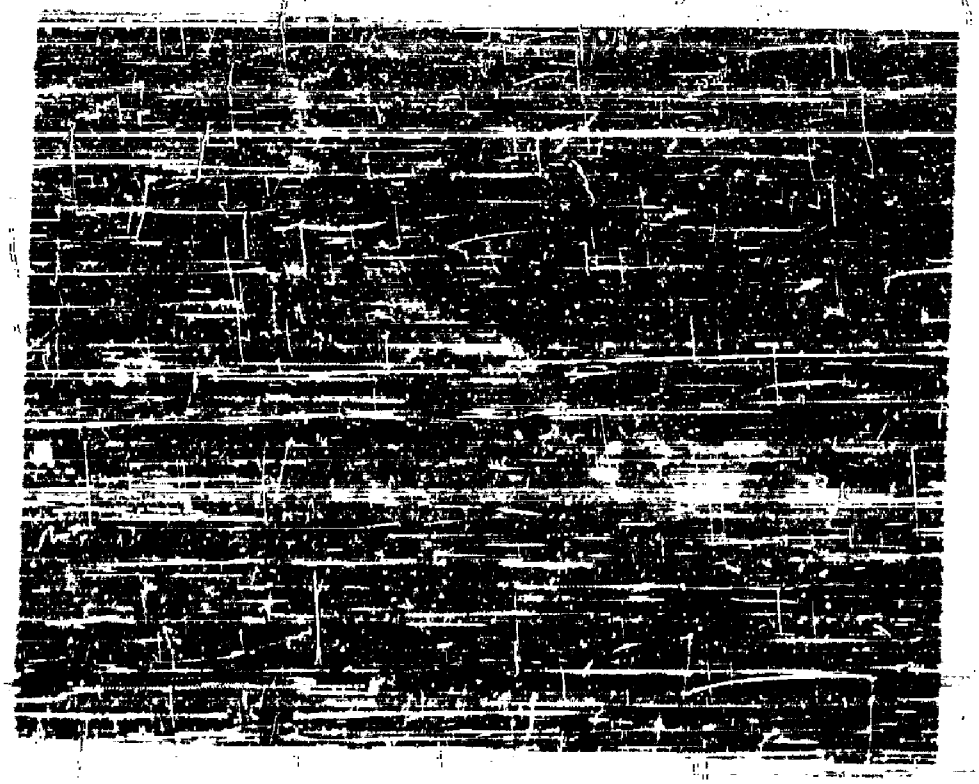


FIG. [illegible] (above). Man wearing ditching suit, [illegible] Type [illegible] dinghy.

FIG. [illegible]. Man in ditching suit, inflating type [illegible] dinghy.

Fig. 19 (above). Man wearing ditching suit, [illegible].

Fig. [illegible] (below). Man in ditching suit, inflating [illegible].

[illegible] Type K

[illegible] Dwelling

[illegible]

[illegible] at Wright Field [illegible] of the Subcommittee, in collaboration with [illegible] Research Council (U.S.) and [illegible] Laboratory, which showed that [illegible] flying cloth[illegible] [illegible] (air temperature [illegible]) [illegible] data; [illegible]

In addition to these [illegible] [illegible] in November, [illegible] individuals [illegible] flying clothing [illegible] protection of a watertight [illegible] without it. Much better [illegible] the exposure suit [illegible]

By October, 1943, there existed a general [illegible] used by flying personnel for protective clothing against exposure. At that time, much [illegible] already [illegible] the development of exposure suits to be worn in [illegible], both by the Farnborough [illegible] Subcommittee. The existing suits [illegible] satisfactory [illegible] [illegible] relatively long project [illegible]

On the other hand, a light-weight watertight suit of the [illegible] type [illegible] developed by [illegible] National Research Council, and it was [illegible] [illegible] the development of [illegible] to be donned over [illegible]

[illegible] on October [illegible], 1943, [illegible] was requested [illegible] possible an exposure suit [illegible] personnel to keep [illegible] should they be forced [illegible] this project was [illegible] requirements and [illegible]

[illegible]

[illegible] and [illegible]

[illegible] the [illegible]

[illegible] immersion and [illegible] station while [illegible]

[illegible] exceeding fifteen minutes; [illegible]

A universal size [illegible]

[illegible] flying suits, flying boots, [illegible]

[illegible] gives the [illegible]

[illegible] least possible [illegible]

[illegible] and manual dexterity [illegible]

[illegible] suit [illegible]

[illegible] operations, [illegible]

[illegible]

[illegible] floating, swimming and boarding dinghies. [illegible]

[illegible]

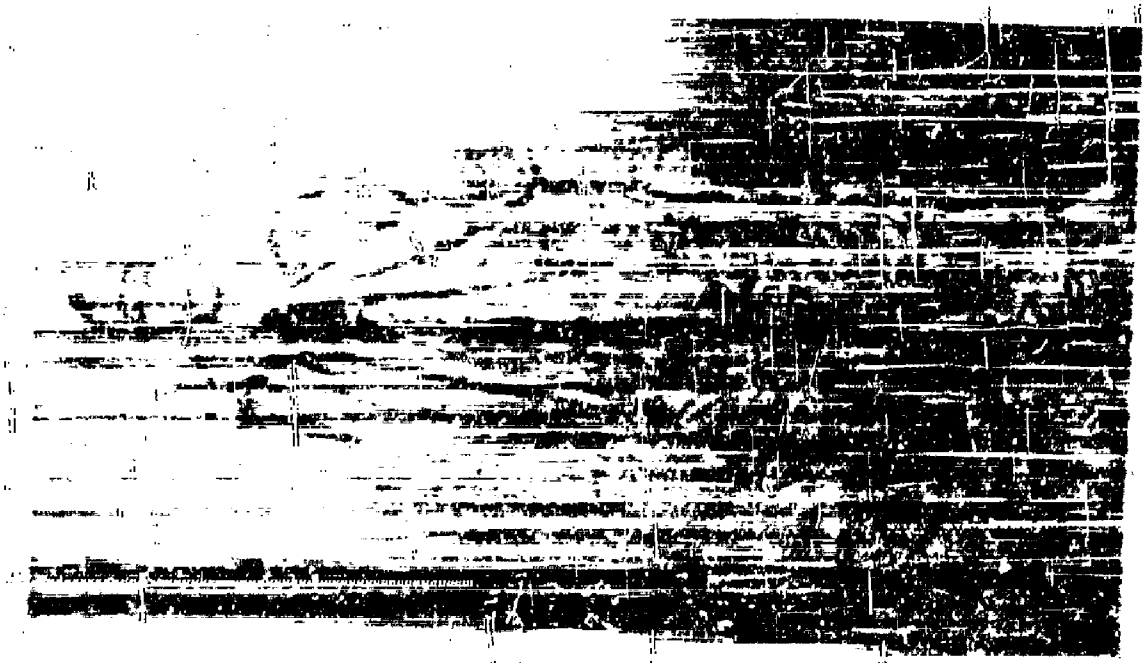
[illegible] one of the most im- [illegible] emergency equipment in [illegible] This conclusion is [illegible]

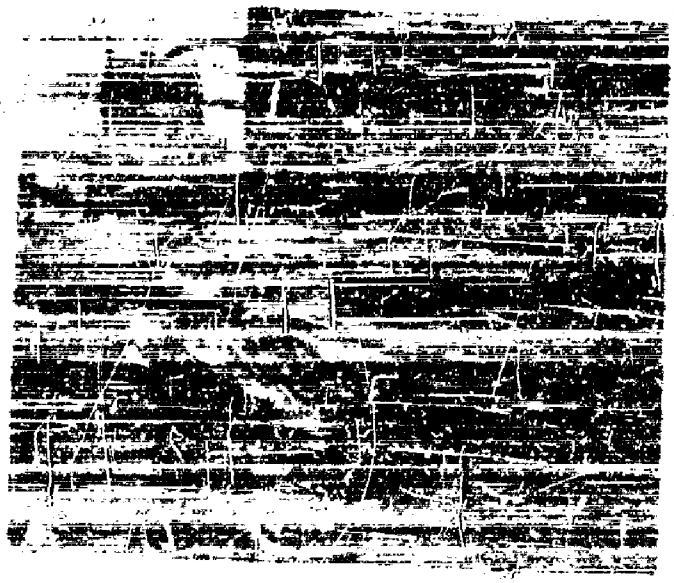
[illegible] difficult [illegible]

[illegible] held in the [illegible]

[illegible]

[illegible] man to lift himself [illegible]





(b) [illegible]

[illegible] will not after his cold [illegible] in a condition to make use of the various other items [illegible]

[illegible] with [illegible] this conclusion is justified by [illegible] finding.

(c) [illegible] afforded a sufficient [illegible]

(d) [illegible] sufficiently [illegible] for a large majority of members of [illegible] involved in [illegible]

[illegible] sufficient ease of [illegible] authority for members of [illegible] all their duties [illegible]

[illegible] were [illegible]

[illegible] position of immersion [illegible] a short period [illegible] at the neck does [illegible] the effective [illegible]

[illegible] of specs finding a final [illegible] of the [illegible] extend down the front and [illegible] were developed to prevent [illegible] opening [illegible] devised, so that the suit could [illegible] and held in such a way as to [illegible]

[illegible] which appeared desirable [illegible]

[illegible] in September were tested for [illegible] with the following results ([illegible]).

[illegible]

[illegible] static resistance of the fabric became in- [illegible]

[illegible] was at all [illegible].

[illegible] for [illegible] qualities of the suits. Later suits are [illegible] and are said to be satisfactory. Whether [illegible] the pigment, to a better [illegible] or to [illegible] processing methods [illegible] known

[illegible] of [illegible] (in a [illegible] pool) [illegible] at the request of [illegible] [illegible] (up to [illegible] in each [illegible]) made little difference in the amount of effort [illegible] is [illegible] due to [illegible] excess weight [illegible] until [illegible] is already more than [illegible] in the [illegible]. [illegible] it is easy to sell the [illegible] [illegible] experiments were levelled at the [illegible] which hampered movements [illegible] [illegible] in the [illegible]

[illegible] Leader Pask, R.A.F.

[illegible]

[illegible] two layers of cloth are vulcanized [illegible] "Jaeger" [illegible] at from [illegible] between centres, according to the location on the [illegible] near the neck separates [illegible] a rubber mattress. [illegible] on the [illegible] [illegible] suit

[illegible] unit is gained. The [illegible] attributed to "short-circuit- [illegible] points [illegible] of the underlying cloth [illegible] prevention of evaporation when run over [illegible] unit [illegible] greater merit than [illegible]

[illegible]

[illegible] the development of [illegible] for [illegible] sets [illegible] The equipment was stable [illegible] ranging between 1000 [illegible] and [illegible] must not be damaged by [illegible] of [illegible] It must not to be easy [illegible] packed [illegible] by parachute, and graded against [illegible]

It was found that the addition of dextrose [illegible] of the [illegible]

[illegible] container fitting into an ordinary [illegible] [illegible] the necessary water conveniently, it was recommended that the administration [illegible] be packed [illegible]

[illegible] water for castaways

[illegible] November, 1944), the [illegible] the [illegible] water [illegible] the [illegible] four men [illegible] work in the [illegible] in the following [illegible] subjects used in each test [illegible] This also [illegible] rapidly. Salt balance [illegible]

[illegible]

The value of these experiments must [illegible] their [illegible] further experiments lasting for a longer time and [illegible] water rations were [illegible]

## Miscellaneous

A [illegible] number of other articles of [illegible] were [illegible] [illegible] [illegible] flying clothing was designed (Meeting 14, [illegible] and 20). [illegible] [illegible] stage of development but this project was never completed [illegible] [illegible] investigation of [illegible] [illegible] but was not carried [illegible] partly owing to lack of [illegible] practice [illegible] requirements and partly due to low priority in importance. The insulation of R.A.F. flying clothing was measured at the request of a visiting officer from the R.A.F. Physiological Laboratory [illegible] thermal insulation of [illegible] for the New Zealand Air [illegible] Mission. A wool [illegible] forces was approved for use by [illegible] [illegible] was given to foot [illegible] materials (C2415, [illegible] buttons (C2147) for use in [illegible] [illegible] waterproofed with [illegible] was developed and tested (Meeting 19). A bleaching suit made of fabric coated with plastic instead of rubber was [illegible] satisfactory in these [illegible] [illegible] (Meeting 14) were made that identity discs should be constructed of [illegible] metal which is highly resistant to fire and salt water, and that they should be suspended [illegible] the neck. Approval was given to a modified parachute harness (C2619). Recommendations were made in respect to soiling and damage to coveralls by oil (C2703) [illegible] was carried out on [illegible] [illegible] resistant to penetration by certain chemicals for the Co-ordinating Committee on Protective Equipment. A mocking [illegible] was developed (Meeting 19). Attention was given to the possibility of the transmission of diseases by the use of unscoured wool reputed to be [illegible] [illegible] and [illegible] (Meeting 19). [illegible] [illegible] [illegible] requirements by wind [illegible] [illegible] concentrations of oxygen [illegible] [illegible] (Meeting 22). No conclusive [illegible] obtained.

Work is still in [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

**Origin of Development**

[illegible] ... alone with suitable respiratory apparatus in excess of that of the [illegible] ... purposes of aviation there are [illegible]

(a) [illegible] ... in the mask [illegible]

(b) [illegible] ... above [illegible] ... if the mask pressure [illegible] ... In practice this procedure has only been used when [illegible] ... in this [illegible] ... the pressure [illegible] ... be raised above the total pressure of the surrounding atmosphere.

[illegible] ... special consideration [illegible] ... equipment the [illegible]

[illegible]

[illegible] ... oxygen becomes [illegible] ... At such levels, provided the rate of oxygen flow [illegible] ... practically pure oxygen is pre- [illegible]

[illegible]

[illegible] ... was first shown at [illegible]

[illegible] ... physiological [illegible] ... programme of [illegible]

[illegible]

[illegible] water, most [illegible] for a useful length of [illegible] Toronto [illegible] arising from an [illegible] pressure.

[illegible] from pressured breathing, it [illegible] and so discomfort, [illegible] pressure at which this discomfort [illegible] pressure [illegible] pass through [illegible] inquire the reason of [illegible] level at that [illegible] work [illegible] unsuitable to it. The [illegible] benefit may be [illegible] may be [illegible] the [illegible]

[illegible] pressure breathing was required, the [illegible] to pass through a valve [illegible] valve. When [illegible] pressure in the suit [illegible] pressurized breathing [illegible] valve. The [illegible] minimum volume of the [illegible]

[illegible] an increase in pulse rate [illegible] of [illegible] of the [illegible] [illegible] (Fig. 63) a decrease in rate of blood flow in the hand (Fig. 64), and a decrease in stroke volume of the heart (as [illegible] ballisto-[illegible] [illegible] investigat- [illegible] [illegible]

Perhaps the most important physiological observation obtained in this work [illegible] concerned the symptoms of collapse which occurred when the pressure [illegible] too high. It should be pointed out that subjects were experimented with pressures considerably higher than [illegible] be used for [illegible] of aviation without a special pressure suit. The experiments were carried out at ground level with pressures [illegible] of water. Collapse was preceded by a feeling of [illegible] usually within a minute after the [illegible] and [illegible] obtained in [illegible] release of pressure [illegible] [illegible] [illegible] pressure chamber on subjects breathing air under pressure at a simulated altitude of [illegible] the presence of some degree of [illegible] the pressure re- [illegible] to cause collapse [illegible]

[illegible]

It was reported that an operational need was [illegible] for [illegible] the effective ceiling of pilots [illegible] United Kingdom [illegible]. Accordingly, the work on pressurized breathing begun in the Banting and [illegible] the [illegible] [illegible] [illegible] Committee [illegible] January 1943 [illegible]. It was found [illegible] immediately to modify the equipment to suit R.A.F. requirements and oxygen installations. The equipment taken [illegible] R.C.A.F. [illegible]

[illegible] R.A.F. [illegible] consequently [illegible] modified [illegible] [illegible] regulator. In the new system oxygen [illegible] was supplied through a [illegible] [illegible] [illegible] [illegible] which [illegible] [illegible] clothing [illegible] the [illegible]

[illegible]

[illegible]

Meanwhile, from discussions with high altitude pilots evidence was collected [illegible] the physiological [illegible] above 40,000 feet described a feeling of not being [illegible] [illegible] were reported. There was therefore good reason to suppose that these pilots [illegible] encountering the effects of [illegible] [illegible] of decompression sickness [illegible] [illegible] significance compared with the effects of anoxia.

[illegible] replaced by an [illegible] representative was [illegible] development of the equipment and with its [illegible] in operational use (C2372). In view of the [illegible] [illegible] among pilots, a request was [illegible] Research Council for 100 jackets and those were produced in Canada without delay (C2373). The Succomalitas's type D emergency light was incorporated. The remainder of the equipment was [illegible] [illegible] the early part of 1944 [illegible] [illegible] increased a man's efficiency at al[illegible] [illegible] jacket itself was [illegible] as being considerably less bulky than the standard [illegible].

Modifications were carried out [illegible] the [illegible] the trials (C2379). In particular, [illegible] [illegible] with adjustable [illegible] pressure, low excess [illegible] and high excess pressure [illegible] [illegible] to the existent was designed, having an automatic safety device by which [illegible] of oxygen to the outside was prevented when the typhoon was disconnect[illegible] [illegible] jacket. In addition a valve was added to [illegible] [illegible] supply before bailing out. This was done [illegible] that reserve oxygen in the jacket itself might not [illegible] A simple arrangement was devised by which the [illegible] [illegible] when pressure [illegible] was to be used.

Final operational trials with the latest type of equipment were begun early in the summer of 1944. [illegible] were produced in Canada and the [illegible] [illegible] United Kingdom as before [illegible] [illegible] and most pilots [illegible]

[illegible] carried out over [illegible]. During these [illegible] a [illegible] and was [illegible] by the [illegible]

[illegible] a considerable amount of work on [illegible] was carried out in [illegible] for testing [illegible]. Simple methods [illegible] rate of leakage [illegible] of the spring-loaded valves [illegible] the jacket as a replacement for the [illegible]. The adequacy of [illegible] was also investigated [illegible] of operational [illegible]

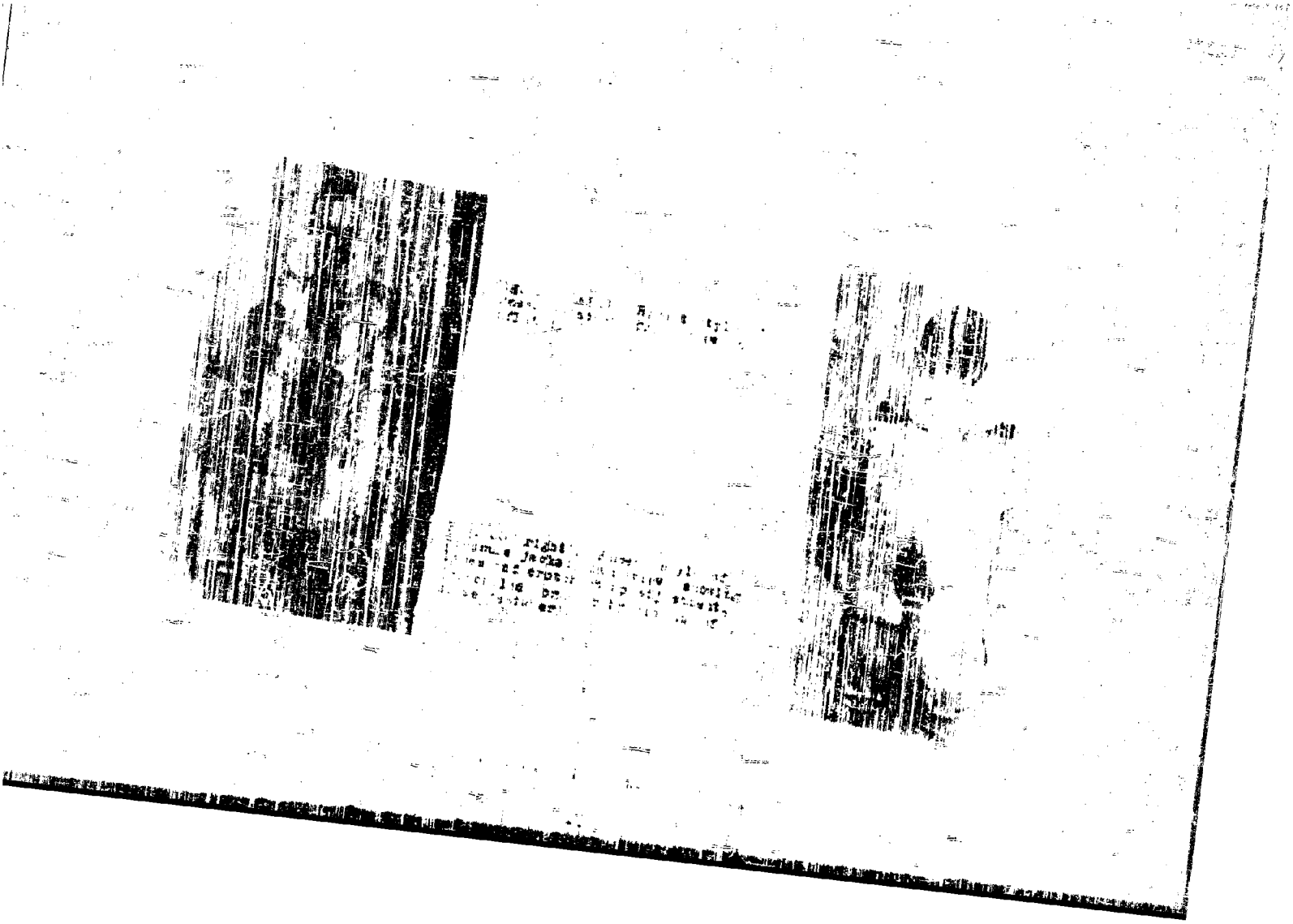
The equipment was finally approved for [illegible] with certain [illegible] modifications. [illegible] manufacture of [illegible]. For this purpose the [illegible] top of the back of the [illegible] by an inflatable [illegible] the property of [illegible] to a face upward [illegible] at an angle of about 45° with the water. [illegible] permeable [illegible] part of [illegible]

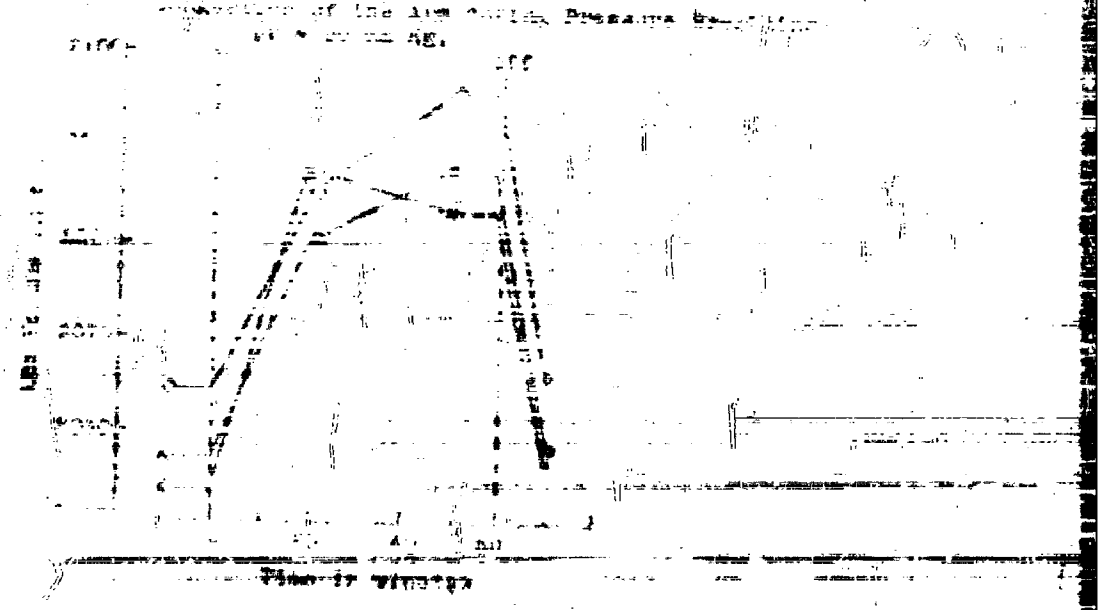
Developmental work [illegible] pursued in [illegible] to improving [illegible] the jacket [illegible] characteristics and [illegible]. The typical [illegible] shown in [illegible] 89, 90, 91 [illegible] described on page [illegible] was also derived from the [illegible] armature [illegible]

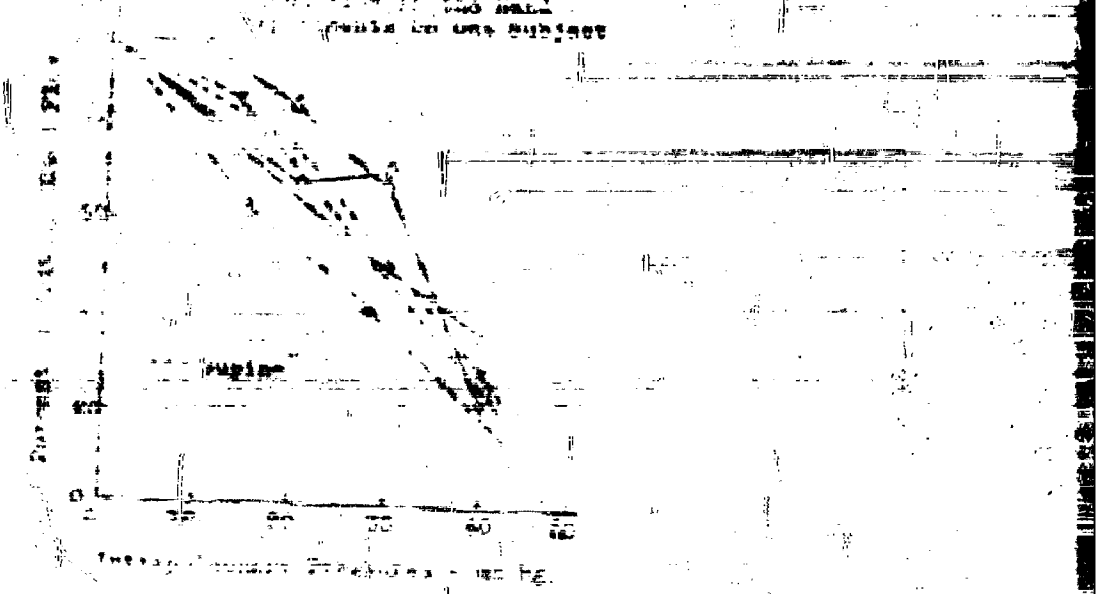
[illegible]

A film entitled "[illegible] for [illegible]" was produced [illegible] to illustrate the [illegible] failure of [illegible]

[illegible] isolated and the use of [illegible]. This film was made [illegible] have proved [illegible]







[illegible] pilot [illegible] Canada and the United States [illegible]

[illegible] modifications were also [illegible]

[illegible] was calculated to be as follows:

Equivalent altitude [illegible]

[illegible] pressure than pressure of [illegible] range of altitude.

[illegible]

[illegible] University of Southern [illegible]

In order [illegible]

[illegible] this equipment [illegible] testing of high [illegible] aircraft factory, Canadian [illegible] equipment was taken to the University [illegible]

[illegible] pressure demand valve, that this [illegible]

[illegible] pilots [illegible] with [illegible]

[illegible] that he felt comfortable during [illegible] a few days earlier [illegible]

A new instrument [illegible] movement [illegible]

[illegible]

Flying Clothing. [illegible]

[illegible] of [illegible] Ventilated Flying Clothing.

The [illegible] of the [illegible] Flying Clothing [illegible]

[illegible]

An Electrical [illegible] construction of [illegible]

[illegible] of [illegible]

[illegible] Operational [illegible]

[illegible]

[illegible] Properties of the [illegible] Suit [illegible]

[illegible] in brackets refer to the original index numbers [illegible] in the [illegible]

[illegible]

[illegible]

[illegible] A.C. [illegible]

[illegible] F. [illegible]

[illegible] Flying [illegible] A.C. [illegible]

[illegible] Substituting [illegible]

[illegible] A.C. [illegible]

[illegible] Electrically Heated [illegible] (34) [illegible] Wing. [illegible]

F. [illegible]

[illegible] A.C. [illegible]

[illegible] Flying [illegible] A.C. [illegible]

[illegible] A.C. [illegible]

[illegible] A.C. [illegible]

[illegible]

[illegible] Point [illegible] Coke (F.O.)
[illegible]

[illegible] Sports Test (Brynia) and the
[illegible]

[illegible]

[illegible]

[illegible] Avis Goodlake

The Breaking up of Kapok in Use and [illegible]
[illegible] on Silkwool (72)

[illegible]
[illegible] flying [illegible]

[illegible] N. Hall
[illegible]
[illegible] the north East Brazing [illegible]

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| [illegible] | [illegible] | A.[illegible] |
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| | | W. Page |
| [illegible] | [illegible] | [illegible] |
| [illegible] | Tailoring [illegible] | [illegible] |
| | | M. [illegible] |
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| [illegible] | Sizing of [illegible], Winter, 1946 | [illegible] |
| | | C.R. Cole [illegible] |
| | [illegible] flying hours. | [illegible] |
| | | A.M. [illegible] |
| [illegible] | [illegible] (U4) | [illegible] |
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| | | [illegible] |
| | | C. Page |
| | [illegible] of [illegible] Materials | P. [illegible] |

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| | [illegible] | [illegible] |
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| | [illegible] | J.H. [illegible] |
| [illegible] | [illegible] Materials. [illegible] | [illegible] |
| [illegible] | [illegible] | A.A. [illegible] |
| [illegible] | [illegible] Evaluation of [illegible] for Flying [illegible] | [illegible] |
| [illegible] | [illegible] in [illegible] Equipment [illegible] | A.C. [illegible] |
| [illegible] | Treated Wool as a Substitute for Kapok in Flotation Equipment. [illegible] | A.C. [illegible] |
| [illegible] | [illegible] | A.C. [illegible]<br>[illegible]<br>[illegible]<br>[illegible] Coke (P/O) |
| [illegible] | [illegible] Regulator, [illegible] for Electrically Heated Flying Clothing. [illegible] | A.C. [illegible] |
| | [illegible] | [illegible] |
| | [illegible] | [illegible] |
| [illegible] | Comparison of [illegible] Fabrics for [illegible] | [illegible] |

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Prototype [illegible] — [illegible]

[illegible] Points of Flying Balance [illegible] — [illegible]

[illegible] — [illegible]

[illegible]

[illegible]

[illegible]

[illegible] Capacity [illegible] — [illegible]

[illegible] of Drying of Fabrics [illegible] — [illegible]

[illegible]

[illegible] Operative [illegible] — [illegible]

[illegible]

[illegible]

| | | |
|---|---|---|
| [illegible] | [illegible] | Authors |
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| [illegible] | [illegible] | [illegible] |

[illegible]

TITLE: Review of the Work of the Subcommittee on Protective Clothing of the Associate Committee on Aviation Medical Research 1942-1945

AUTHOR(S) : Kitching, J. A.; Page, E.

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ABSTRACT:

An account of war-research activities is given comprising three major groups of problems: the physical and chemical properties of materials used in clothing; the ability of clothing to offer physiological protection; and individual items of protection such as helmets, goggles, winter and summer suits, electrically and air-heated clothing, breathing equipment, containers for serum, and several others.

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