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ENGINEERING EVALUATION OF AGE LIFE EXTENSION, T-10 TROOP MAIN PARACHUTE

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Army Natick Laboratories
Natick, Massachusetts

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An engineering evaluation of T-10 Troop Main Parachute Equipment sampled from the six to twelve year total-age classes in service at Fort Bragg, NC was conducted by the US Army Natick Laboratories. Dynamic drop tests were made on harnesses, and laboratory strength and elongation tests were made on nylon material components. The findings support the present 13 year total age limit for harnesses and risers, and lead to the conclusion that the 12 year limit recently established for T-10 Chest Reserve Parachute Assemblies applies

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*) equally to the Main Parachutes. Log book data were insufficient to provide a basis for establishing limits for initial storage life and service life, as distinguished from total life.

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ENGINEERING EVALUATION OF AGE LIFE EXTENSION, T-10 TROOP MAIN PARACHUTES

by

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FOREWORD

This engineering evaluation of aged T-10 Troop Main Parachute Assemblies is a continuation of a series of studies to develop data on which to base total life limits and storage and service life limits without discarding an excessive number of items that are still serviceable.

The cumulative test and analytical data also provide background information as to causes of deterioration and possible guidance for maintenance and inspection procedures; and they may be useful in developing and validating non-destructive test systems that could supplement or replace the present criteria of maximum useful life. These studies further reveal the value of establishing sustained programs for keeping storage, usage, and maintenance records, so that new problems may be addressed and procedures updated in the context of parachute histories, using relatively small samplings for testing.

This program was initiated for action by Natick Laboratories as a result of the Air Items Life Extension Conference, U.S. Army Aviation Systems Command, St. Louis, Mo., 28 February to 1 March, 1973, and was funded through F2624204DC33-04 (CD-12), Airdrop Equipment Technology.

The work was conducted by textile engineering personnel of the Clothing and Personal Life Support Equipment Laboratory (C&PLSEL) acting in support of the Airdrop Engineering Laboratory (ADEL). Guidance and assistance of Messrs. William Lewis, Herman Weber, Arthur Claridge and Peter Stalker of ADEL are acknowledged. Enlisted personnel detailed from the Climatic Research Laboratory also participated, as well as summer aides under the Youth Opportunity Program, which made possible the laboratory testing of thousands of individual material specimens without major impact on other programs.

The conclusions of this study have been incorporated in recommendations to the Army Aviation Systems Command[6] and were implemented in subsequent directives.

ENGINEERING EVALUATION OF AGE LIFE EXTENSION, T-10 TROOP MAIN PARACHUTES

I. PROJECT BACKGROUND

The main goal of this project was to develop test data on the component nylon materials of aging T-10 Troop Main Parachute equipment, as a basis for validating or changing the prescribed useful life limits of existing parachutes while still meeting the dual requirements of reliability and economy. Related objectives were: to refine criteria for inspection and repair; to explore possible distinctions between initial storage periods and service life in the life-limit formulae; and to re-examine earlier findings that there is no direct relation between parachute condition and jump history.

This is part of an on-going program to establish formulae for discarding equipment, based on avoiding excessive replacement and repair costs while maintaining reliability control. At present there are no feasible methods for non-destructive testing of individual parachute units. The present project was initiated as a result of the Air Items Life Extension Conference, U. S. Army Aviation Systems Command, February-March, 1973.

In previous similar studies of the T-10 Troop Chest Reserve Parachute Assemblies, total life limits (i.e., from date of manufacture) were found to be generally valid as a practical means for reliability control.[2,3] For the reserve equipment maturing at the time of those studies, it was concluded that the then-existing limit of 10 years total life was somewhat too conservative. Modest extensions to 12 years were found to be warranted for the T-10 reserve canopies and 13 years for the harnesses and risers.

However, new insights were also gained as to how nylon parachute components age, and they revealed that it is risky to generalize: to apply data obtained for one type of equipment to another type, or to extrapolate data obtained for one year of manufacture to other years. As the referenced reports discuss in detail, deterioration is now seen to relate chiefly to such specific and local factors as the initial characteristics of the material and subsequent handling and exposure to radiation and contaminants (though not to climatic environment, as will be seen); it does not occur uniformly for all parachutes or even for sections of one parachute unit.

Thus the Air Items Life Extension Conference recognized the need for data specific to the T-10 Troop Main Parachutes of the age classes now in use, before any change in age limits could be instituted.

As a result of data from the earlier studies and the increased understanding of the deterioration process, the Conference also recognized that there is only a very indirect association between jump history and the condition of parachute materials. Further, many of the log books for parachutes in service were replacements in which "recorded jumps" were based in large part by an assumed 10 jumps per year rather than the actual number.

Accordingly it was concluded that there was then no sound engineering basis for establishing an overall limit on number of jumps for a parachute or for including number of jumps as a factor in the formulae for arriving at excess repair costs — not, at least, on the basis of log book entries. Regulations were later issued to eliminate jump history as criteria in these areas. However, in the present study one objective was to examine the data developed on the T-10 Troop Main Parachutes to further explore the relationship between jump history and materials condition.

II. SAMPLING AND TEST PLAN

A. Sampling -

In the previous studies of reserve parachute equipment, worldwide samplings were obtained. However, the materials showed few or no differences in condition that appeared related to their geographical sources and climatic environments. Also, there were no discernible differences between samples from two high-use continental locations, Fort Bragg and Fort Benning. Consequently, it was agreed that the samples of T-10 main parachute equipment for the present study would be drawn from sources within Fort Bragg.

Based on examination and discussion by the Natick Laboratories team with cognizant XVIII Corps personnel at Fort Bragg on 7-8 March 1973, representative assortments of T-10 main parachute assemblies were selected from operating and maintenance elements. It was concluded from examination that a major portion of the samples could validly be taken from recently accumulated stocks of equipment that had been set aside for salvage because they were over-age or too costly to repair. This plan would provide a good cross-section, and at the same time, conserve usable assets. Identified sample lots were subsequently assembled by Fort Bragg personnel, and were received at Natick Laboratories by mid-April 1973.

In addition to the used T-10 main parachutes, T-10 main and reserve parachutes that had not been opened from their depot packs since they were manufactured in 1967 were obtained for comparison testing, as part of the effort to distinguish between initial storage and subsequent service as factors in deterioration. Six MCI-1 maneuverable parachutes were also obtained for comparison with the T-10 main parachutes.

B. Test Plan

The test plan included:

1. Full riggers' inspection.
2. Obtaining samples of materials from within the units of equipment.
3. Laboratory testing.

The plan generally followed the procedures used in the prior surveys of reserve parachutes. However, such conditions as fraying, chafing and frictional fusing were observed and recorded in more detail, so that their relation to basic physical test properties could be determined by later analyses. Examination was also made of the entries in those log books which were received with the sampled equipment. In cutting out specimens for testing, the fabric samples were taken at different positions around the canopy and at different elevations, in a spiral manner, and recorded by position so as to provide for subsequent analysis by top-to-bottom position.

III. LABORATORY TEST METHODS

The canopy fabric, suspension lines, riser webbing and harness webbing were tested in general accordance with the appropriate test methods described in Federal Standard 191, with modifications necessary to adapt the specimens to the test equipment as described below:

A. Canopy Fabric — The canopies are made of nylon ripstop fabric, requirements for which are specified in MIL-C-7020, Type I. The breaking strength, elongation, and tear strength were determined separately in the warp and filling directions in canopy fabric specimens obtained from individual sections of five gores distributed over the entire canopy. Three tests each in the warp and filling directions were conducted for each section, and the mean was calculated; except that fewer tests were given some sections that were too small to yield enough specimens. By Method 5104, Federal Standard 191, the minimum ravel strip breaking strength requirement for the canopy fabric is 42 pounds and the ultimate elongation requirement is a minimum of 20% in both the warp and filling directions. Similarly, by Method 5134 (tongue tear), the minimum tongue tearing strength requirement in both warp and filling directions is 5 pounds.

B. Suspension Lines — The suspension lines are made of nylon cord, requirements for which are specified in MIL-C-5040, Type II. Five separate lines distributed around the canopy were tested. By Method 4102, using spool-type jaws, the minimum breaking strength and elongation requirements for the nylon cord are 375 pounds and 30%, respectively. However, a modification was made for the elongation measurement to avoid the possible hazard inherent in the test method: the total length of the cord was measured between the two spool-type jaws when the cord was mounted under pre-tension, and jaw travel was obtained from the Instron chart. Repeated comparisons showed that this value is within 1% of tha value obtained using the conventional gauge marks described in the test method.

C. Risers — The webbing in both the risers and harnesses were made of nylon, requirements for which are specified in MIL-W-4088, Type XIII. The minimum breaking strength requirement for this webbing is 6500 lbs. One leg of each riser was tested with a Tinius-Olsen webbing tester. A heavy-duty separable link connector was substituted for the regular connector in the stitched loop of the upper section of the riser leg. This connector was engaged with the upper jaw by a doubled piece of separate webbing. The remaining portion of the riser webbing was engaged with the lower jaw.

D. Harnesses — The horizontal back-strap section was of sufficient length to be engaged by the split-drum test jaws in the normal manner. The diagonal back strap was tested by cutting the stitching at the forward loop (which attaches to the release assembly hardware) to open it out and make a free end. The loop for the back strap adjuster was used at the other end, but for safety the adjuster hardware (which failed at as low as 2300 pounds in first trials) was replaced by a heavy duty separable link connector through which a separate webbing piece was doubled for engagement with the other jaw. The leg strap was tested by cutting at the edge of the saddle to provide one free end. A separate webbing piece was doubled through the adjustable lug hardware slot for engagement with the other jaw of the tester. The leg strap webbing was pulled through the adjustable lug until the rolled stop was about 3 inches from the lug slot, and the test started in that configuration.

E. Additional Comments — All data, including visual observations, were recorded with an identity code for each sample unit, and by gore and section for the canopy fabric. Since the primary purpose of this survey and report was to recommend immediate decisions on the equipments now in service, only the summarized data and the more obvious interpretations and conclusions are presented here. However, follow-up analyses are being made for more obscure trends and correlations that may prove informative.

Strength data on the webbing and fabric components were obtained solely at the slow rates of extension required in the specification tests. However, previous work has shown that the values thus obtained for these types of relatively uniform woven canopy materials are comparable to values obtained under more realistic dynamic conditions — usually, in fact, slightly lower. The relationship of dynamic to semi-static strength test values for suspension lines is discussed in the report on reserve parachutes.[2]

In the evaluation of results, the concept of strength loss is based of necessity on the assumed original strength of the particular material and component. Since direct before-and-after comparisons cannot be made, a typical baseline level or range somewhat above the specification minimum was assumed, based on experience as to what might be expected for these materials as manufactured.

For purposes of studying general trends which may be prudently extrapolated a few years ahead, the data were considered en masse by comparison to the baseline levels and between progressive age groups. However, the paramount concern throughout is with the extreme cases and their probabilities, since these are the limiting reliability factors.

IV. DROP TESTS ON HARNESSES

A number of the oldest T-10 harness assemblies representing various manufacturers were included in the sampling. Seventeen of these were subjected to instrumented shock test proof loading while mounted in full configuration on a 250 pound torso dummy, which was dropped and snubbed from a crane boom. Recorded total shock loads varied from 5175 to 6000 pounds. These are at least 25% above the highest force recorded in the TECOM study data shown in Chart 15. No failure, damage or sign of overstrain was observable following these overload drop tests. These harnesses were subsequently tested by the laboratory as described below.

V. LABORATORY TESTS ON CANOPY ASSEMBLIES

A. Canopy Fabric — The warp and filling tensile strength data obtained on the T-10 main canopy fabric are presented by year classes in Chart 1, and collectively in Chart 2. Elongations are presented in the same manner in Charts 3 and 4, and tear strengths in Charts 5 and 6.

Several observations and conclusions can be drawn from the data. The distribution patterns appear quite normal in the statistical sense, and can be assessed by direct examination with reasonable confidence for the immediate purposes of management consideration. Additional data analysis is being carried out for further technical background and future guidance, but it is not expected to alter the basic conclusions of the surveillance study.

From the levels and distributions of the lower strength and elongation values found in the sampling, indications are that the canopy fabrics in the present populations of T-10 main canopies present no hazard at their present ages. While some individual values are significantly below the specification minima of 42 pounds strength and 20% elongation, these represent only local areas and not any canopy as a whole. In fact, more detailed examination of the basic data shows no particular within-canopy grouping of low values, and only a slight occasional association of low values for locations at the bottom and near the apex. It is thus concluded that any hazard lies in the possibility of local failure in a minor area rather than of a massive failure throughout a major area or whole canopy. This view is consistent with the findings of the previous studies of reserve parachute equipment, further indicating that the nature of the problem is primarily one of the cumulative incidence of local influences and specific effects rather than general deterioration of nylon as a class.

The inspection charts and supplemental notations taken during the riggers' examination, prior to the cutting out of laboratory test specimens, were reviewed for any readily apparent correlation with the test data. Since no correlations were found of sufficient distinction to provide new guidance for practical inspection criteria, these rather extensive records are not included or summarized in this report. The general observation is that the visual evidence of damage in canopy fabrics, such as frictional fuse burns, fraying, chafing, and yarn distortion are generally independent of basic detorioration processes within the material. Apparently the deployment, ground use, and handling conditions responsible for these types of physical damage are not directly associated with the exposures and contacts causing losses in intrinsic strength and elongation properties. No new recommendations for visual inspection criteria are forthcoming from this study.

B. Suspension Lines — The strength test data for the suspension lines are presented in Charts 7 and 8, and the elongation data in 9 and 10. Most of the strength values are below the specification minima of 375 pounds tensile strength and 30% elongation. This general lowering of tensile strength during service is characteristic of suspension lines. It is attributable to mechanical conditioning of the braided sheath and core structure, locally or overall, rather than to deterioration of the nylon fibers themselves. As noted in studies summarized in NLABS Technical Report 68-45-CM[1], it occurs primarily during the initial 20 to 30 jumps; after that there is a leveling off. The normal test strength of well-used but undeteriorated line is found to be about 325 pounds, which may be taken as the basis for comparison. The test data for this sampling show a number of individual values below this level, with some as low as 200 pounds. This degree of departure from the norm is proportionally greater than for the canopy fabric, indicating the greater sensitivity of the lines to usage and exposure during service. In this sense, as well as others as noted below, the lines are to be considered the more critical of the two components.

Following the rough estimation procedure used previously in the reserve parachute study, in which the worst sample was compared with the worst known condition of unbalanced loading, the maximum recorded total load of 2340 pounds is taken from the data in Chart 15. With the maximum unbalance of loading for one side at 66.9% of the total as shown in Chart 16, and with this distributed evenly over the 15 lines per side, the worst case loading per line would be in the 104 pound range. This estimate indicates that even under this highly unlikely combination of circumstances, there is a significant reserve load capacity.

Some further consideration must be given to the fact that the residual strength figures are based on specification type tests at a low strain rate, while the maximum load figures represent a dynamic situation. The earlier study showed that dynamic testing in the laboratory gave values as much as 35% below those from the standard test. However, it may be assumed that the dynamic strength efficiency in the full length of a suspension line would be greater than in the abbreviated laboratory test conditions. Accordingly, a reserve capacity is still indicated for the worst combination, though not by multiple factors.

It is also recognized that in a hang-up or other malfunction where a much higher load might be imposed on one or two lines, it would be very unlikely that the difference between the lowest value of 200 pounds and the normal 325-pound capacity for the lines so involved would make the difference between success or failure of the jump.

The elongation data for the suspension lines similarly show a wide range, with more than a third of the values below the 30% specification minimum and also below the apparent norm of 28% for used lines. Examination showed the usual broad association of low elongations with low breaking strength. However, there were also a few instances of lower elongation, as by increased modulus or stiffening, without marked lowering of breaking strength. Such changes in stretch characteristics might affect the load distribution between adjacent lines, but not to a degree considered greatly significant for the range of values shown.

Unlike the situation found with the strength of the canopy fabric, the suspension lines do show a more distinct association of relatively high or low strength and elongation values within individual assemblies. Actually, most of the low values were within four or five assemblies. This grouping may reflect the characteristics of the particular lot of the original line material — its particular susceptibility to age or environmental conditions —; more probably it reflects an unusual amount or severity of exposure. Since the lines in a canopy assembly stretched on the ground or a table would probably be fairly equally exposed (unlike areas of the canopy), this repetition of characteristics within individual units is at least consistent with the concept that the condition is due to sunlight exposure in service, as perhaps from a delay in pick-up during a training exercise.

C. Canopy Assemblies — With respect to the T-10 main canopy assemblies as a whole, it is considered that the suspension lines are the limiting components for the following reasons:

(1) Both the degree of strength and elongation loss as shown for the poorest sample and the spread of the test results, indicate that the reliability of the lines is less predictable than the reliability of the canopies, and that there is a higher probability of multiple line failures in aged equipment than there is of serious failures over major areas of the canopy.

(2) The lines tend to lose their initial elongation characteristics, and thus to alter load distribution.

(3) In riggers' or shop inspection, the lines would not as readily show visible evidence of the kind of extreme deterioration or internal damage that would cause questionable assemblies to be condemned and removed from the active population.

In view of the data and considerations noted here, it is believed that the materials in the T-10 main canopy assemblies as represented by the sampling are still reliable at their present ages, but they are approaching the point where performance cannot be depended on, and where serious material failures could occur in the more highly stressed elements under extreme loading conditions during deployment. A modest extension to 12 years total age from date of manufacture appears warranted and appropriate.

D. Other Observations — It is observed that the levels and the distributions of the data for the T-10 main canopy assemblies are quite similar to those found in prior evaluations of the T-10 reserve assemblies[2,3]. These similarities have two important implications with respect to reliability control, asset management, and related future surveillance programs. One is that the T-10 main and reserve parachute populations can be considered in many respects to have much in common and do not require completely separate and distinct service life criteria and limits. Related to this is the conclusion that the degradation problem with T-10 main parachute canopy assemblies is associated more with incidental causes than with direct effects of jumping (other than the noted initial drop in line test strength); otherwise more marked differences would have been found between the main and the reserve parachute populations. This conclusion supports the decision of the Air Items Life Extension Conference to eliminate number of jumps (actual and assumed) as a service life limit criterion.

Another observation is that the data show no clear trend lines with progressive age from the most recent 1967 sample back to the oldest 1951 year class samples. This apparent lack of age trend lines would at first seem to negate the validity of the age life limits as the means of reliability control. However, the data must be considered in the context of several conditions, both with respect to the population samples and the particular samples. One condition is that the data reflect only age from time of item manufacture, leaving a considerable range of uncertainty as to time of yarn or cloth manufacture. (More recent specification requirements will serve to reduce this range in the future.) Another and probably more significant condition is that the data reflect only total elapsed time, with no distinction between time in original storage and time in subsequent service. Since most of the log books noted in the on-sight survey and received with the samples were replacement books giving no indication of first-service dates, the hoped-for analysis to distinguish between initial storage and service periods could not be made. (As a result of the Life Extension Conference, canopies are now being stamped with the date of first removal from initial storage pack.) However, from the relatively few original log books available, it was evident that there was practically no correlation between total age and time in service. In fact, some of the oldest equipment had apparently been in service the least time. Discussions with on-site personnel also indicated that this condition is far from exceptional within currently active equipment populations. A third condition is that many of the assemblies in the sampling had (intentionally) been selected from parachutes being salvaged because of excess repair costs. Presumably, they would thus include a greater than average proportion of canopies which have been subjected to severe service and exposure conditions. This factor would also tend to obscure any trend by total age which might be acting within the parachute population as a whole.

Thus, while the data do not directly and positively validate the age limit system, they are not inconsistent with it. In fact, one can conclude from the same data that the combination of inspection standards, excess repair cost criteria, and overall age limits, which continues as the basis for withdrawing the older and the more questionable equipment from the active stocks, is successful in maintaining reliability. It is to be emphasized here that it is the combination of the three contributing elements which makes up the total reliability system. No major change should be made for any one element without recognition of its effect on the other elements and on the total system.

The log book system has become ineffective from the point of view of service life management, in the sense of this study and report. The new requirement for stamping the date on the canopy when it is first put in service will eventually provide a basis for distinction between initial storage life and service life in the age limits to be prescribed.

E. Maneuverable Parachutes — A supplemental sampling of six MCI-1 maneuverable parachutes was tested in a similar manner to develop indications as to whether they can be considered equivalent to the regular T-10 main parachutes from the standpoint of age-life limits. With the exception of one small area within one section, the canopy fabric strength and elongation values were close to or above the specification minima. There is no evidence from the data shown in Chart 11 that the MCI-1 parachutes present any greater or different reliability control problem than the regular T-10 mains, assuming that the usage and maintenance remain the same.

No suspension lines or log books were supplied with the MCI-1 samples, which were all of 1964 manufacture. Accordingly, no further analysis could be made. If the maneuverable parachutes become a larger portion of the total troop main parachute population in the future, they will be sampled more extensively in subsequent surveillance programs.

F. Initial Storage Parachutes — To establish a benchmark and check on the characteristics of unused parachutes of corresponding ages since time of manufacture, T-10 main and reserve parachutes still in the original depot pack, were selected for test from the three manufacturers represented in the inventories. However, the shipment included mains from only one manufacturer. These were all of 1967 manufacture; they were the oldest on hand and thus at least represent the upper range of storage times which are being encountered in typical turn-over and stock management operations. The canopy fabric strength and elongation values were all found to be above the specification minima (Chart 12) and in the range typical of new materials. The values for the suspension lines include some which are slightly below the specification elongation requirement. However, since there is no basis for comparison, it is not known whether these lower values are due to deviations in the original material or to some stiffening of the lines during aging in the depot pack. A more extensive study will be required if a clear-cut distinction is to be made between original storage age and service or total age. However, an interim system may be considered, as discussed in Section VIII.

VI. LABORATORY TESTS ON RISERS

The breaking strength data for the T-10 main risers are shown in Chart 13. The values are generally below the specification minimum of 6500 pounds, which is attributable in large part to the typical lowering of strength efficiency in the local area at the end of the sewn section of the hardware attachment loop. In other cases, as indicated in the Chart, the data reflect actual breaking of the sewing thread used in the seams. In either circumstance the values represent the limiting strengths of the riser assemblies. The normal for assemblies of webbing and thread of full original strength may be considered in the 5300-5700 pound range for the complete assembly, and this is a more appropriate basis for comparison than the original strength of unsewn webbing.

Using the estimation method of worst sample vs worst condition comparison which was used previously (paragraph 5B), the data from Charts 15 and 16 indicate the worst condition to be 2340 x 67%, or 1570 pounds maximum loading on either side. A safety factor of at least three to one appears to be well maintained within the current T-10 riser assemblies. These findings are fully consistent with earlier survey results for comparable year classes and attained ages, and further support the decision to extend the overall age limit from 10 to 13 years. However, since risers approaching the 13 year limit were not yet available for this sampling, the data do not suffice to support a decision on a still further extension to a 15 year limit.

VII. LABORATORY TESTS ON HARNESSES

Each of the 10-year and older T-10 harnesses, which had been previously proof-loaded by shock tests in full configuration, was divided into three sections and prepared for laboratory strength testing in the same manner as the T-10 reserve parachute harnesses in the previous study.[2,3] The data are shown in Chart 14. In general, the findings from this relatively small sampling are consistent with those from the more extensive previous sampling of equivalent age.

A. Horizontal Backstraps — The horizontal backstrap section is considered to represent the basic condition of the webbing as it might be affected by age and casual exposure, because it has a simple, straight configuration and is less subject to local mechanical stresses and chemical influences than other sections. With one exception, the test values are slightly below the specification minimum of 6500 pounds, but they are within a rather narrow range.

Since the harnesses may be used in conjunction with the T-10 reserve parachute as the worst-condition case, the maximum recorded loads for the reserves is taken from Charts 15 and 16 for comparison. The assumed peak combination of recorded loading and distribution of 4160 x 0.15, or 625 pounds, is very low compared to the observed reserve of strength in the horizontal backstrap webbing, indicating that this section of the harness is not of critical concern in determining service life limits. However, it is significant that some strength has been lost even in this least exposed section of the harnesses, thus this type of passive degradation must be a contributing factor in the greater losses observed in the more highly stressed parts.

B. Diagonal Backstraps — Tests of the diagonal backstrap sections showed much greater strength losses and more scattered results than the horizontal sections (Chart 14). The breaks in these test sections occurred in various locations. There were two failures of the stitched seams, one at a relatively high value and the other at a low value, as shown in shaded portions of the histograms. Some sections broke in the free sections of the webbing. The majority broke at the end of the stitched loop, in the most common failure patterns for such webbing components. The lowest values, which were only about one-half of the specification minimum, were in the free sections of the webbing, thus clearly indicating deterioration of basic strength, independent of configuration factors. However, since the worst combined condition assumed for this section is 4160 x 0.14, or 600 pounds, which is less than 20% of the lowest value found, it is also apparent that the diagonal backstrap sections of the harnesses are not critical or limiting factors.

C. Leg Straps — In this sampling as in previous studies, the leg strap components were shown to be the most affected by the factors limiting the overall strength of the harness assembly (Chart 14). Without exception, in these test samples the webbing slipped through the adjustment hardware until the rolled stop at the end jammed and pinched into the hardware opening, and the breaks all occurred at that point. The slippage commenced fairly early in the test sequence, when the loads were somewhere in the 1500 pound range and well below the final breaking loads. The elastic keepers (which had not been used in the previous tests in conjunction with the reserve parachutes) were ineffective in preventing the slippage in the tests reported here. Some of the individual test values and the general level in this sampling were slightly below those in the earlier survey. These differences may reflect true differences in the condition of the materials, but more likely they reflect test conditions that changed the nature and location of the breaks: in these tests, the rolled end was allowed to slide up and jam into the hardware while under test tension, rather than being pre-positioned as in the preceding study. The procedure used in this study is considered to be the more realistic of the two. These lower values corroborate previous conclusions that the leg strap sections in the configuration of the present harness are the limiting factor in service life considerations.

Assuming the maximum recorded load and distribution from Charts 15 and 16, it is conceivable as a worst condition that a leg strap might be subjected to 4160 x 0.28, or 1165 pounds. However, the lowest test strength value would still indicate a two to one safety factor even in this unlikely circumstance.

D. Total Harness Assembly— It is apparent from the data and comparisons that the 10-year-old harnesses as represented by this sampling present no immediate hazard from the point of view of webbing and stitching failures. It is true that significant losses of strength have occurred, and that the wide scatter of test results for the more critical sections makes it difficult to predict the probability of failure under extreme conditions in the total population. However, in view of the probabilities and remaining safety factors, the results of this supplementary survey are considered to support fully the earlier decision to extend the age life limit for T-10 harnesses by a conservative three years, for a total of 13 years of elapsed time since date of manufacture. While a subsequent survey of 13 year old harnesses might provide a basis for further extension, the three year extension may suffice to facilitate an economical phase-over to the improved harness assembly.

VIII. DISCUSSION

A. General — The above-reported findings and considerations generally confirm the prior analyses of service and total life aspects of troop parachutes, and they support the recommendations and decisions that have been made. They show that age, deployment and drop operations have little direct effect on the deterioration of nylon parachute components compared to the effects of incidental and highly variable circumstances experienced by individual equipment units or local sections within units. They also show that the present reliability control system, incorporating the combination of inspection criteria, repair cost limits, and age life limits, has been quite successful in maintaining serviceability within the active parachute populations, without applying unreasonable safety factors or causing grossly excessive rejection and replacement rates.

While it is recognized that the present system is imprecise and far from the ultimate in direct cost savings, there are compensating advantages in operational simplicity, familiarity, and confidence based on successful experience.

B. Non-destructive Testing — Two approaches to improving the system have been suggested. One is developing a feasible nondestructive testing technique whereby individual equipment units could be checked routinely on a "go", "no-go" basis. However, previous attempts to develop such a test system have been unrewarding; in fact, they revealed potential hazards that might be introduced by such a system if it is not sensitive to any and all types and combinations of changes and degradation processes in the nylon fibrous system. For example, a test system that responds to some indicators of deterioration — e.g., changes in polymer chain lengths induced by radiation or chemical influences — might be insensitive to others — e.g., changes in crystallinity, bound moisture, fracture point generation, or surface effects. Also, there is the problem of how specific a condition may be to a local area of the test item: statistically, the section in test may represent the whole or the worst area. At this time, at least, the prospect of a reliable nondestructive test system for economical on-site routine operation appears rather remote.

C. Improved Stock Management — The other area of prospective improvement is in stock management and related record keeping. For lack of appropriate records on the time of entry into service, the surveys to date have been unable to develop data to distinguish between original storage life and service life in their effects on the condition of the materials.

A directive has been issued to indelibly mark on each item the first date of "service", taken as the date of removal from the original manufacturer's package or container. In time, this system will enable a factual analysis of the situation. Meanwhile, however, there appears to be enough evidence to warrant consideration of a life limit system which will to some degree recognize the difference between initial storage and subsequent service conditions. Some of the factors are noted below.

The test values on the small sampling of six-year old parachutes in original containers, plus spot checks, studies and observations over a number of years by all of the Armed Services, lead to the conclusion that degradation occurs slowly in the initial storage period, if at all, compared to the degradation that may occur later in the service period. It cannot be assumed that no changes will occur, and that the state of the material at the end of, say, five years of storage is identical in all respects to its original state. There may have been internal changes that would predispose the material to subsequent degradation processes. Thus, the storage time cannot be ignored, but it seems reasonable to penalize storage time less than service time in the service life formula.

One way to accomplish this would be an equivalency formula: for example, two years of initial storage would count as equivalent to one year in service. This has no factual basis, however, and even if it were valid in earlier years, it probably would not be later, and from a stock management point of view, it may erase or even reverse the incentive for an orderly turnover of stock and for obtaining adequate service from all items in the system.

Another system, currently followed by the Navy and Air Force, is to establish two limits: one for elapsed time in service, the other for total elapsed time from date of manufacture. It is understood that these limits were established with little factual backing, but they have apparently proved practical both from the point of view of reliability control and stock management. Limits for troop-type parachutes might be 12 years service life or 15 years total life. If such a system is put into operation, it should be subject to continuous surveillance to detect any unfavorable deviations from the pattern, and also to detect opportunities to further extend these limits.

IX. SUMMARY CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Troop Main Personnel Parachute Canopies as represented by samplings from 1961 through 1967 year classes are suitable for continued service through 12 years from the dates of manufacture indicated thereon. This conclusion is applicable worldwide, and includes the T-10 (MC1) the MCI-1 (Maneuverable) and HALO parachutes. The conclusion is extendable to up-coming maturing year classes, provided there are no marked changes determined in subsequent surveillance.

2. The findings from the additional samplings of Troop Parachute Riser Assemblies (1960-1967) and Harness Assemblies (1960-1963) continue to support the current 13 year

service life from date of manufacture. The conclusion is extendable to up-coming maturing year classes, provided there are no marked changes determined in subsequent surveillance.

3. A sustained surveillance program for matured Troop Personnel Parachute Equipment (canopies, risers, harnesses) should be instituted as a means of checking on the reliability and economy of adopted age life limits, because of possible changes in materials, service and maintenance circumstances and environments.

4. There is insufficient valid data from log books to make any determination or immediate recommendation with respect to distinction between original storage age and in-service age in prescribing total life limits for Troop Personnel Parachute Equipment.

5. Visual evidences of color change, minor damage, etc., cannot be related to causes of basic degradation, nor considered reliable indicators of basic material conditions; no new or special guidelines for inspection criteria can be offered.

6. From the findings of this and previous similar evaluations of Troop Personnel Parachute Equipment, further significant extensions of service life limits are probably not warranted at this time. Any further extensions of total life limits in the future should probably be based on establishment of a distinct initial storage life allowance and limit.

B. Recommendations

It is recommended that a sustained surveillance program for maturing Troop Personnel Parachute Equipment be instituted to monitor the life management system. As part of this program, a basis should be developed for establishing limits that distinguish between initial storage and service periods, and for recording parachute histories on this basis.

<u>References:</u>

1. "Strength Losses in Nylon Parachute Materials with Time, Exposure and Use", U.S. Army Natick Laboratories Technical Report 68-45-EM, March 1968.
2. "Engineering Evaluation of Age Life Extension, T-10 Harnesses, Risers and T-10 Troop Chest Reserve Parachute Canopies", U.S. Army Natick Laboratories Technical Report 72-59-CE, March 1972.
3. "Engineering Evaluation of Age Life Extension, T-10 Harnesses, Risers, and T-10 Troop Chest Reserve Parachute Canopies, Supplement i", U.S. Army Natick Laboratories Technical Report 74-9-CE, October 1973.
4. Memorandum for Record, AMCRD-FS, Subject: "Air Items Life Extension Conference", 7 March 1973.
5. Report of Travel, 14 March 1973, Messrs. Claridge, Weber and Wells, to XVIII Corps, Fort Bragg, N. C., 6-8 March 1973.
6. Letter, USANLABS, STSNL-APE, dated 30 November 1973 to Commander, USAAVSCOM, ATTN: AMSAV-SI, Subject: Age Life Extensions for Troop Type Personnel Parachute Canopies, Harnesses and Risers.

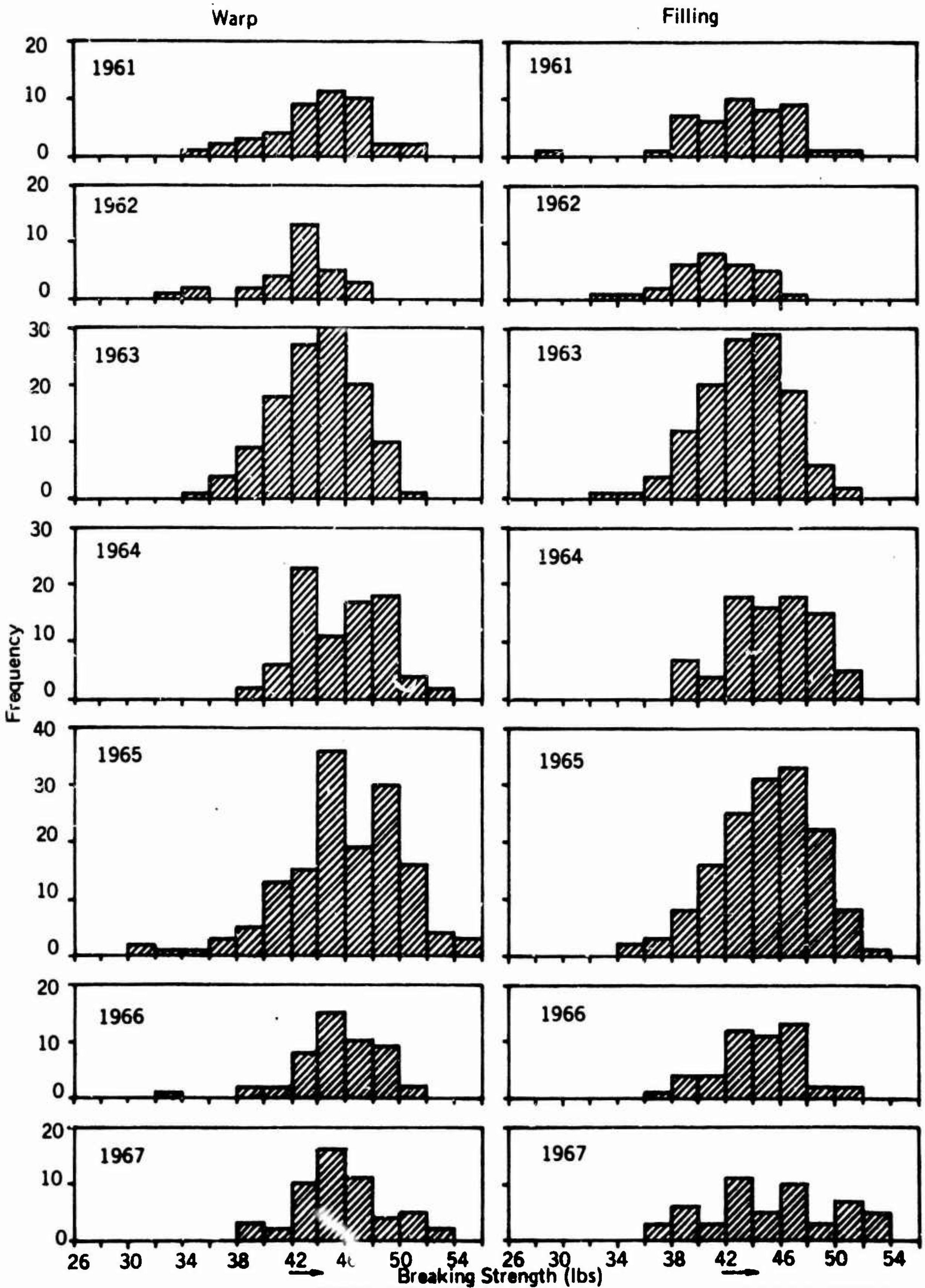


CHART 1. BREAKING STRENGTH HISTOGRAMS OF T-10 MAIN CANOPY FABRIC BY AGE CLASS

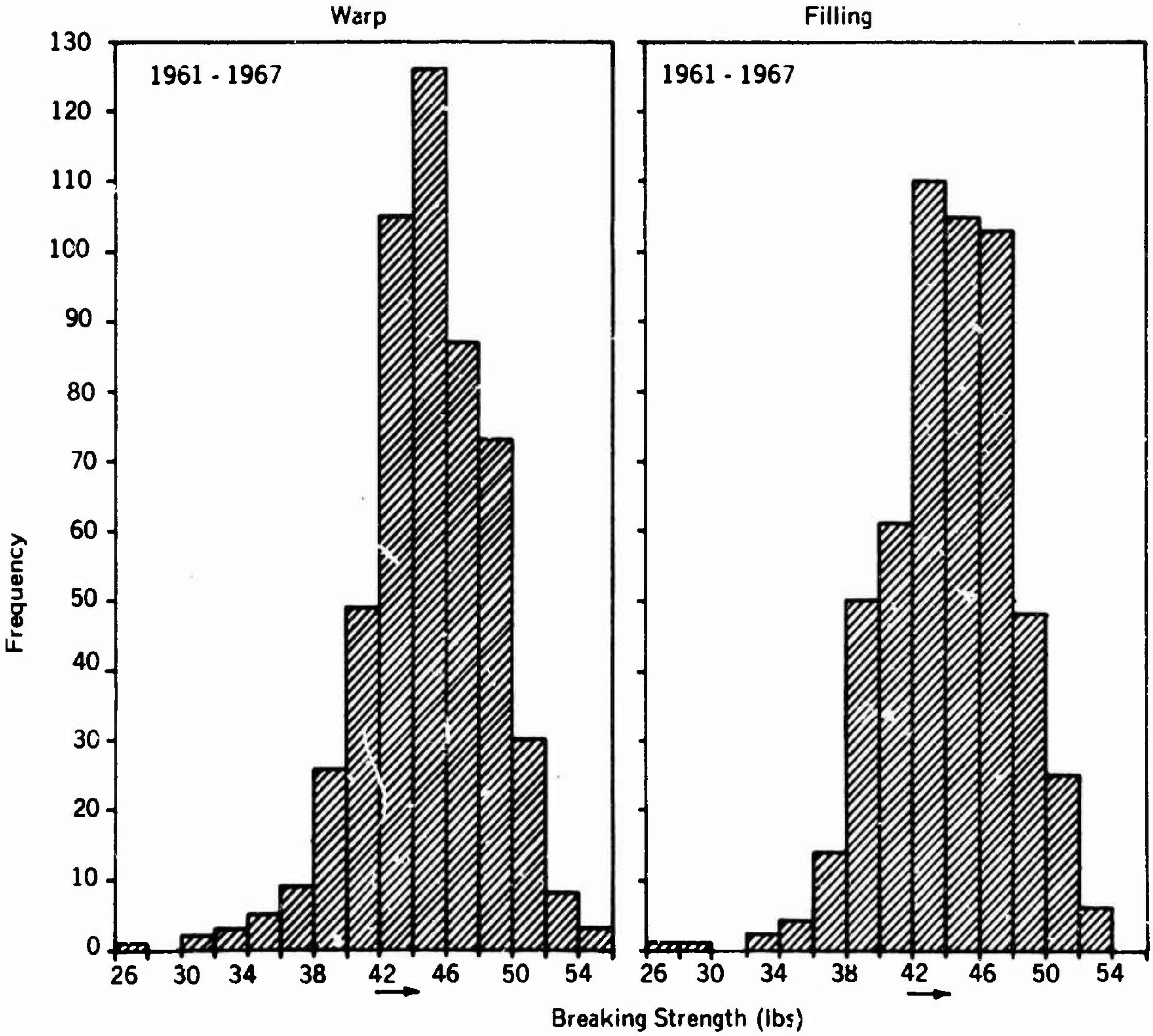


CHART 2. BREAKING STRENGTH HISTOGRAMS OF T-10 MAIN CANOPY FABRIC IN PARACHUTES MANUFACTURED IN 1961 - 1967.

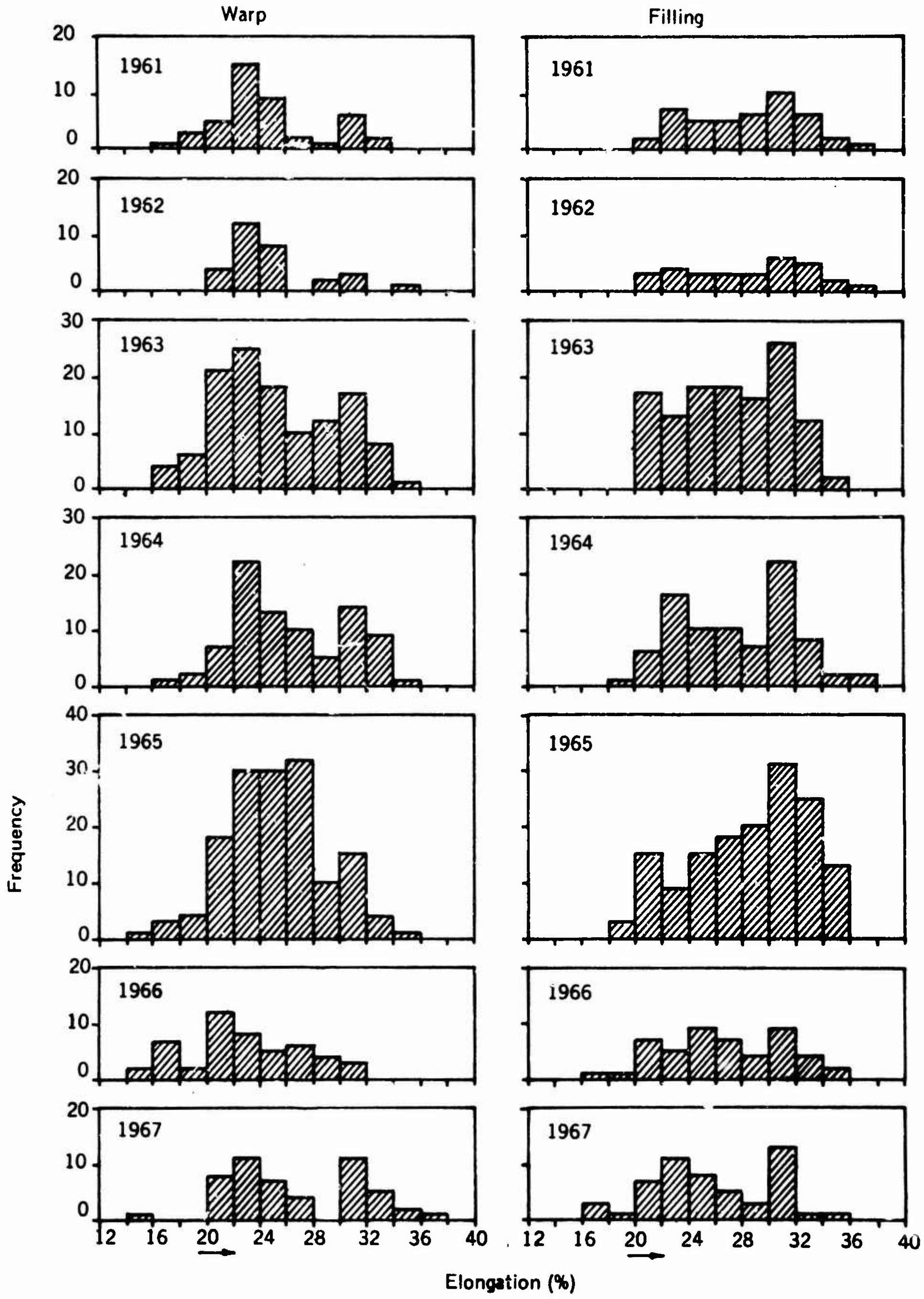


CHART 3. ELONGATION HISTOGRAMS OF T-10 MAIN CANOPY FABRIC BY AGE CLASS.

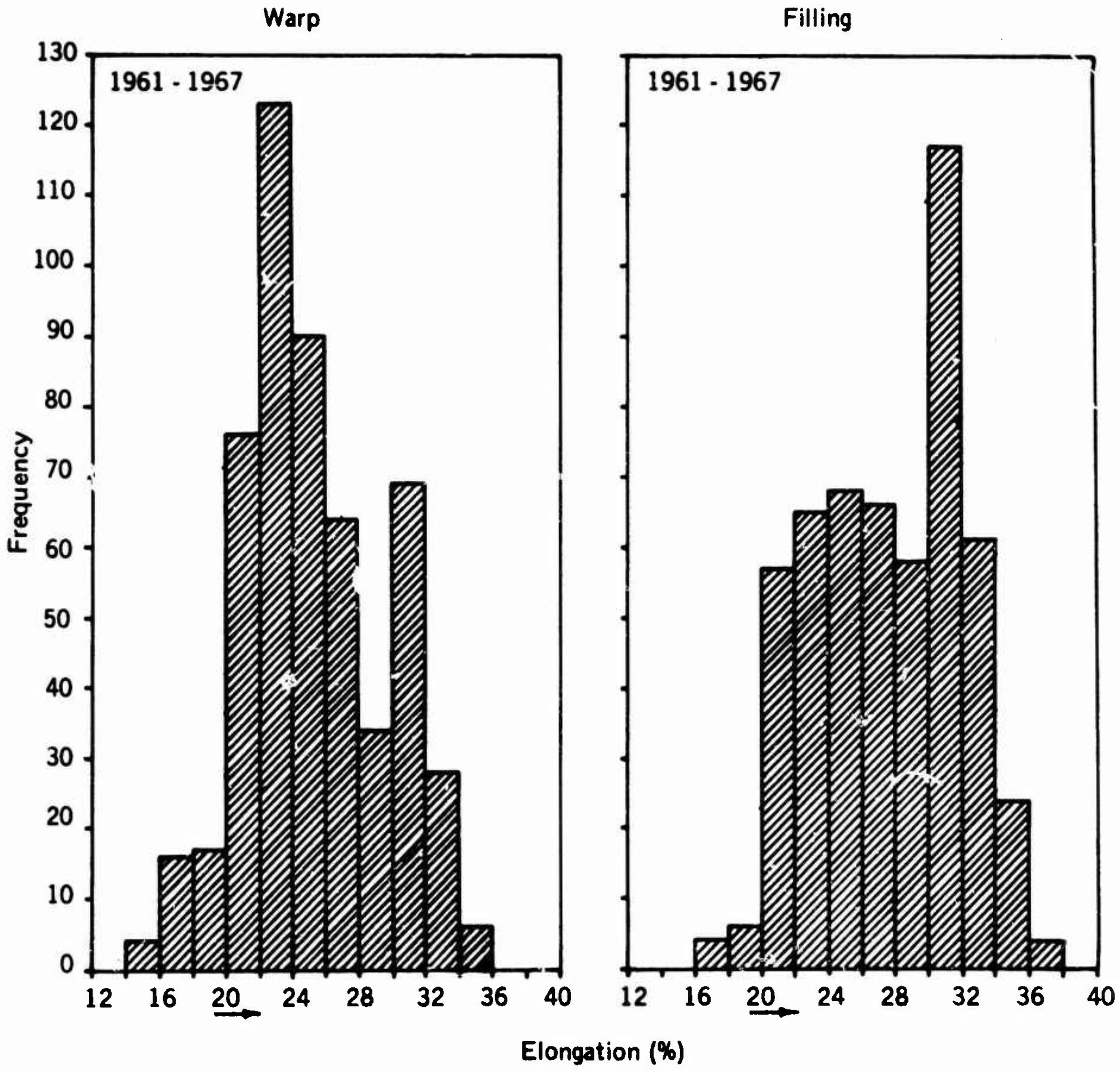


CHART 4. ELONGATION HISTOGRAMS OF T-10 MAIN CANOPY FABRIC IN PARACHUTES MANUFACTURED IN 1961 - 1967

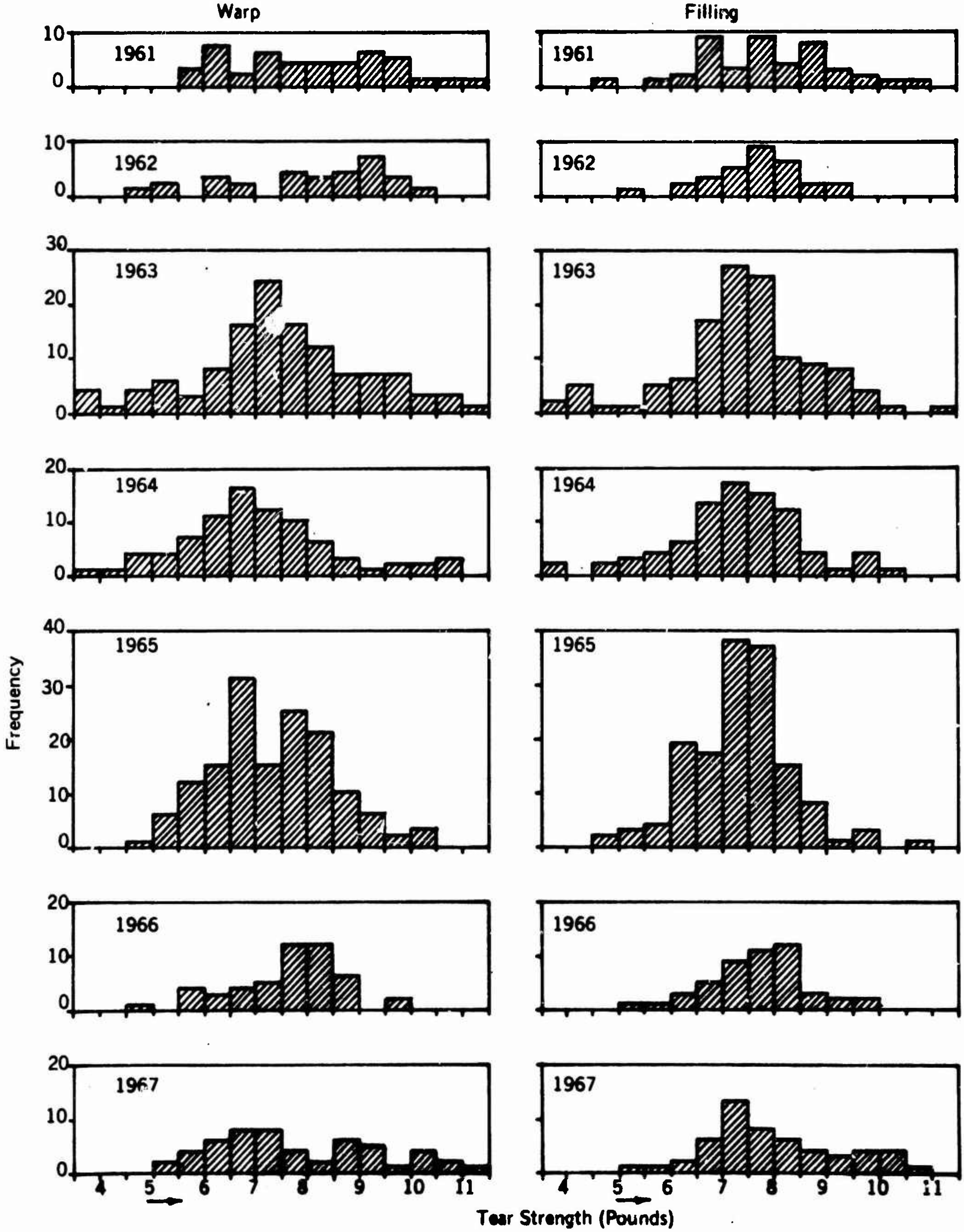


CHART 5. TEAR STRENGTH HISTOGRAMS OF T-10 MAIN CANOPY FABRIC BY AGE CLASS

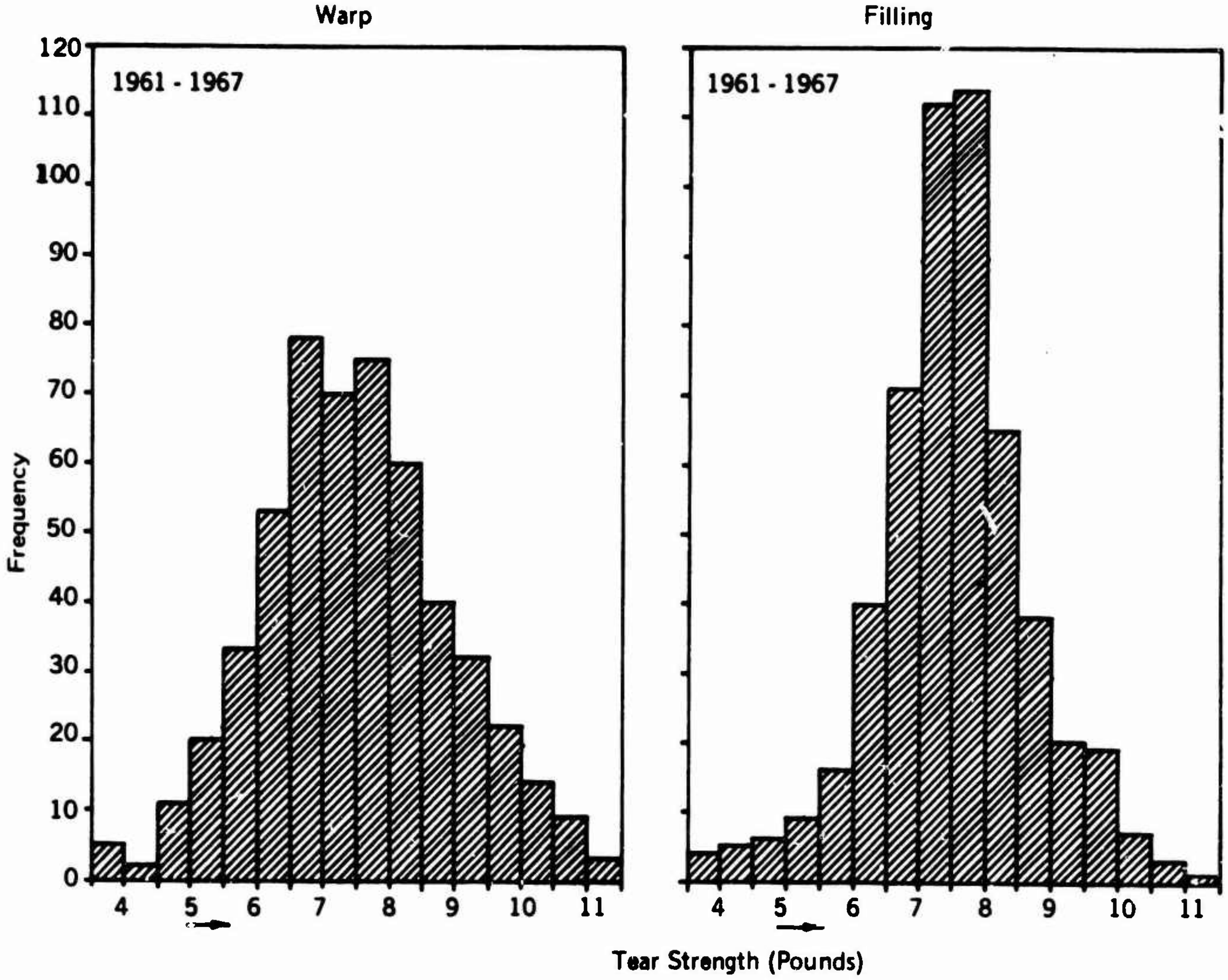


CHART 6. TEAR STRENGTH HISTOGRAMS OF T-10 MAIN CANOPY FABRIC IN PARACHUTES MANUFACTURED IN 1961-1967

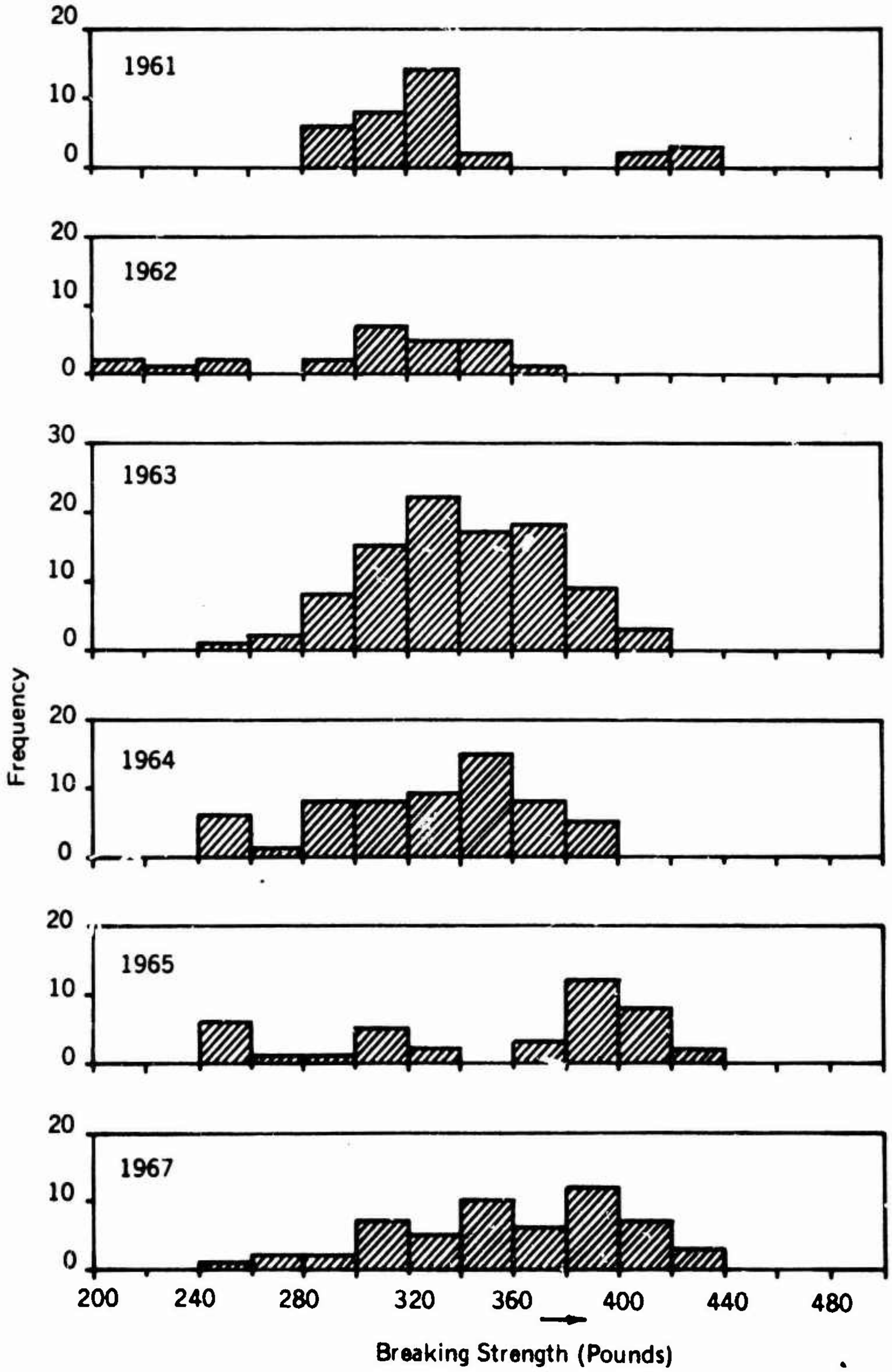


CHART 7. BREAKING STRENGTH HISTOGRAMS OF T-10 MAIN SUSPENSION LINES BY AGE CLASS

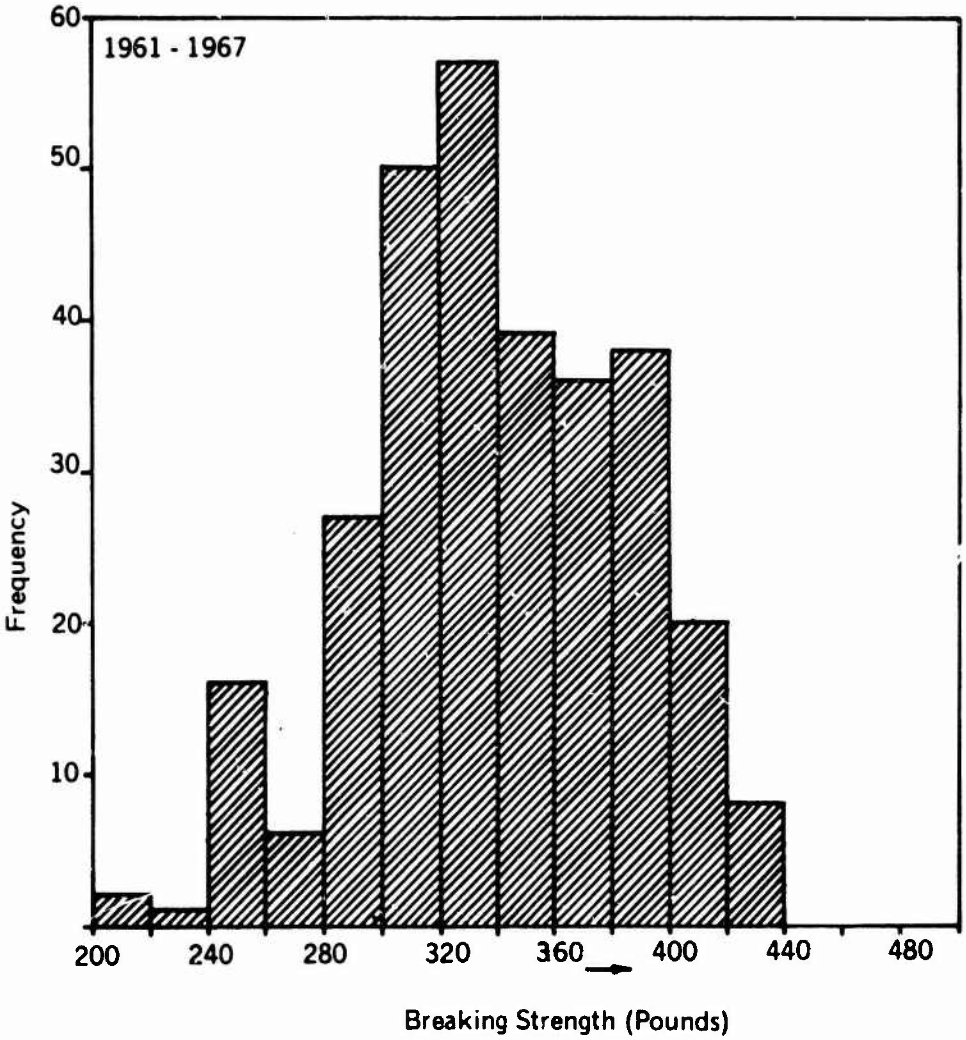


CHART 8. BREAKING STRENGTH HISTOGRAM OF T-10 MAIN SUSPENSION LINES MANUFACTURED IN 1961-1967

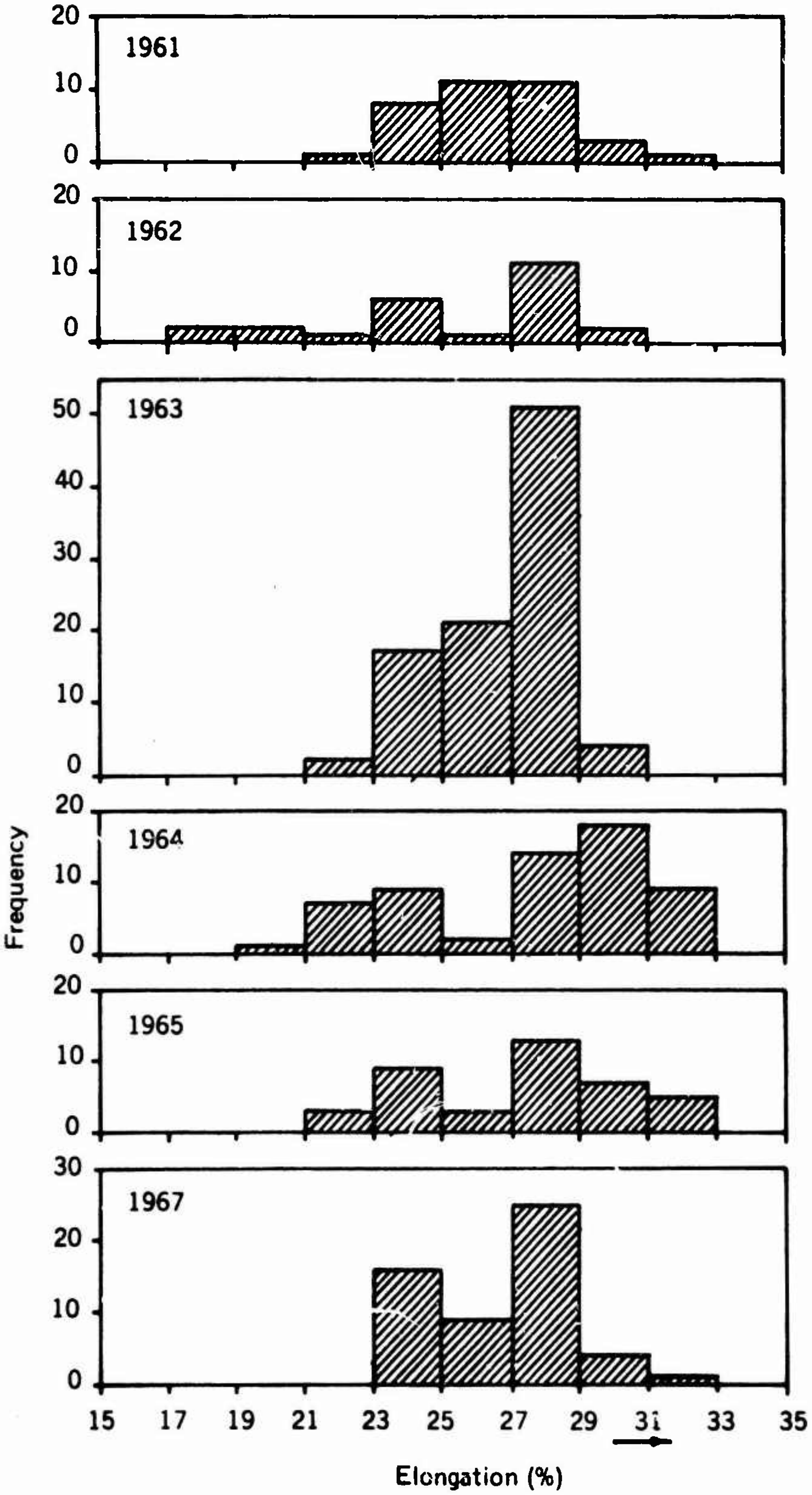


CHART 9. ELONGATION HISTOGRAMS OF T-10 MAIN SUSPENSION LINES BY AGE CLASS

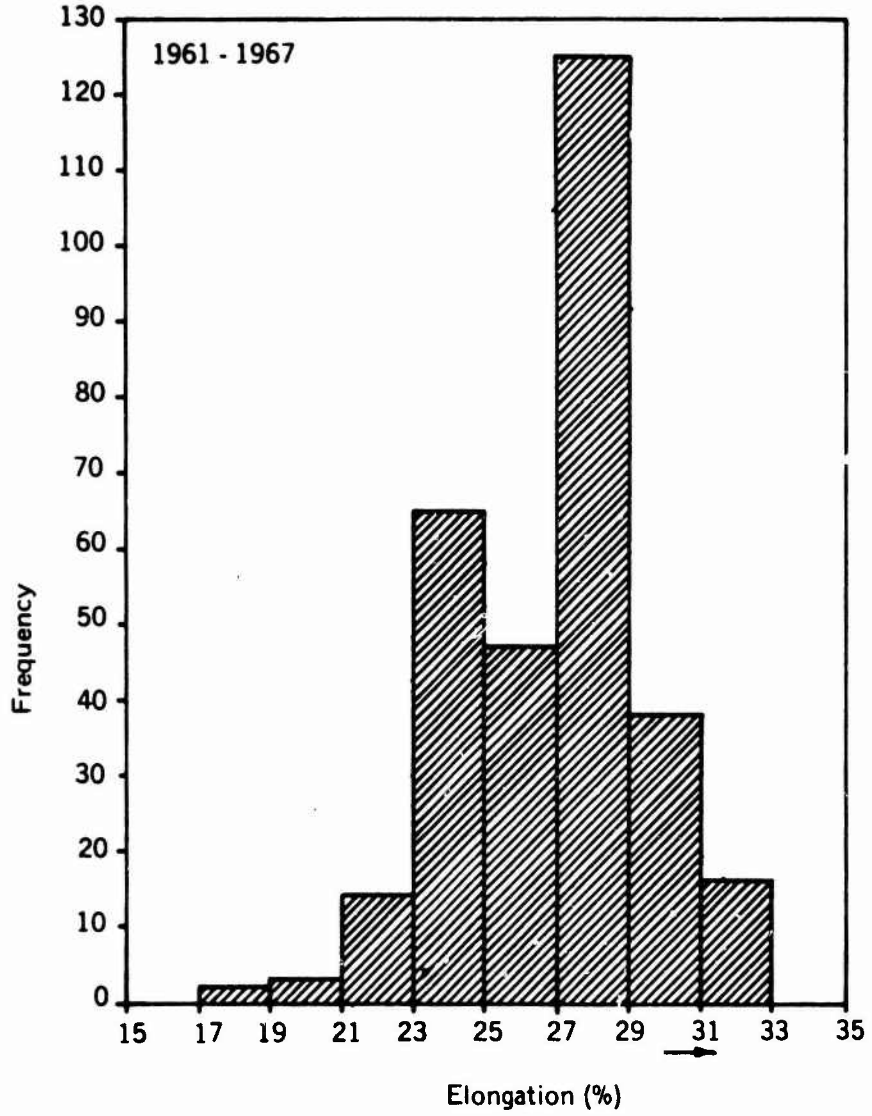
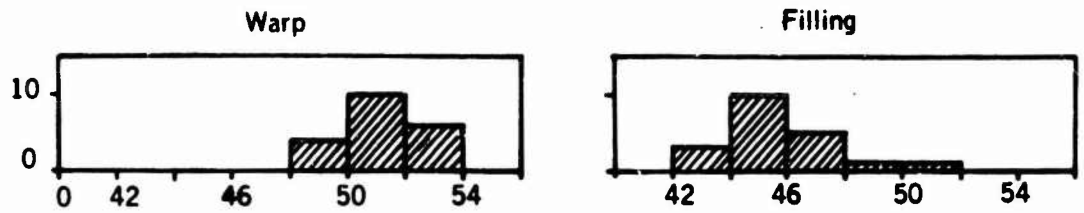
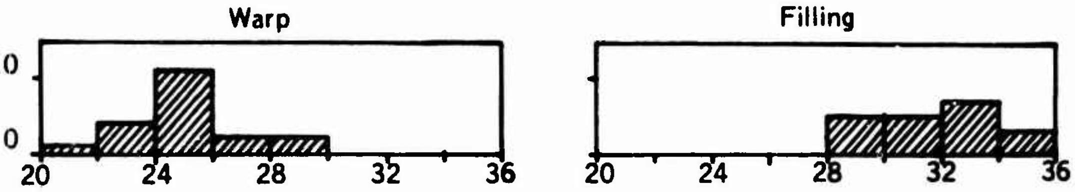


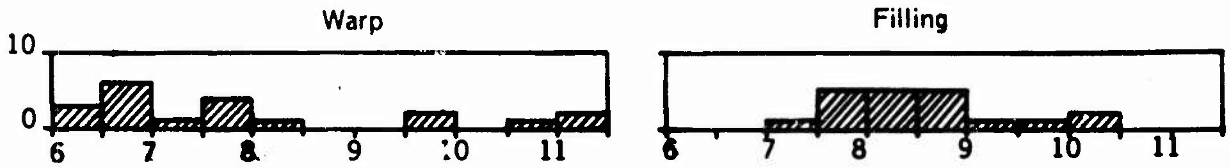
CHART 10. ELONGATION HISTOGRAMS OF T-10 SUSPENSION LINES MANUFACTURED IN 1961 - 1967



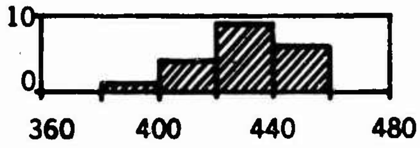
Breaking Strength of Canopy Fabric (Pounds)



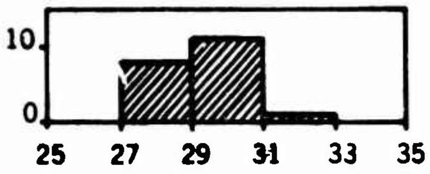
Elongation of Canopy Fabric (%)



Tear Strength of Canopy Fabric (Pounds)

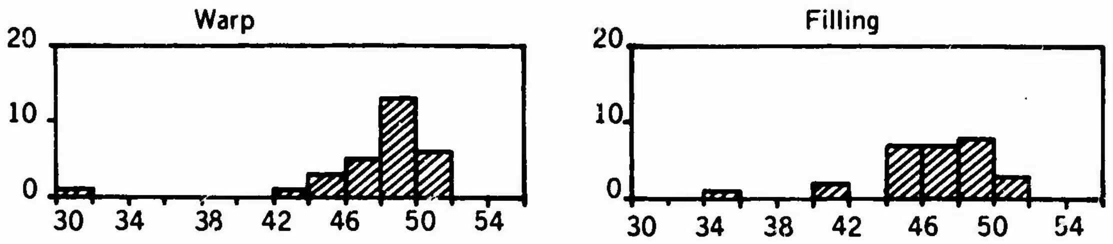


Breaking Strength of Suspension Lines (Pounds)

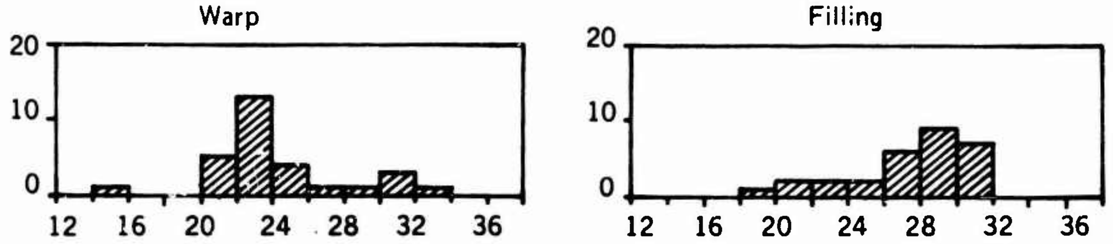


Elongation of Suspension Lines (%)

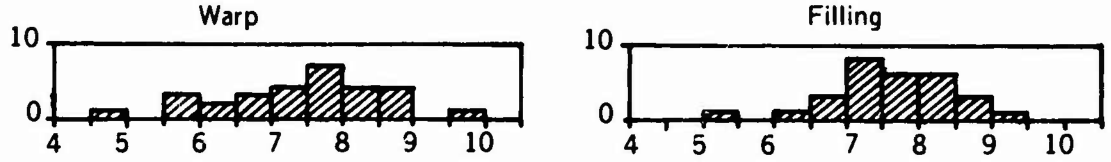
CHART 11. HISTOGRAMS OF VARIOUS CHARACTERISTICS OF T–10 PARACHUTES MANUFACTURED IN 1967 BUT REMAINED IN DEPOT PACKS UNUSED.



Breaking Strength (Pounds)



Elongation (%)



Tear Strength (Pounds)

CHART 12. HISTOGRAMS OF VARIOUS CHARACTERISTICS OF MCI-1 (MANEUVERABLE) PARACHUTE CANOPY FABRIC

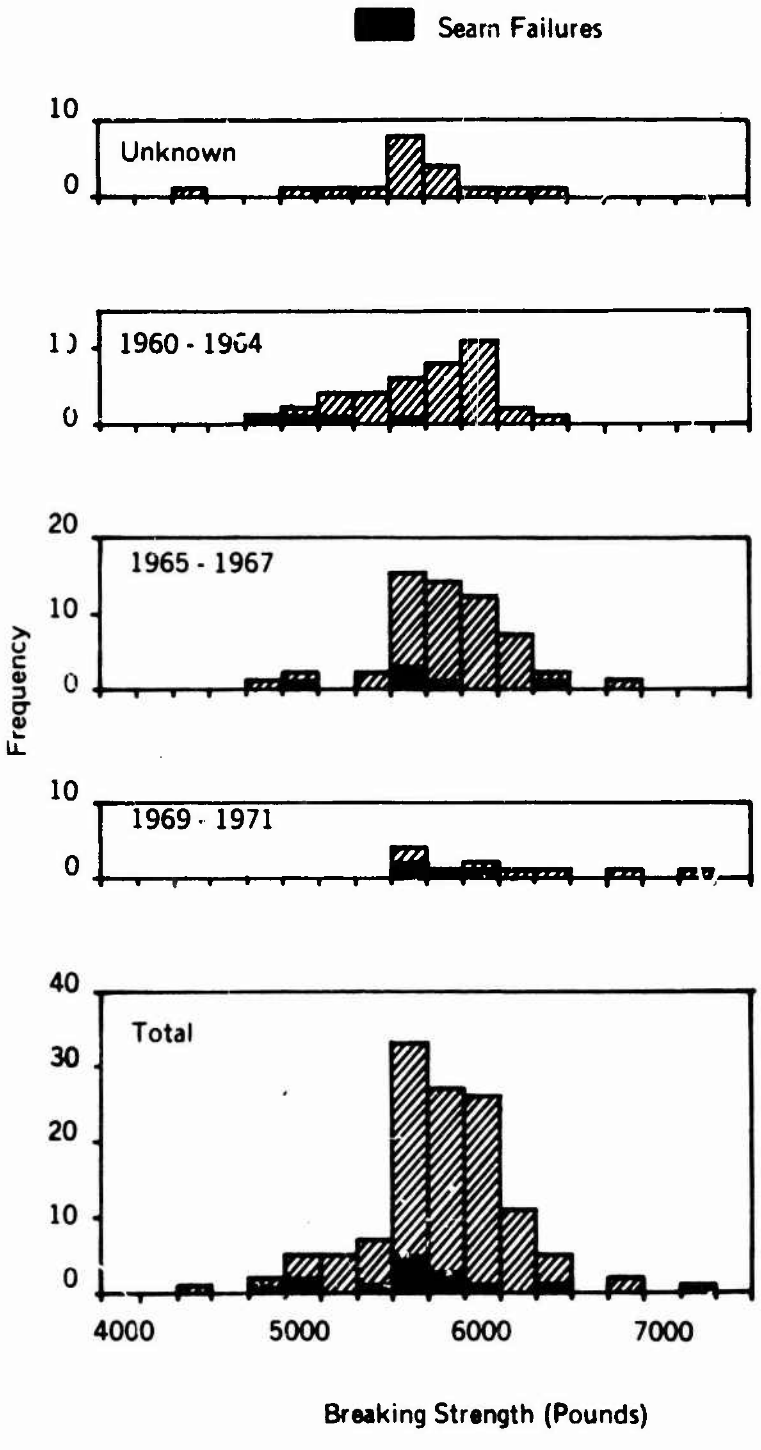


CHART 13. BREAKING STRENGTH HISTOGRAMS OF T—10 MAIN RISERS BY AGE CLASS

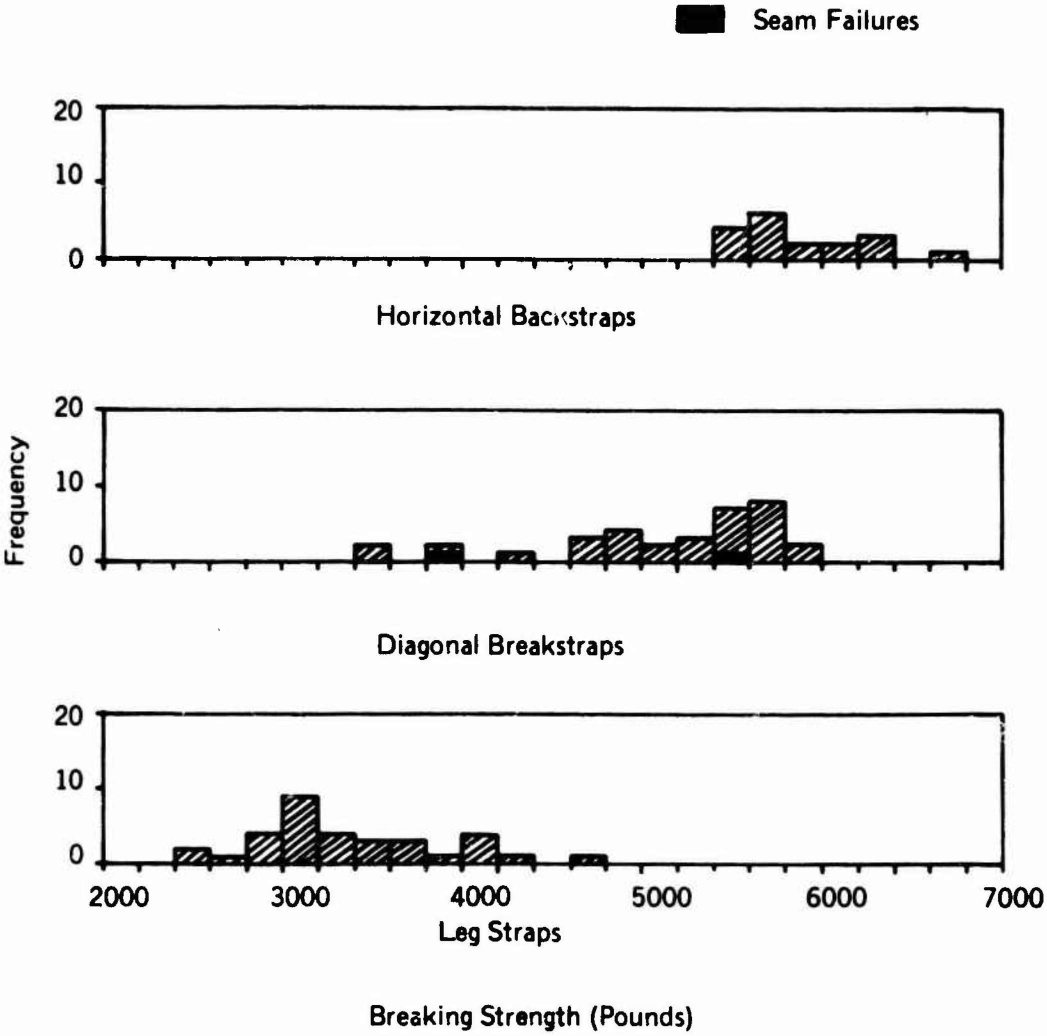


CHART 14. BREAKING STRENGTH HISTOGRAMS OF T-10 MAIN HARNESS WEBBING MANUFACTURED IN 1960- 1963.

T-10 Main Parachute

	Opening Force 7,100 Ft (lb)	Opening Force 7,100 Ft (g)	Opening Time 7,100 Ft (sec)	Rate of Descent 6,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	2189.6	8.1	4.4	22.6	24.4
Minimum	1436.5	5.3	3.6	19.0	17.4
Average	1574.1	5.8	4.1	20.9	20.3
Range	753.1	2.8	0.8	3.6	7.0

	Opening Force 11,100 Ft (lb)	Opening Force 11,100 Ft (g)	Opening Time 11,100 Ft (sec)	Rate of Descent 10,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	2342.8	8.7	4.8	25.4	22.4
Minimum	1238.5	4.6	2.8	20.4	14.9
Average	1578.9	5.8	4.1	21.6	18.8
Range	1104.3	4.1	2.0	5.0	7.5

T-10 Reserve Parachute

	Opening Force 7,100 Ft (lb)	Opening Force 7,100 Ft (g)	Opening Time 7,100 Ft (sec)	Rate of Descent 6,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	3773.3	14.0	5.6	39.2	40.1
Minimum	1676.3	6.2	3.6	17.4	18.7
Average	2630.0	9.7	4.5	28.9	27.3
Range	2097.3	7.8	2.0	21.8	21.4

	Opening Force 11,100 Ft (lb)	Opening Force 11,100 Ft (g)	Opening Time 11,100 Ft (sec)	Rate of Descent 10,000 Ft (ft/sec)	Rate of Descent 464 Ft (ft/sec)
Maximum	4162.9	15.4	8.4	32.0	27.8
Minimum	2392.4	8.9	3.6	23.7	20.7
Average	3507.0	13.0	5.7	28.9	24.5
Range	1770.5	5.5	4.8	8.3	7.1

CHART 15 RDTE Project No. 1F162203D19517, USATECOM Project No. 8-EG065-000-002/003, Engineering and Service Test of Standard Air Delivery Equipment (Personnel and Cargo at High Drop Zone Elevations)

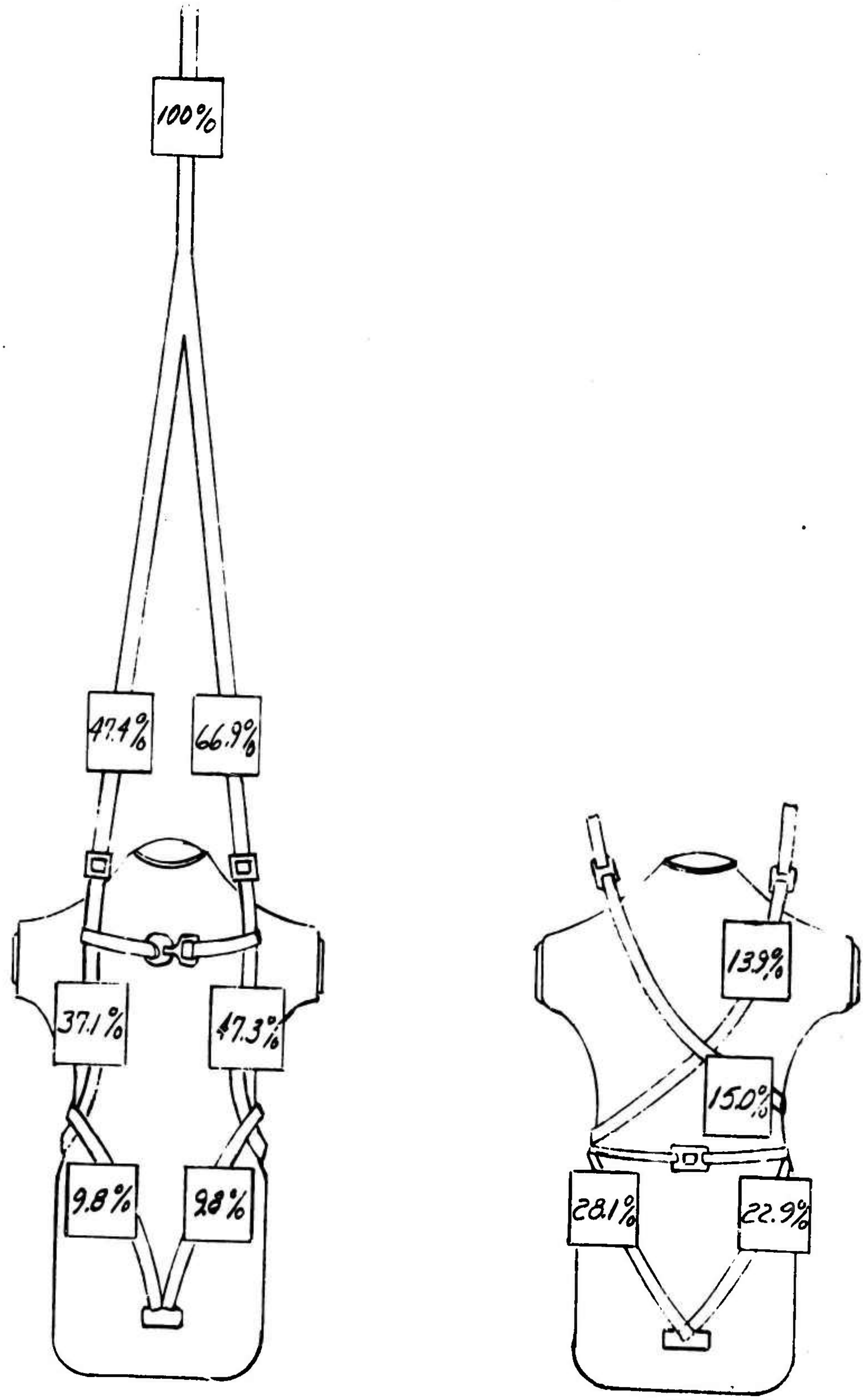


CHART 16 Maximum Force Percentages Measured on a Parachute Harness During Canopy Opening