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COMPARATIVE EVALUATION OF SWIM FINS

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Washington, D. C.

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NAVY EXPERIMENTAL DIVING UNIT
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EVALUATION REPORT 18-57

COMPARATIVE EVALUATION OF SWIM FINS

PROJECT NS186-203 SUBTASK 9 TEST 1

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CONDUCTED

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ABSTRACT

Fourteen commercially available types of swim fins were evaluated for efficiency and comfort with the aim of determining which were the most suitable for Naval use and of learning what factors in design favor these characteristics. Efficiency was studied by measurement of oxygen consumption in stationary swimming against a constant force in 15-minute runs. The differences found in efficiency were large enough to have distinct operational importance. Systematic recording of the subject's impressions showed large differences in comfort. Only one of the most efficient fins was rated "above average" in comfort. In general, large blade area favored efficiency, and show-like enclosure for the foot favored comfort. Observations of swimming technique emphasized the differences between stationary swimming and free swimming and the conclusions concerning efficiency must remain tentative until the importance of these differences can be determined. Furthered study with free swimming is recommended to this end.

SUMMARY

PROBLEM

(1) Determine which of the commercially available types of swim fins are most suitable for Naval use from the standpoints of efficiency and comfort.

(2) Determine what factors in fin design are most conductive to efficiency and comfort.

(3) Learn as much as possible about the relationships between fin efficiency and swimming technique.

FINDINGS

(1) Out of 14 types studied, only 3 were found to have outstanding efficiency according to measurements of oxygen consumption in stationary underwater swimming. Only one of these was rated "above average" in comfort. Two others were also considered reasonably satisfactory in both respects.

(2) In general, the most efficient fins were those with the largest blade area, and the most comfortable were those with full foot enclosure ("shoe type").

(3) Observation of swimming techniques emphasized differences between free and stationary swimming. Conclusions concerning fin efficiency are considered tentative until the importance of these differences be assessed.

RECOMMENDATIONS

(1) Conduct further studies with unrestricted underwater swimming to determine validity of stationary swimming as an evaluation technique.

(2) If the findings of this study are validated, procure indicated fin types for naval use and continue use of stationary swimming as simplest method for future evaluations of fin-efficiency.

ADMINISTRATIVE INFORMATION

This project was authorized by the Bureau of Ships by telephone on January 25, 1956 and assigned project number 186-203/(9) 1.

The project involved using twelve men as subjects. The actual runs required two tenders, a recorder and a supervisor in addition to the subject. A large amount of work was required for description and various measurements of the fins and in analysis and correlation of physical, physiological and subjective data.

The following estimation indicates the approximate number of man hours expended in this investigation:

DESCRIPTION	MANHOURS
General preparation	36
Actual runs	225
Fin measurements, etc.	75
Tabulation and analysis	60
Report preparation	60
Total	456

The swimming runs were conducted by F. T. STRICKLAND, GMC. Descriptions and measurements of fins were made by F. T. STRICKLAND and W. G. FISCHER, BM1. Compilation of data and preparation of the report were accomplished by W. G. FISCHER. E. H. LAMPHIER, LT. (MC), USN prepared the project outline and provided general supervision.

Work commenced on February 23, 1956. Swimming runs were completed on May 2, 1956. Work was resumed (measurements, compilation of data, preparation of report) May 3, 1956 and completed March 1, 1957. This report is issued in the Evaluation Report Series. It is the final report of the project.

CONTENTS

REGISTER OF FINS STUDIED

Desig. Letter Assigned	Commerical Name	Manufacturer or source
A	Duck Feet ("Gaint U.D.T")	Spearfisherman, Huntington Beach, Cal. (1)
B	Voit-Churchill (regular)	W. J. Voit Rubber Co. Los Angeles, Cal (2) (3)
C	Voit Viking	
D	Cressi Rondine (reg.)	" " " " " (3)
E	Duck Feet (Reg.)	Cressi, Genoa, Italy (4)
F	Voit-Churchill ("U.D.T.")	Spearfisherman, Huntington Beach, Cal. (1)
G	" " (Gaint)	
H	Cressi Rondine (Gigante)	W. J. Voit Rubber Co., Los Angles, Cal. (2) (3)
I	Manatee (Reg.)	" " " "
J	Manatee (Gaint)	Cressi, Genoa, Italy (4)
K	Skin Diver	U.S. Divers Co., Los Angeles Cal.
L	Power Dive	" " " " "
M	Aqua Matic	" " " " "
N	Mares "Caraiba 55"	" " " " "
		Mares, Rappallo, Italy

Notes:
(1) Now Swimaster Division of Pacific Moulded Produce Co. Los Angeles, Calif.
(2) These types originally manufactured by Owen Churchill, Los Angeles Calif.
(3) Now a subsidiary of American Machine and Foundry Co.
(4) Distr. by Healthways, Los Angeles, Calif. (Now manufactured in U.S.A)
(5) Distr. by the General Tire and Rubber Co. Pennsylvania Athletic products Division, Akron, Ohio.

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FIGURES

1. INTRODUCTION

1.1 Introduction

1.1.1 Many types of swim fins are now commerically available and some of the differences between them are pronounced. Preliminary studies indicated that the resulting differences in propulsion efficiency in underwater swimming might well be important in terms of operational effectiveness and of gas use rates in scuba diving. Differences in comfort are obviously also important. However, available information offers no basis for choosing among specific types or for assessing the various characterics of fin design. It is especially hard to evaluate actual efficiency. Subjective impressions of efficiency are likely to be quite unreliable as a small advantage in comfort may influence a man in favor of an efficient fin.

1.1.2 The need for comparative evaluation of available fins lead to establishment of this project. It was intended to provide conclusive measurements of efficiency. It was also intended to consider all factors which enter into selection of the best types of fins for naval use.

1.2 Objectives

1.2.1 The objectives of this study were:

1. To determine by comparative evaluation the swim fins available on the commerical market are most suitable for naval use, considering primarily:

   a. Efficiency in propulsion

   b. Comfort and related factors

2. To determine, if possible, in the course of evaluation, what factors in fin design are most important from the standpoint of efficiency and comfort.

3. To learn as much as possible about interrelationships between fin characteristics and underwater swimming technique in regard to efficiency of propulsion.

1.3 Scope

1.3.1 The project was intended to be an evaluation of fins and not a study of fin swimming technique. However, certain additional measurements related to technique were obtained where practical.

1.3.2 The comparisons were made with stationary underwater swimming against a single force. Time did not permit conducting desired measurements during free swimming in open water.

2. DESCRIPTION

2.1 General

2.1.1 Fourteen different makes and types of fins were evaluated in this study. These included the fins most commonly used in the Navy, the leading ones on the commercial market and most of the available types having unusual features.

2.1.2 Letter designations were assigned to avoid use of commercial names. (The key to these names is included in this report as material to be withheld from distribution beyond the Department of Defense).

2.2 Characteristics of fins

2.2.1 Swim fins are devices for increasing the propulsive force generated by the legs and feet in swimming by providing larger surface areas for transmission of musclar force to the water. The reduce "propeller slip."

2.2.2 Available fins have a majority of features in common. Type provide a shoe or strap foot attachment and a blade which amounts to an extension of the foot beyond the toes.

2.2.3 There are two main types of foot attachments; full shoe and heel strap:

1. The more common (heel strap) provides a foot pocket with the heel cut away, having a heel strap. In some models the strap is in one piece, integral with the fin; and in other models the strap is separate, in tow pieces, provides some adjustment for foot size.

2. The other type provides a full "shoe" enclosing the foot completely. No adjustment of size is possible with this type.

2.2.4 The "blade" is the extension of the fin beyond the toes, usually consisting of two ribs extending forward with one from either side of the foot and a web between the ribs. It may have additional stiffening such as ridges in the web itself.

2.2.5 There are several means of stiffening, with ribs being the most common.

1. The ribs are thick rubber ridges that are joined to the foot section of the fin to help stiffen the body of the web.

2. The web is that piece of flexible moulded rubber which joins the rib together forming the propulsion part of the fin.

2.3 Fin materials

2.3.1 Terms used by manufacturers to describe materials used include:

1. Pure rubber gum
2. Gem rubber
3. Live rubber
4. Synthetic rubber
5. Hard rubber
6. Moulded rubber

The actual significance of these terms is ill-defined.

3. PROCEDURE

3.1 Preliminary steps

3.1.1 An assortment of fins representing the major types offered on the commerical market were obtained.

3.1.2 A code letter was assigned to each type or model and a number to each pair of fins within the type or model. (See article 2.1.2).

3.1.3 Measurements of size, contours, stiffness and hardness were made using the methods indicated in Figure 15 and Table 2.

3.1.4 The indicated physical measurements and related observations concerning each type of fin were recorded on Data Form #2, shown in Appendix C. A separate form was used for each type or model.

3.1.5 A top, bottom, and side view photograph was taken of each type or model. These photographs are presented as Figures 1 through 14.

3.1.6 Each subject was assigned a "baseline" fin to be used for making his "baseline" oxygen consumption runs, taking into consideration, where possible, the following:

1. Experience with a particular type or model.

2. Random assignment in regards to size of man compared to size (blade area) of fin.

3. Best possible fit from sizes available.

3.1.7 "Baseline" runs were runs made to establish each each man's plateau of efficiency on a given type of fin. Three or more baseline runs were made by each subject, and an average of O_2 consumption value derived from these runs was used for data purposes in comparisons of the fins. The assignment of baseline fins to individual subjects is indicated in Table 6.

3.1.8 The order of subject-runs with the various fins is indicated in Table 5.

3.1.9 The height, weight, age and various body measurements of the subjects were determined and recorded. (See Table 4)

3.2 Conduct of runs

3.2.1 The runs consisted of underwater swimming against a counter-weight "trapeze rigged to exert a force of 8 pounds against the swimmer. (In previously studying "trapeze swimming", an eight-pound force was found to produce the same average oxygen consumption as open-water swimming at a speed of 0.85 kts. See EDU Formal Report 1-55 "A Trapeze Swim-Ergometer" for further details.

3.2.2 The subjects employed a closed circuit oxygen rebreathing scuba (a 1952 Lambertsen Amphibious Respiratory Unit, Model T-4). Oxygen was supplied from a small, calibrated cylinder. The pressure drop in this cylinder provided the basis for measurement of oxygen consumption. This procedure is described further in Appendix D.

3.2.3 The runs were of 15 minutes duration, and the following information was recorded periodically during the runs:

1. Pressure reading of supply cylinder, recorded every minute
2. Number of kicks per minute
3. Kick width
4. Degree of knee bending.
5. Fin flexion
6. Consistency of style
7. Unusual features, if any

3.2.4 A graph of cylinder pressure versus time was made for each run (Appendix D).

3.2.5 Each subject made one comparison run on each type of fin and recorded his impression and findings as to comfort, etc., on the subjects impression form, Data Form #4 (Appendix C). These impressions were later compiled on a single form for each type of fin.

3.3.5 At the conclusion of the regular evaluation runs, each subject made an additional run on fin types A & B to obtain an indication of the amount of improvement in swimming technique which might have occurred since A, B, C, & D were originally studied.

3.4 Fin sizes

3.4.1 In general, only one foot-size of each fin-type was available for study (what these sizes were is shown in Table 3), and in several cases only one size is manufactured. Except in two cases (C and E) the size was "large". In a few cases, the fit was so poor that a subject was unable to make a run with a given fin. Where the fin was simply too large, subjects often wore foam neoprene "boot sox" to improve the fit. This was a reasonably satisfactory arrangement in many cases.

4. RESULTS

4.1 General

4.1.1 Information concerning the various types of fin is presented in Tables 1 to 3. Table 4 contains height, weight and various body measurements of the subjects. The oxygen consumption values are presented in Tables 6 to 8. Tables 10 to 12 summarize the subject's impressions of the fins, and specific comments are presented in Appendix B. Oxygen consumption values and comfort ratings are tabulated together in Table 9 and presented graphical in Figure 16.

4.2 Oxygen consumption

4.2.1 The average oxygen consumption for all subjects using all fins was 1.30 liter per minute, and the range of means for individual fins was from 1.13 to 1.46 liters per minute. The lowest mean oxygen consumption values, indicating the greatest efficiency of propulsion in the kind of swimming involved, were obtained with types M, C, and A in that order. The highest values, indicating the least efficiency, were obtained with types F, B, G and N.

4.2.2 Comparison of the initial and final runs with types A and B indicated an improvement (reduction in oxygen consumption) of 14% and 16% respectively.

4.2.3 Examination of "baseline" data (Table 6) shows distinct improvement in the performance of some subjects making repeated runs using a given fin, but there is considerable irregularity in the baseline results as a whole. Table 9 indicates that the mean of baseline values used for data purposes is 1.26 liter/min. compared to the overall mean of 1.30 liters/min.

4.3 Comfort ratings

4.3.1 Examination of Table 10 and Figure 16 indicates that the fins which received the highest overall comfort ratings were types H, J, and D. Types C, F, and G were also above average. All fins of the "shoe" type were rated "average" or above. The fins most distinctly below average in respect to comfort were B, M, and K.

4.3.2 Note that 2 of the 3 most efficient fins, types A & M, were below average in comfort and that some which were below average in efficiency rated high in comfort. In the case of fins A & M, examination of the tabulated subjective impressions (Table 10) indicates that one of the main complaints was that the fins slipped, slid or had a tendency to turn on the foot while swimming.

4.3.3 Examination of Table 10 also indicates that in many cases (never in more than half of the runs concerned, however) discomfort was attributed to poor fit. This was particularly true in the case of types C, E, and I. (C and E had the smallest foot-sizes of the fins used.) In general, the most frequent specific complaints were concerned with "slipping or sliding" and "rotating on the foot" and with "pressing on bones" and "cramped toes". The former complaints were most frequent with large foot-size fins, the latter with the smaller ones. In almost all types (See Table 12), the majority indicated that they considered fit satisfactory. Type A yielded the most "too large" comments. The "medium large" fins (C and E) were considered too small by 4 individuals. One was unable to use C at all, and another could not use K. Only one "extra large" fin was considered too small by any subject. In three cases, the boot sox were worn by a majority of the subjects (with fins A, B and H).

4.3.4 Subject's impressions of swimming ease (Table 11) showed a considerable proportior of "easier" comments with types E, H, J and M. A majority considered swimming harder than usual with A, B, K, and N. Unusual fatigue was reported more frequently with these types than with the others, as was a necessity for altering technique in order to get the most out of the fins. The types which the majority of subjects indicated they would be "satisfied to continue using" were C, D, E, H and J. When questioned specifically about types A and M (those ranking highest in efficinecy), a cross-section of the subjects expressed the opinion that these types were too large for sustained swimming from the stand-point of endurance. Unusual difficulty in walking when wearing the fins was reported most frequently with types A, C, D, H and M.

4.4 Physical measurements

4.4.1 Blade area values, as recorded in table 2, indicate that the types having the greatest area were M, J, A, C, G and H in that order. Types B, F, K and N had the smallest blades.

4.4.2 Among the fins showing larger blade areas, the data concerning stiffness indicates that only G was markedly below average in this respect. The photographs, figures 1 to 14, show that this fin lacks the ribbing characteristics of most of the other; and the durometer readings show that this fin was also relatively low in "hardness" of its rubber.

4.4.3 The highest durometer readings were obtained from types H, L,and D. The lowest were obtained from A, B and J. Only L, N, and C indicated much difference between the hardness of rubber used in the foot attachment and the blade, with the blade being the hardest.

4.4.4 Types which had positive buoyancy (which floated in water) were A, B, C, E, and F. The rest ranged from neutral to 0.5 pounds negative.

4.5 Swimming techniques

4.5.1 In almost all cases, the wimming technique employed by the subjects included a slow rate, (average about 18 cycles per minute), and a wide kick ranging from 30 to 44 inches, heel to heel, with considerable bending of the knees. (Tabulation of this information in detail was not considered worthwhile.)

5. DISCUSSION

5.1 General

5.1.1 As figure 16 shows, the oxygen consumption data permits considerable differentiation of the various fins studied as to their efficiency for the kind of swimming employed in these tests.

5.1.2 The fact that one group of fins was studied separately at the beginning of the project, (Types A,B,C,D) and that the general efficiency of the subjects improved considerably during the course of study, it is not likely to have made any important difference in the relative standing of the types tested. The averages of the early and late values for types A and B were used as their mean values in the graph. The average improvement (Table 8) was 15%, so the mean values for types C and D would probably have been only 7 to 8% lower if later runs had been made and the data computed in the same way. Type C is already distinctly above average in efficiency. Type D would probably have remained in the "average" or "below average" group. However, it is clear that the "learning factor" is large enough to be a potential source of considerable error in fin evaluation.

5.1.3 In general "practice" on the part of the subject (as seen in the baseline data, Table 6 and 9) made relatively little difference in the apparent efficiency of a fin. The overall difference in oxygen consumption between the "baseline runs" and the general comparison runs is so small that extensive practice with a fin being studied could not usually be justified in future evaluations of this type.

5.1.4 The difference in mean oxygen consumption with the various fins seem relatively small in these tests. However, if it is valid to consider these differences in terms of sustained free swimming, they represent a sizeable operational advantage with a more efficent fin. Calculation based on data from EDU Formal Report 14-54 (Oxygen Consumption in Underwater Swimming) indicates that a man using the type M fin, which had the lowest mean O_2 consumption of all types, could swim approximate 30% farther at normal speed with a given air or oxygen supply than he could with type F, which had the highest mean oxygen consumption. In terms of speed, a man could swim approximately 20% faster (without increasing his effort or using any more air or oxygen) by using the type M fin instead of the type F.

5.2 Factors influencing efficiency

5.2.1 The findings of these tests shows a positive relationship between blade size and efficiency. The fins with the largest blade also showed the greater efficiency provided that the stiffening was sufficient for the size. There were only tow instances in the evaluation where high efficiency and a large blade did not go hand in hand. One, (Type G) was a fin that was above average in blade size but with very little stiffening. This type yielded the second highest mean oxygen consumption of all types. In the other instance (Type E), the fin had a slightly smaller than average blade but had good stiffening and yielded the the fourth lowest oxygen consumption.

5.3 Factors influencing comfort

5.3.1 Poor fit was clearly an important factor in the discomfort reported with several of the types. Except in the few cases (only H and J) according to table 3 in which no other size was manufactured, failure to obtain and use a proper range of sizes was a serious defect in the study.

The comfort data must be interpreted cautiously for this reason. Use of the foam neoprene boot socks with "too large" fins probably reduced the number of complaints materially, especially with fins like A, B and H.

5.3.2 The general acceptance of the "shoe" types, despite problems of size, indicates that arrangement favors comfort.

5.4 Validity of subjects estimates of efficiency

5.4.1 Until the present work, about the only index of the efficiency of a fin has been the user's opinion. This study afforded an opportunity for comparing opinions with an objective measurement. The subjects' estimates of ease classified the fins as having above or below average efficiency almost as well as did the oxygen consumption data. Only in the case of type A was marked divergence noted.

5.4.2 In this connection, however, note that stationary swimming on the "trapeze" requires the subject to produce a specific force by his efforts throughout the run. He must accomplish a definite amount of external work, and it should not be unduly difficult for him to tell whether one type of fin requires more effort in the process than another. In unrestricted swimming in open water, this would not be the case, unless the swimmer had a constant indication of his speed, his opinion would probably be much less reliable.

5.5 The "Ideal" fin

5.5.1 To have the best suitability for naval use, a swim fin must obviously be as efficient and as comfortable as possible. Although this study shows that these qualities are not found together in many available types, they should not be incompatible.

5.5.2 The results indicate that optimum efficiency can be expected from a fin with a large, well stiffened blade. The fin with the largest blade area (Type M) was the most efficient, so the study gives no indication of what the upper limit of desirable blade area may be. The limit might be imposed by the cumbersome nature of a large fin rather than by a drop in efficiency with increasing size. It is also possible that free swimming would show less advantage in large blade area than was noted in this study (See 5.6.1). In addition the fact that many of the subjects expressed the opinion that the larger fin would cause excessive fatigue on a long swim may indicate another limiting factor. This study does not indicate the optimum shape or curvature of the blade, and these factors may be quite important, especially in free swimming. The relatively good performance of types E and H which had smaller than average blade area, suggest that good design can yield a reasonably efficient fin even if a large blade proves impractical for some reason.

(For example, the unusual difficulty of walking was rated while wearing all of the large blade fins might be a serious drawback in some operations).

5.5.3 If both comfort and efficiency could not be provided, comfort might be considered more vital. The importance of providing an adequate range of foot-sizes is emphasized by the influence of fit on comfort and the generally poor comfort rating of fins with adjustable straps. Proper design of the foot pocket (and strap, if one is used) is evidently crucial even though detailed specifications are one readily inferred from the data. As was pointed out, a large proportion of fins with the shoe type arrangement obtained a high comfort rating than did those with heel straps. Reports from the field indicate that fins of the shoes type tend to come off in operations such as high-speed pickups of swimmers by small boats, but correction of this defect should not be difficult. Provision of a strap or lanyared around the ankle to prevent loss of the fin has been suggested. One of the basic types (represented by D and H) is now provided with an "instep lock strap". Positive buoyancy is also a desirable feature in this connection, since it favors recovery of a lost fin.

5.5.4 Among the fins tested, only type C showed outstanding efficiency as well as above-average comfort. Types J and H combine high comfort rating with above-average efficiency. Types M and A showed high efficiency, but they were below average in comfort. Without knowing how much "relative weight" to give comfort and efficiency ratings, it is difficult to rank the various types in order of "overall merit". Fins which ranked below average in either respect probably need not be considered for procurement. However, several types which are already efficient could probably be made acceptable by relatively small changes in design to improve comfort. Simply using proper foot sizes would help considerably in some cases.

5.6 <u>Questions requiring further study</u>

5.6.1 The fact that this study had to be restricted in several ways leaves a number of important questions incompletely answered. Most of these concern the apparent desirability of large blade area.

5.6.2 One factor that could not be evaluated in these tests was "fin drag" (the drag created by the fins trailing in the water in free swimming). This would have to be tested by "free swimming" runs and might vary with the individual kick style of the subjects employed. The kick style used in trapeze swimming is almost certainly different from that used in free swimming. The width of kick used in trapeze swimming varied from about 30 to 44 inches, depending on the size of the individual. In free swimming it would probably be considerably shorter, possibly as much as one-third less. These observations may be particularly significant in view of the obvious fact that movement-through-water is minimal in "trapeze" swimming.

5.6.3 It is also possible that the most efficient fins in these tests would tire a man too quickly in sustained swimming unless he was highly experienced and his leg muscles were well conditioned (See articles 4.3.4 and 5.5.2).

6. CONCLUSIONS

6.1 Findings

6.1.1 Measurement of oxygen consumption in stationary swimming against a given force showed distinct differences in the propulsive efficiency of various fins (article 5.1.1).

6.1.2 Improvement in the subjects' swimming efficiency during the course of the study caused the mean oxygen consumption to decrease about 15%. (article 5.1.2).

6.1.3 The comfort of swim fins, as indicated by the standarized rating by users, varied widely amoung the various types (Section 5.3, Figure (6)).

6.1.4 With few exceptions, the fins with the largest blade area showed the greatest efficiency (Article 5.2.1).

6.1.5 Fins with the shoe type foot socket received the greatest proportion of high comfort ratings (Article 5.3.2).

6.1.6 Relatively few fins ranked high in both comfort and efficiency. Only type C had both outstanding efficiency and an above-average comfort rating. Types J and H combined good comfort ratings with above-average efficiency (Article 5.5.4, Figure 16).

6.1.7 Observations of kick rate and other aspects of swimming technique indicated definite differences between "Trapeze" and free swimming in addition to the obvious absence of "movement through the water" in the former (Article 5.6.2).

6.2 Conclusions

6.2.1 The observations of this study warrant the following conclusions in terms of methods employed.

1. Measurement of oxygen consumption in the standarized form of swimming provides a satisfactory means of determining the relative efficiency of different types of fins (Article 5.1.1).

2. Improvement of subjects' swimming ability during the course of study is a potential source of error in applying this method of evaluation, but it did not seriously effect the results of this study (Article 5.1.2).

3. Large blade area (assuming adequate stiffening) favors optimum efficiency (Article 5.2.1).

4. A "shoe" type foot socket is most conducive to comfort (Article 5.3.2). (Measures to prevent this type of fin from coming off in certain operational situations may be required.) (Article 5.5.3).

5. Giving efficiency somewhat more "weight" than comfort, the type C fin is considered the best of commercially available types for general naval use. Types H and J should also be suitable (Article 5.5.4).

6.2.2 These conclusions, especially 3 and 5, must be considered tentative in view of the limitations of this study. The importance of the differences between trapeze swimming and free swimming in this connection has not been evaluated (Article 5.6.2), and the influence of longer use and fatigue on efficiency and comfort was not investigated (Article 5.5.2 and 5.6.3).

6.3 Recommendations

6.3.1 The primary recommendation concerns further work to determine the validity of the results of the present study (Section 5.6). The basic requirement is for a limited series of free swimming runs conducted along the following lines:

1. Include not only the most promising fin types in this study (i.e. C, H and J) but also a sufficient cross section of the other types to permit adequate comparisons. Omit those obviously poor from the standpoint of comfort; assure use of proper foot size wherever possible.

2. Conduct runs at a range of controlled speeds (i.e. 0.7, 0.85, and 1.0 knots).

3. Insure that at least some of the runs are of sufficient length to determine the effect of longer use and fatigue on efficiency and comfort. (Article 5.6.3).

4. Arrange assignment of fins and scheduling of subjects' runs to minimize "learning" effects (Article 5.1.2).

5. Secure "operational" tests which will demonstrate any possible defects such as the tendency for a given type to come off during swimming pickup. (Article 5.5.3).

6.3.2 If the results of the present study are validated, the following recommendations are considered warranted:

1. For procurement of fins for naval use, let type C be the first choice. If alternative types are required, consider types J and H. If the manufacturers of types A and M will take indicated steps for improvement of comfort of these types, consider these fins for further evaluation and possible procurement (Section 5.5).

2. Consider developmental study to investigate maximum practical efficiency through large blade area, optimum shape and curvature, etc. Concentrate on shoe-type foot socket in developmental models.

3. Continue use of trapeze swimming studies as simplest procedure for evaluation of comfort and efficiency of fins.

[illegible]

GENERAL DESCRIPTION OF FINS

(See notes)

Overall Size	Color	Stated "Type" of Rubber	Fit: E = Either foot R.-L = right or left	Foot ("Shoe") or strap	Stiffening	ANGLES: End (1)	ANGLES: Plantar off-set or (2) curvature	ANGLES: Lateral off-set (3)
large	brown	gum	E	strap	3 ribs	12° conv.	0	0
av.	green	live	R-L	"	2 ribs	26° lat.	0	5°
lg.	blue	moulded	R-L	shoe	2 ribs	19° lat.	curv.	5°
av.	black	?	E	"	2 ribs	18° conc.	25°	0
av.	brown	pure gum	E	strap	3 ribs	12° conv.	0	0
av.	green	?	R-L	"	2 ribs	26° lat.	0	5°
large	green	live	R-L	"	2 ribs	18° lat.	0	5°
large	black	syn.?	E	shoe	2 ribs	20° conc.	17°	0
av.+	brown	gum	E	strap	3 ribs	7° conv.	0	0
large	brown	gum	E	strap	3 ribs	7° conv.	0	0
av.	blue	molded	E	adj. strap	small ribs	0	0	0
av. +	black	syn.?	E	shoe	3 ribs	0	27°	0
very large	black	syn.?	E	adj. strap	3 ribs 2 ridges	12° conv.	10° curv.	0
av.	black	moulded	E	adj. strap	3 ribs	10° conc.	12	0

Notes: (1) conv. = end of fin convex, angles back medially to laterally.
conc. = end of fin concave, angles out.
lat. = lateral side longer, angles back to medial side.
(2) Fin blade angled or curved down in relation to plane of foot.
(3) Midline of blade angled laterally (out) in relation to midline of foot

[illegible]

[illegible]

(See notes below)

Measured (1)	Length (in.) at longest dimension	Width (in.) at widest point	Maximum thickness (in.)	Blade surface area (sq. in.)	Foot Socket Length (in.) (2)	Foot Socket Width (in.) at instep	Buoyancy (3)	Durometer Reading Foot	Durometer Reading Blade	Stiffness Index (4)
	20.8	8.8	3.3	124	10.8	3.5	+	45	45	6.5
	15.8	8.8	3.5	83	11.5	3.4	+	45	45	2.0
	20.8	9.0	2.5	115	11.0	2.8	+	42	60	3.0
	18.0	7.8	2.3	95	11.1	3.0	-0.1	58	70	7.5
	17.5	8.0	2.9	91	10.0	3.0	+	43	43	4.0
	15.8	8.8	3.4	83	11.6	3.4	+	45	60	3.0
	20.0	9.8	3.5	110	11.8	3.0	0	47	47	0.5
*	20.1	8.1	2.8	109	11.9	3.1	-0.3	47	83	4.0
	18.3	9.5	3.0	104	10.4	2.8	0	53	53	5.0
*	20.0	10.5	3.0	128	10.3	3.3	0	48	48	4.5
	14.5	7.9	2.0	85	9.5	3.3	-0.1	68	68	4.5
	18.0	7.5	2.0	93	10.0	2.8	-0.1	50	78	4.0
	18.5	10.0	2.3	141	-	3.5	-0.5	65	65	8.0
	18.0	8.2	2.3	88	11.0	3.0	-0.1	50	68	6.0

sterisk indicates this appears to be only size made.

ash indicates fin has adjustable strap.

= neutrally buoyant, + = positive buoyancy, - = negative (value given is weight (in water).

lue given is weight (in pounds) required to bend fin down to 30 degrees as shown n Figure 4.

[illegible]

(Foot sizes said to be manufactured, with corresponding shoe sizes where given)

Foot Type	Small	Medium	Medium Large	Large	Extra Large	Other
A			7-9	9-11	11-13*	
B	X	X	X	X*	X	
C		7-9	9-11*	11-14		
D		5-7	7-9	9-11*	11-13	
E	X	5-7	7-9*	9-11		
F	X?	X?	X	X*	X?	
G	X?	X?	X?	X	X*	
H					11-13*	Giant size 13-15
I		6-8	8-9	9-12*		
J				9-11	12-15*	
K		4-8		8-13*		
L		4-8		9-11*		
M		4-8		8-13*		
N		4-8		8-13*		

X = size said to be manufactured; corresponding foot size data not available

* = used in this study.

DATA CONCERNING SUBJECTS

NAME	HEIGHT (feet & inches)	WEIGHT (pounds)	THIGH circumf. (Inches)	CALF circumf. (Inches)	LEG lgth.	KNEE lgth.	SHOE SIZE (Navy)	AGE (yrs)	FIN-SWIM experience (yrs.)	Baseline Fins	Baseline O2 cons. (liters/min.
des GRANGES	5-9½	194	22	15	34	19	9C	37	3	H	
[illegible]ILLER	5-10½	166.8	21½	15	35 3/4	20	3½E	34	3½	B	1.30
[illegible]OLLINGSWORTH	5-9	180	22½	15½	36	20 3/4	8½E	31	9	A	1.08
[illegible]ENSEN	5-6½	136	20	14½	33	19½	6½D	27	7	C	1.23
[illegible]EIDEN	5-11	170	21	15	35½	21	9D	27	6mo.	D	1.55
[illegible]ILLOUGHBY	5-6	163	23	14½	33	18	5½D	28	6	E	1.15
[illegible]DAME	6-0	202.4	23	16	38	21	9½W	28	3mo.	J	1.16
[illegible]	6-3	229	24	17	37	21	10½D	31	4	G	1.69
[illegible]UGLIA	4-10½	153	21	14½	33½	19	8D	30	6	L	1.11
[illegible]IRK	5-7	143	19	13½	35½	18	7D	30	1	I	1.30
[illegible]ERPURK	5-11	181	22	15	38	20½	9½T	24	2	L	1.52
[illegible]NES	5-7½	178	23	14½	34	19	9D	25	3	M	.98

All runs made
in "56"

TABLE 5 - Sequence of Runs
* = Baseline Fin
# = No Fit

Fin/Subject & Date	A	B	C	D	E	F	G	H	I	J	K	L	M	N
MILLER	2.23	*	3-2	3-1	3-21	3-19	3-26	3-27	4-10	4-11	4-12	4-15	4-16	4-17
HOLLINGSWORTH	*	5-7	3-1	2-29	3-21	3-19	3-22	4-5	4-9	3-28	4-3	4-4	4-10	4-11
LEYDEN	3-1	3-5	3-2	*	3-21	3-19	3-26	3-27	4-2	4-3	4-5	4-6	4-9	4-10
JENSEN	3-1	3-5	*	3-2	3-21	3-19	3-26	4-4	4-2	4-15	4-10	5-22	4-9	4-11
CAPTAIN	3-8	3-7	3-5	3-12	3-26	3-21	3-22	*	4-11	4-12	4-13	4-20	4-17	5-1
ADAMS	3-5	3-7	3-12	3-8	3-22	3-21	3-26	4-4	4-12	*	3-28	3-29	4-10	4-13
KOHL	3-5	3-7	3-12	3-8	3-22	3-21	*	4-4	4-3	3-27	#	4-2	4-16	4-20
KIRK	3-8	3-7	3-5	3-12	3-21	3-19	3-22	4-2	*	4-5	4-20	3-27	4-16	4-17
SUGLIA	3-13	3-5	3-12	3-13	3-26	3-21	3-26	4-3	4-4	4-6	3-27	4-2	4-11	*
WILLOUGHBY	3-8	3-13	3-12	3-5	*	3-19	3-22	4-26	3-27	3-29	4-25	4-30	5-1	5-1
FUNDERBURK	4-30	4-26	#	4-25	4-24	4-23	4-20	4-12	4-3	4-4	4-10	*	4-9	4-6
HAWES	5-1	5-2	4-30	4-30	4-26	4-20	4-17	4-3	3-29	4-2	4-16	4-5	*	4-9

(liters per minute, STPD)	MILLER (R)	HOLLINGSWORTH (A)	LEYDEN (D)	JENSEN (C)	des GRANGES (H)	ADAMS (J)	KOHL (G)	KIRK (I)	SUGLIA (N)	WILLOUGHBY (E)	FUNDERBURK (L)	HAYES (M)
	2-27 1.23	2-21 1.14	2-27 1.15	2-21 1.73	3-29 1.47	4-5 1.49	3-26 1.50	4-6 1.35	4-9 1.01	3-21 1.29	4-11 1.54	4-12 1.15
	2-28 1.23	2-27 1.07	2-28 1.15	2-23 1.52	5-2 1.48	4-16 1.12	4-23 1.73	4-23 1.26	4-13 1.45	5-2 1.09	4-17 1.64	5-2 1.05
	2-29 1.40	2-28 1.08	2-29 1.39	2-27 1.34	5-3 1.32	4-17 1.35	4-25 1.76	4-24 1.32	4-16 1.02	5-2 1.10	4-24 1.49	5-7 1.16
	4-24 1.15		4-23 1.16	2-28 1.21	5-10 1.09				4-23 1.15			
	4-25 1.18		4-24 1.66	2-29 1.33	5-10 1.11							
			4-29 1.09	4-23 1.15								
				4-24 .96								
				4-25 1.10								
ue used	1.10	1.10	1.23	1.13	1.29	1.32	1.66	1.31	1.16	1.16	1.56	1.12

OXYGEN CONSUMPTION VALUES FROM COMPARISON RUNS (Liters per minute, STPD)

# indicates fin did not fit well enough to permit run.
* asterisk indicates baseline fin for subject; value from Table 6.

(The values or fins A & B are the mean of early late runs; See table 8.)

Fin / Subject	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Subj Mean
MILLER	1.02	1.10*	.93	1.12	1.08	1.10	1.09	.97	1.18	1.22	1.05	1.19	.92	1.05	1.08
HOLLINGSWORTH	1.10*	1.08	1.07	1.43	.95	1.20	1.09	1.35	1.24	1.04	1.23	1.54	1.25	1.39	1.21
[illegible]DEN	1.17	1.63	1.40	1.23*	1.24	1.93	1.35	1.05	1.15	1.14	1.49	1.25	.94	1.19	1.30
JENSEN	1.22	1.69	1.13*	1.29	1.17	1.62	1.32	1.09	1.00	1.19	1.28	1.46	1.12	1.57	1.30
CAPTAIN	1.22	1.38	1.20	1.51	1.11	1.62	1.45	1.29*	1.79	1.30	1.50	1.61	1.32	1.46	1.41
ADAMS	1.32	1.49	1115	1.39	1.28	1.59	1.39	1.19	1.22	1.32	1.48	1.22	1.19	1.31	1.32
KOHL	1.22	1.60	1.10	1.54	1.53	1.65	*1.66	1.53	1.69	1.25	#	1.46	1.28	1.78	1.48
[illegible]IRK	1.15	1.41	1.00	1.19	1.20	1.39	1.21	1.24	*1.31	1.49	1.38	1.16	1.28	1.31	1.27
SUGLIA	1.33	1.36	1.25	1.19	1.50	1.32	1.42	1.23	1.14	1.30	1.39	1.14	1.22	1.16*	1.28
WILLOUGHBY.	1.13	1.46	1.10	1.42	1.16*	1.35	1.40	1.38	1.09	.98	1.28	1.29	.93	1.45	1.23
FUNDERBURK	.95	1.02	#	1.15	1.22	1.32	1.65	1.33	1.24	1.26	1.49	1.56*	1.05	1.90	1.32
HANES	1.28	1.62	1.35	1.41	1.38	1.43	1.71	1.59	1.33	1.19	1.50	1.54	1.12*	1.45	1.42
Fin's mean	1.17	1.40	1.16	1.32	1.22	1.46	1.40	1.27	1.28	1.22	1.37	1.37	1.13	1.40	1.30

TABLE [illegible]

([illegible])

During Runs Comparison of 1st & 2nd Runs "A" & "B"

	A		B		MEAN	
SUBJECT	1	2	1	22	A	B
MILLER	1.19	.85	1.10*	1.03	1.02	1.10*
HOLLINGSWORTH	1.10*	.82	1.32	.84	1.10*	1.08
LEYDEN	1.42	.93	2.02	1.25	1.17	1.63
JENSEN	1.28	1.16	1.79	1.59	1.22	1.69
CAPTAIN	1.51	.93	1.57	1.20	1.22	1.38
ADAMS	1.49	1.15	1.63	1.35	1.32	1.49
KOHL	1.40	1.05	1.75	1.45	1.22	1.60
KIRK	1.34	1.15	1.40	1.42	1.15	1.41
SUGLIA	1.40	1.26	1.51	1.22	1.33	1.36
WILLOUGHBY	1.01	1.25	1.52	1.39	1.13	1.46
HANES	1.15	1.41	1.61	1.63	1.28	1.62
FUNDERBURK	.95	.95	1.12	.93	.95	1.02
Mean	1.25	1.08	1.53	1.28	1.17	1.40
		-.17		-.25		

A - 14%

B - 16%

Av - 15%

TABLE 9

Analysis of mean Oxygen
Consumption values; Comfort Ratings

in Type	Mean O2 cons.	% + or - overall mean	Baseline O2 cons.	Baseline's % + or - mean	Comfort Rating (Points)
A	1.17	-10	1.10	-15.4	18
B	1.40	+7.7	1.10	-15.4	16
C	1.16	-10.8	1.13	-13.1	23
D	1.32	+1.5	1.23	-5.4	27
E	1.22	-6.2	1.16	-10.8	20
F	1.46	+12.3	-	-	23
G	1.40	+7.7	1.66	+27.7	23
H	1.27	-2.3	1.29	-0.8	28
I	1.28	-1.5	1.31	+0.8	24
J	1.22	-6.2	1.32	+1.5	27
K	1.37	+5.4	-	-	19
L	1.37	+5.4	1.56	+20	22
M	1.13	-13	1.12	-13.8	17
N	1.40	+7.7	1.16	-10.8	22
Overall Mean	1.30	Baseline Mean	1.26		22

TABLE 11

SUBJECTS' IMPRESSION OF FINS: [illegible]

(Number of subjects checking items concerned in Data Form No.4)

No. of runs concerned	Swimming "ease"			Unusual fatigue					Required alteration of normal technique	Satisfied to continue using	Unusually difficult to walk when wearing
	Easier than usual	Harder	About same	Location: General	Legs	Feet	Ankles	Certain muscles			
12	2	7	3	5	3	6	5	6	6	3	11
24	0	16	7	9	7	6	6	6	9	5	1
14	3	2	9	1	1	2	2	4	1	8	9
14	3	2	8	2	2	1	0	2	1	8	9
14	6	3	5	3	0	2	0	3	2	9	1
11	1	3	7	4	3	2	3	3	1	6	2
13	2	5	6	3	2	0	0	0	2	6	0
15	7	3	6	4	2	1	1	2	1	11	9
14	2	4	8	1	1	2	0	4	3	6	5
13	6	2	4	2	1	2	1	1	3	7	8
12	0	8	3	4	55	4	3	3	4	1	1
16	1	8	7	5	5	4	4	6	5	1	5
14	6	2	6	3	2	3	1	2	3	6	12
14	5	8	1	5	4	4	4	5	4	5	3

TABLE 10

SUBJECTS' IMPRESSION OF ... [illegible]

(Number of subjects checking items concerned in Data Form No. 4)

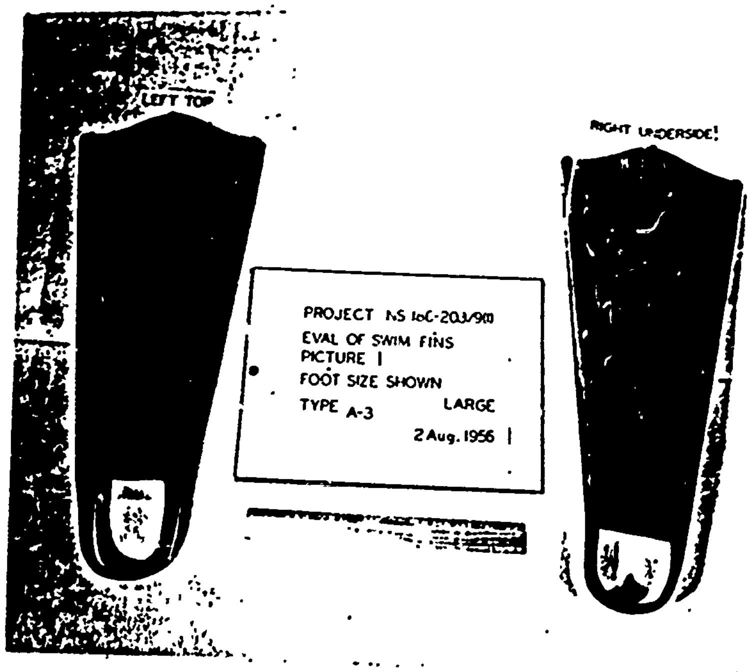
Subject	Foot size used	Comfort rating: Excellent	Good	Fair	Poor	Very poor	Overall comfort "Score" (1)	Specific complaints: Chafed or rubbed	Caused blisters	Pressed on bones	Cramped toes	Pinched	Slipped or slid	Turned on foot	Tended to come off	Discomfort attributed to poor fit	Number of runs concerned
	XL	1	4	3	0	4	18	2	2	3	1	0	5	4	0	4	12
	L	3	8	10	1	2	16	2	0	1	0	0	7	6	2	4	24
	ML	5	2	4	1	2	23	1	2	6	4	3	0	0	0	7	14
	L	6	3	3	2	0	27	1	0	2	2	2	1	2	0	4	14
	ML	2	5	4	1	2	20	3	4	3	6	2	2	1	0	7	14
	L	2	7	1	0	1	23	1	0	1	0	0	2	3	1	0	11
	XL	4	4	4	1	0	23	2	1	0	0	0	4	4	1	4	13
	XL	5	9	0	1	1	28	1	1	0	0	0	6	3	3	1	15
	L	3	5	5	1	0	24	4	3	0	4	1	5	1	1	7	14
	XL	5	3	3	1	1	27	0	0	2	3	0	2	1	1	4	13
	L	0	6	3	2	1	19	0	2	2	1	1	1	1	1	2	12
	L	2	8	4	2	0	22	1	1	2	2	2	2	4	1	1	16
	L	1	5	4	2	2	17	3	1	3	3	1	4	5	3	3	14
	L	5	2	3	3	1	22	0	0	4	1	1	3	2	6	1	14
Total or mean		44	71	51	18	17	22	21	17	29	27	13	44	37	20	49	200

Notes: (1) Overall comfort rating score calculated by adding 3 points for each "excellent", 2 for "good", 1 for "fair", 0 for "poor" and "very poor". In cases where the number of runs was other than 14, score was adjusted correspondingly, placing most wt. on impression of fine "baseline" subject[illegible]

TABLE 12

SUBJECTS' IMPRESSION OF FINS FIT

Fin Type	Foot Size Available	Impression of fit			Used foam neoprene "boot sock"	Attributed poor general comfort to poor fit	Number of subject runs concerned
		Satisfactory	Too Large	Too Small			
A	XL	5	7	0	8	4	12
B	L	15	4	2	16	4	24
C	ML	7	-	4	1	7	14
D	L	10	1	2	2	4	14
E	ML	6	1	4	0	7	14
F	L	9	2	0	5	0	11
G	XL	8	5	0	5	4	13
H	XL	11	5	0	11	1	15
I	L	8	3	2	2	7	14
J	XL	8	1	1	2	4	13
K	L	6	0	2	0	2	12
L	L	7	3	3	0	1	16
M	L	7	2	1	1	3	14
N	L	8	0	2	0	1	14


LEFT TOP
RIGHT UNDERSIDE!
PROJECT NS 106-203/900
EVAL OF SWIM FINS
PICTURE I
FOOT SIZE SHOWN
TYPE A-3 LARGE
2 Aug. 1956

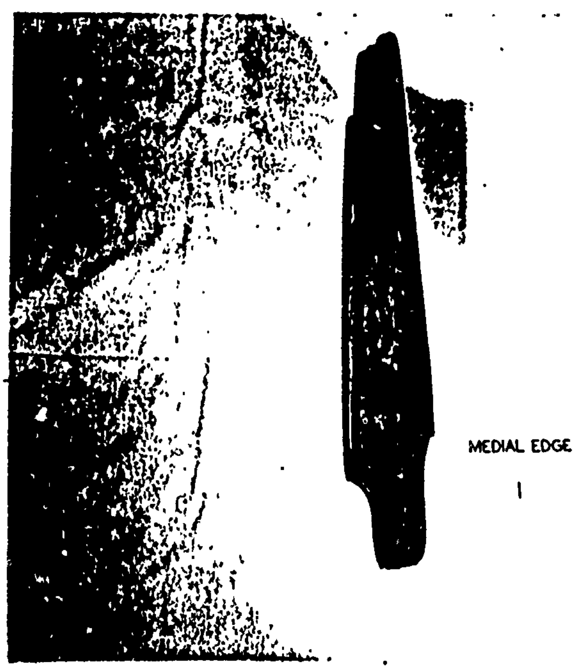

MEDIAL EDGE

FIG. 1 FIN A-3

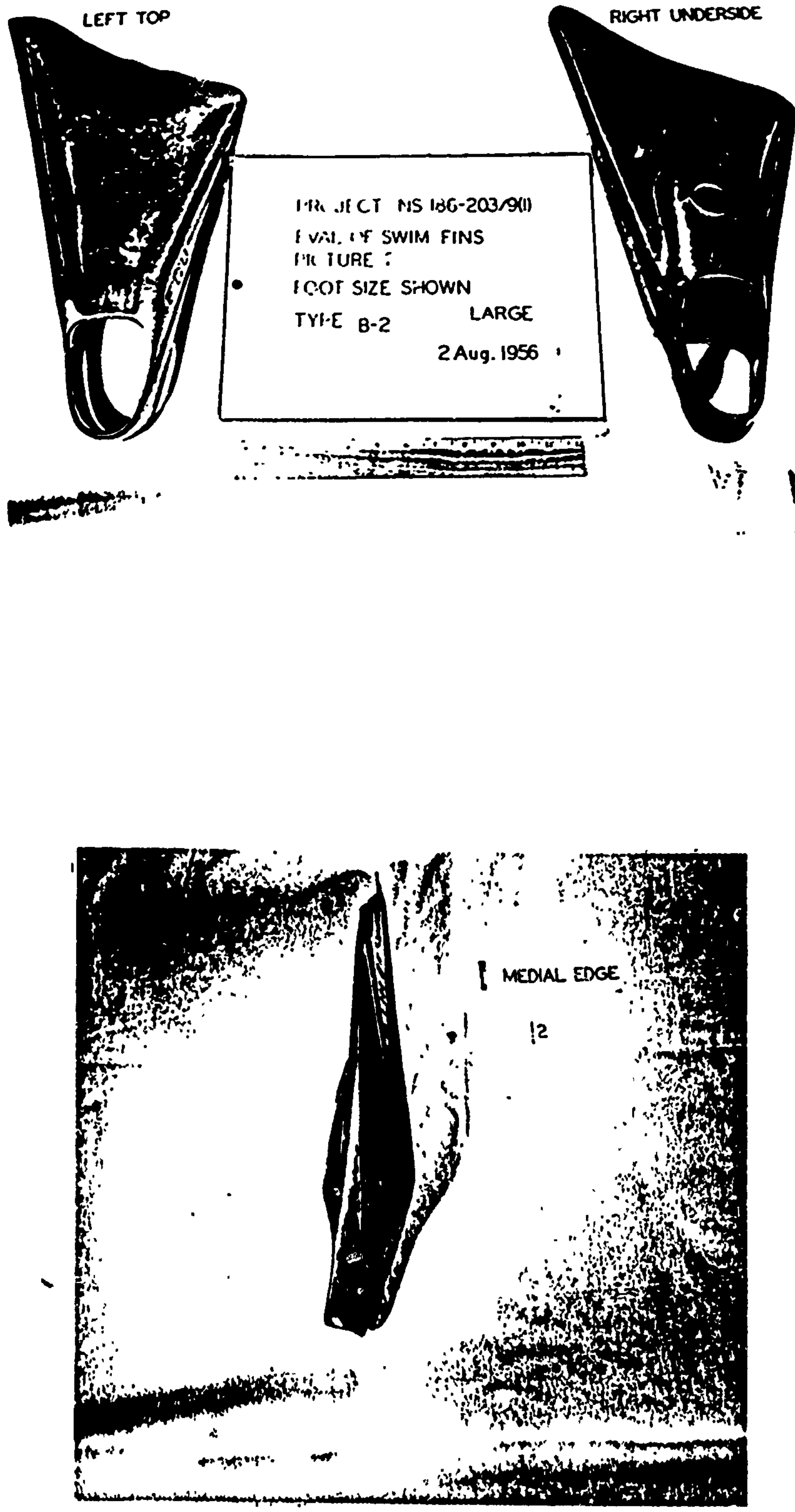
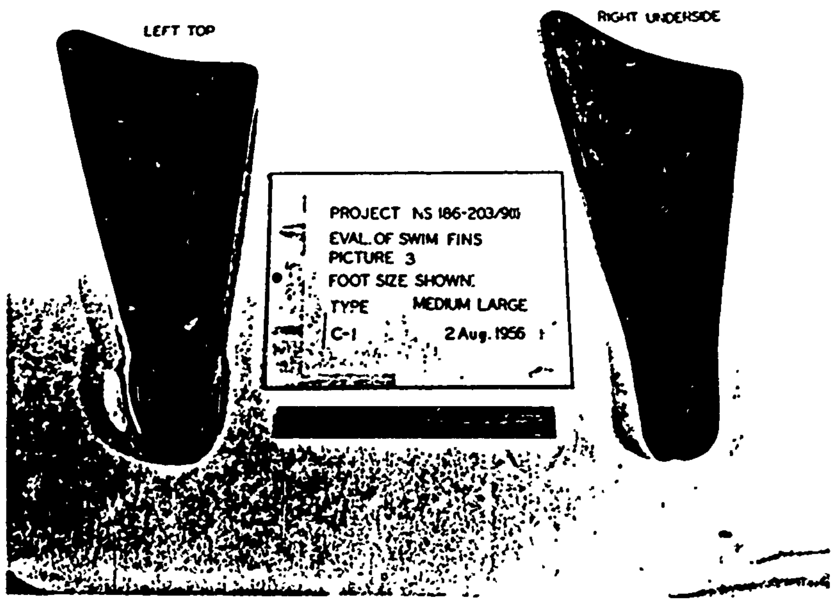

LEFT TOP
RIGHT UNDERSIDE
EVAL OF SWIM FINS
FOOT SIZE SHOWN
TYPE B-2
LARGE
2 Aug. 1956
MEDIAL EDGE
12

FIG 2 FIN B-2


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 186-203/901
EVAL. OF SWIM FINS
PICTURE 3
FOOT SIZE SHOWN:
TYPE MEDIUM LARGE
C-1 2 Aug. 1956

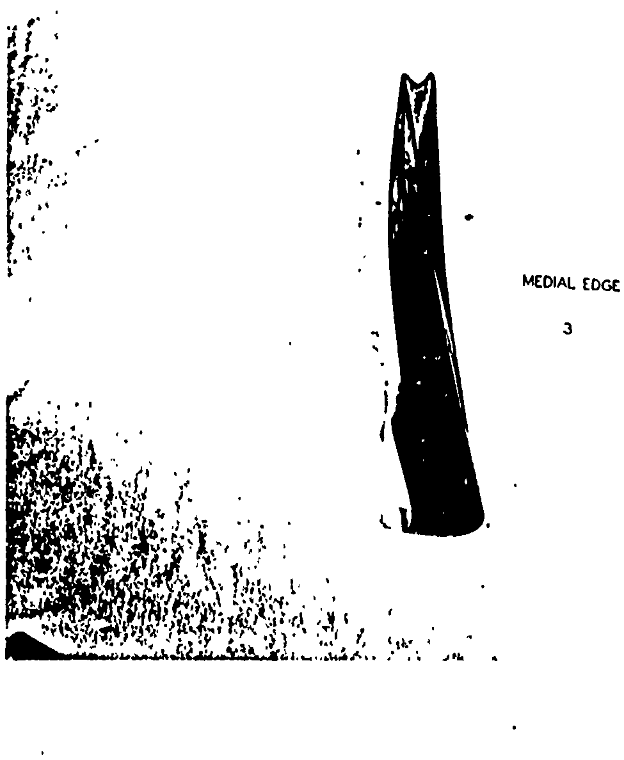
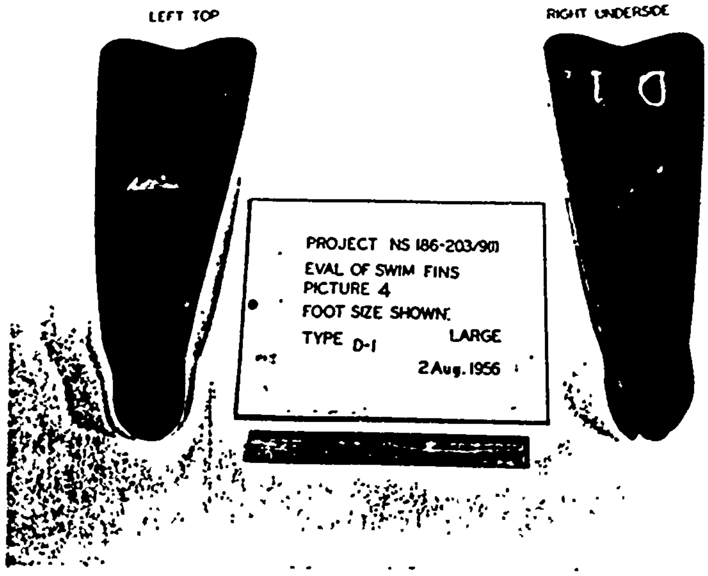

MEDIAL EDGE
3

FIG. 3 FIN C-1


LEFT TOP
RIGHT UNDERSIDE
D 1
PROJECT NS 186-203/901
EVAL OF SWIM FINS
PICTURE 4
FOOT SIZE SHOWN:
TYPE D-1
LARGE
2 Aug. 1956

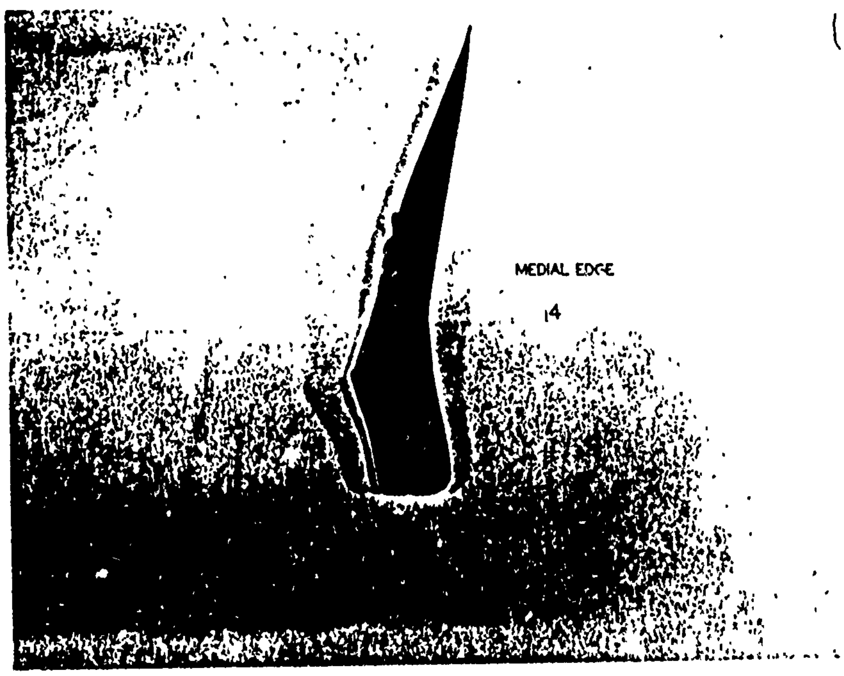
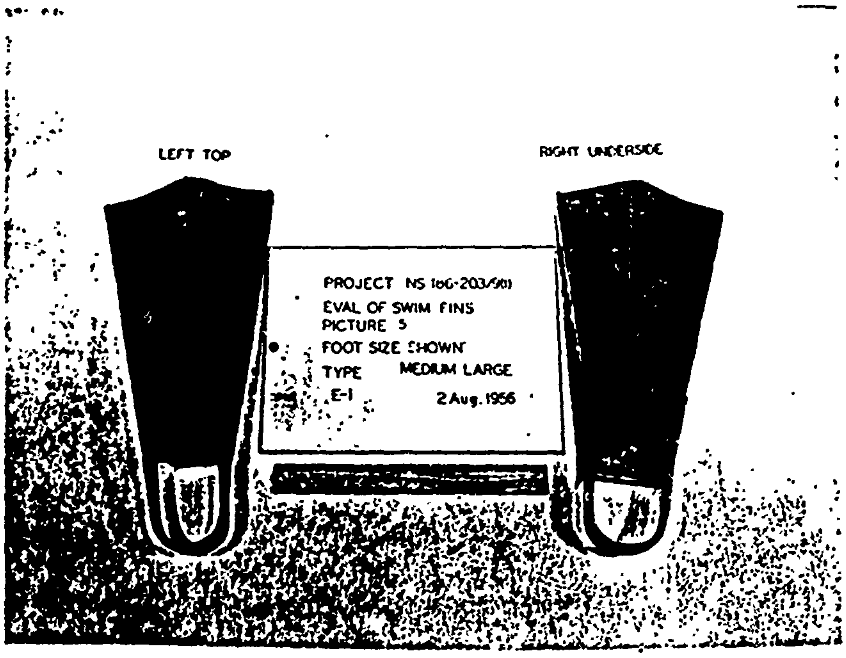

MEDIAL EDGE
14

FIG. 4 FIN D-1


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 166-203/901
EVAL OF SWIM FINS
PICTURE 5
FOOT SIZE SHOWN
TYPE MEDIUM LARGE
E-1
2 Aug. 1956

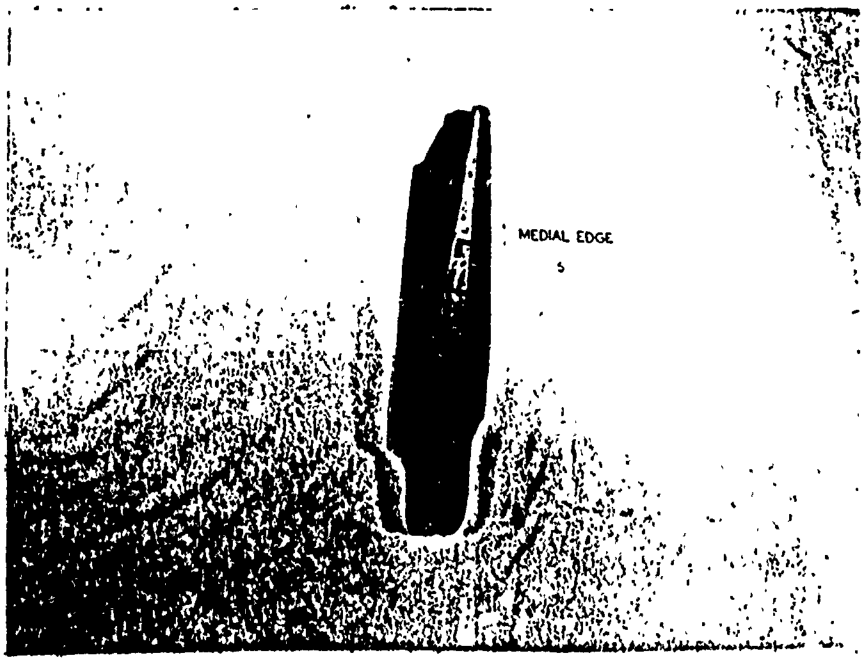
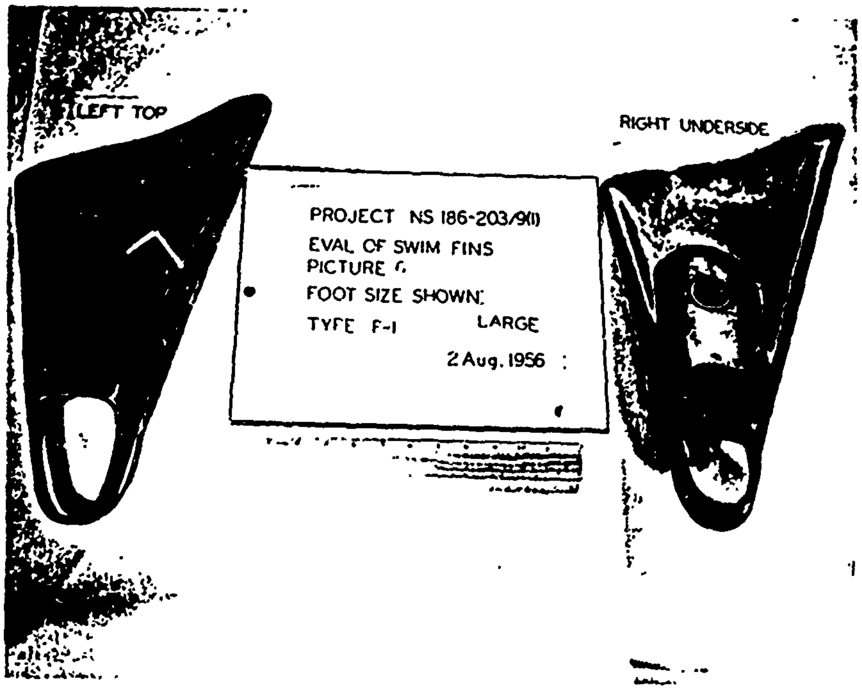

MEDIAL EDGE
5

FIG. 5 FIN E-1


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 186-203/9(1)
EVAL OF SWIM FINS
PICTURE 6
FOOT SIZE SHOWN:
TYPE F-1 LARGE
2 Aug. 1956

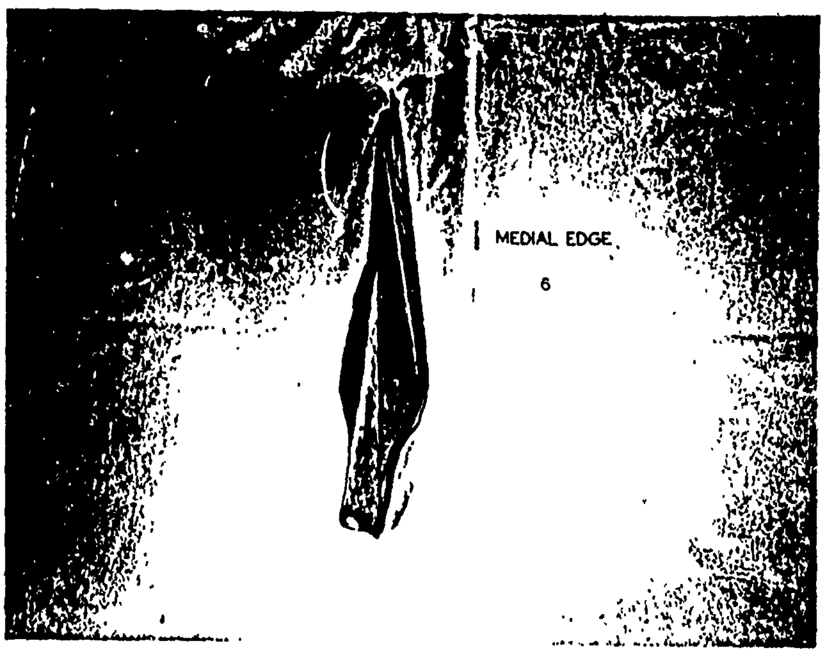
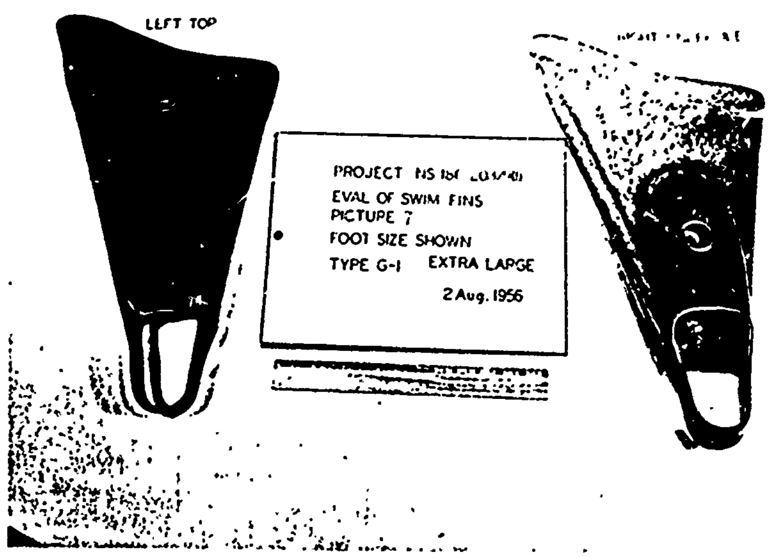

MEDIAL EDGE
6

FIG 6 FIN F-1


LEFT TOP
EVAL OF SWIM FINS
PICTURE 7
FOOT SIZE SHOWN
TYPE G-1 EXTRA LARGE
2 Aug. 1956

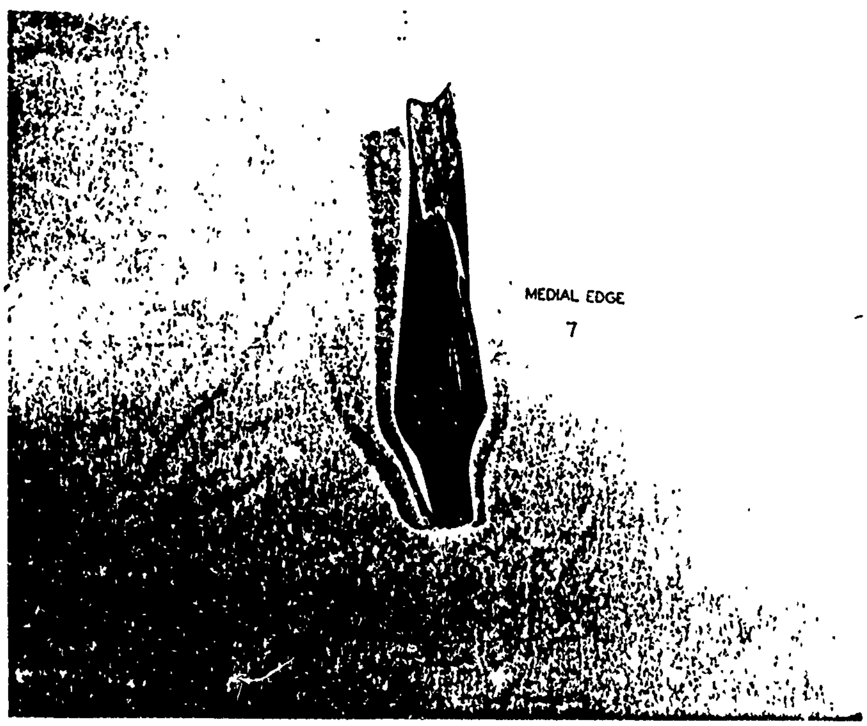
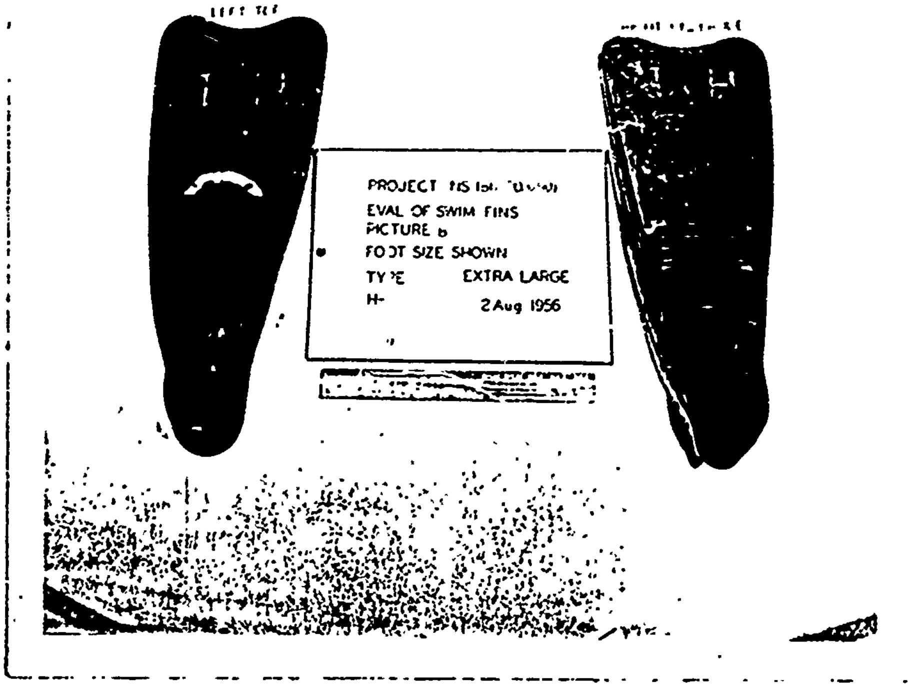

MEDIAL EDGE
7

FIG 7 FIN G-1


PROJECT NS 15[illegible]
EVAL OF SWIM FINS
PICTURE 6
FOOT SIZE SHOWN
TYPE EXTRA LARGE
H-
2 Aug 1956

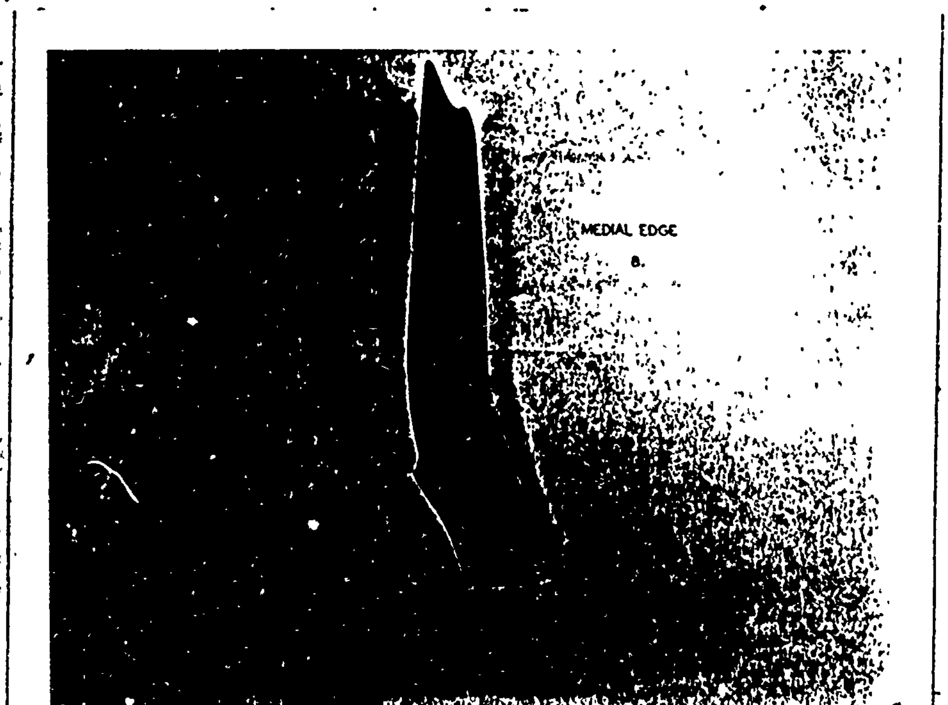
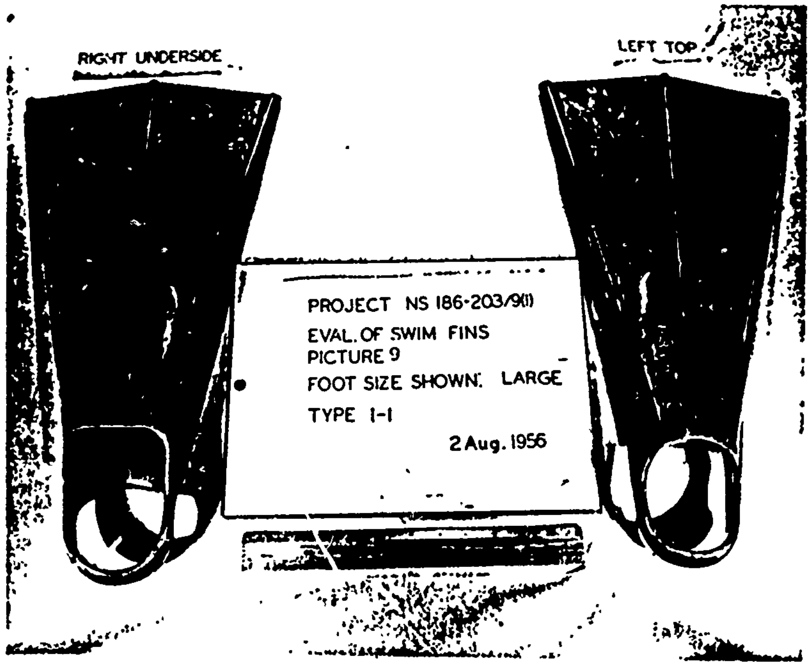

MEDIAL EDGE
8.

FIG 8 FIN H-1


RIGHT UNDERSIDE
LEFT TOP
PROJECT NS 186-203/9(1)
EVAL. OF SWIM FINS
PICTURE 9
FOOT SIZE SHOWN: LARGE
TYPE 1-1
2 Aug. 1956

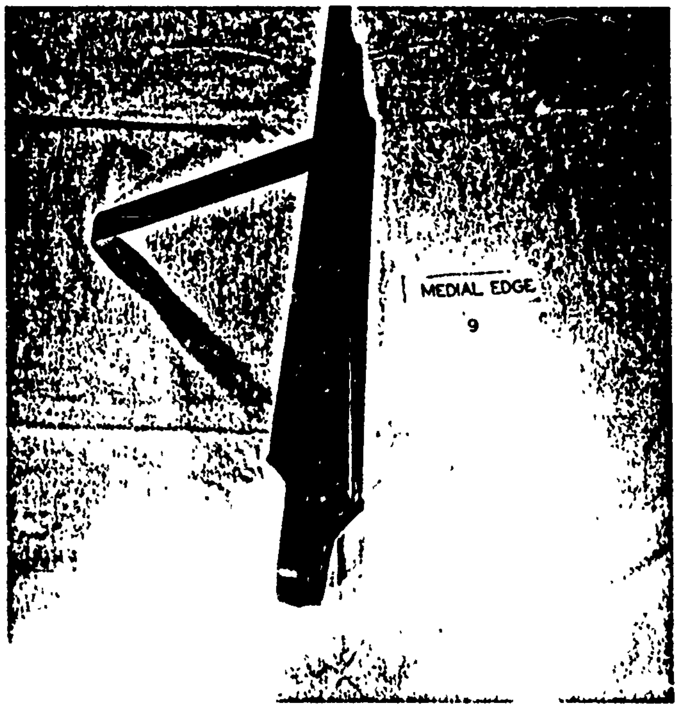
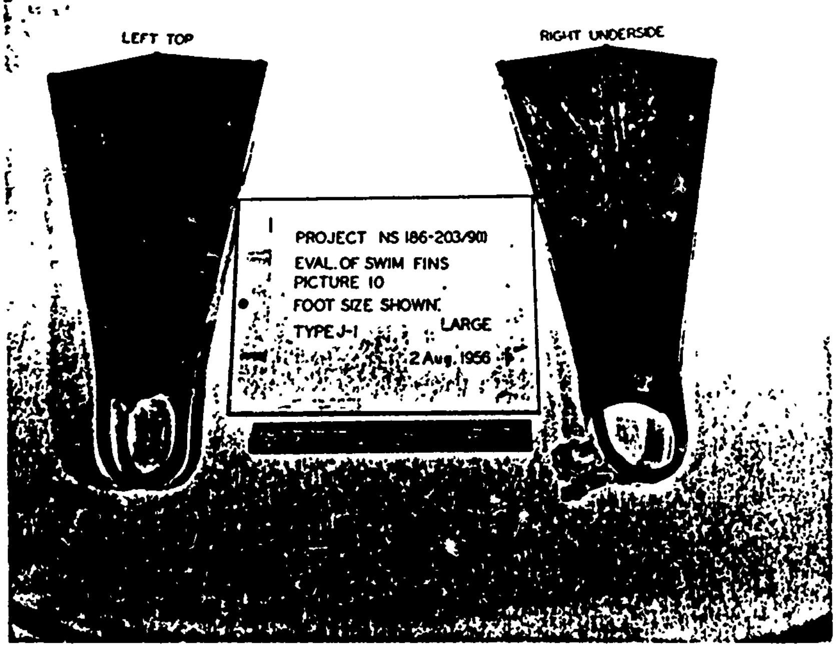

MEDIAL EDGE
9

FIG 9 FIN I-1


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 186-203/900
EVAL. OF SWIM FINS
PICTURE 10
FOOT SIZE SHOWN:
TYPE J-1
LARGE
2 Aug. 1956

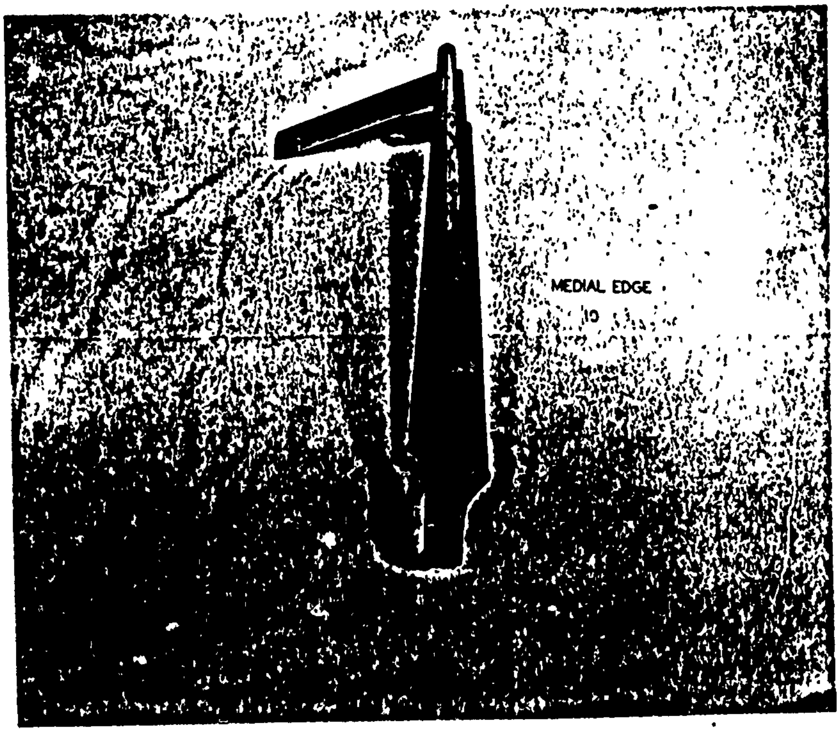
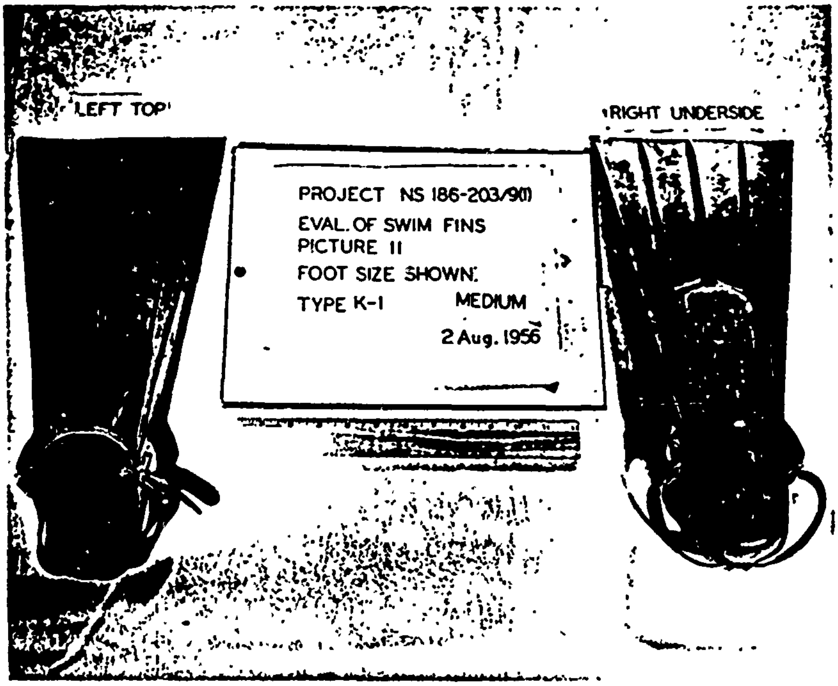

MEDIAL EDGE
10

FIG 10 FIN J-1


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 186-203/901
EVAL. OF SWIM FINS
PICTURE 11
FOOT SIZE SHOWN:
TYPE K-1 MEDIUM
2 Aug. 1956

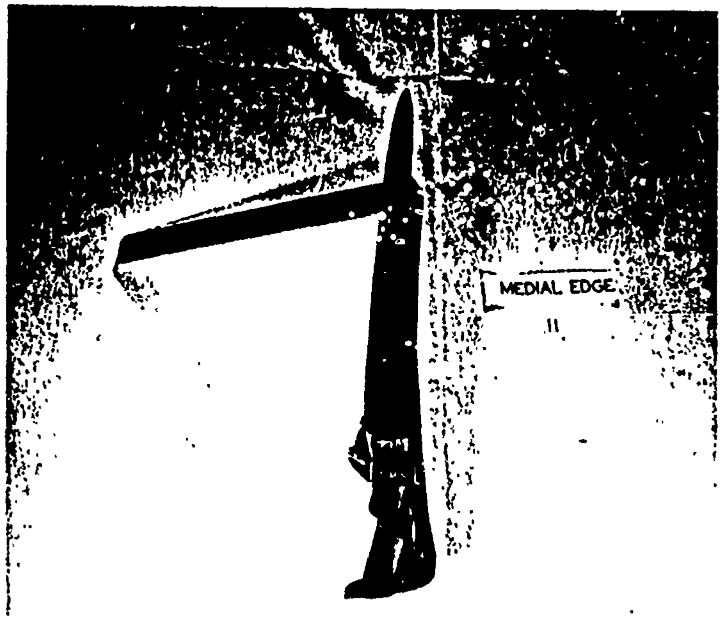
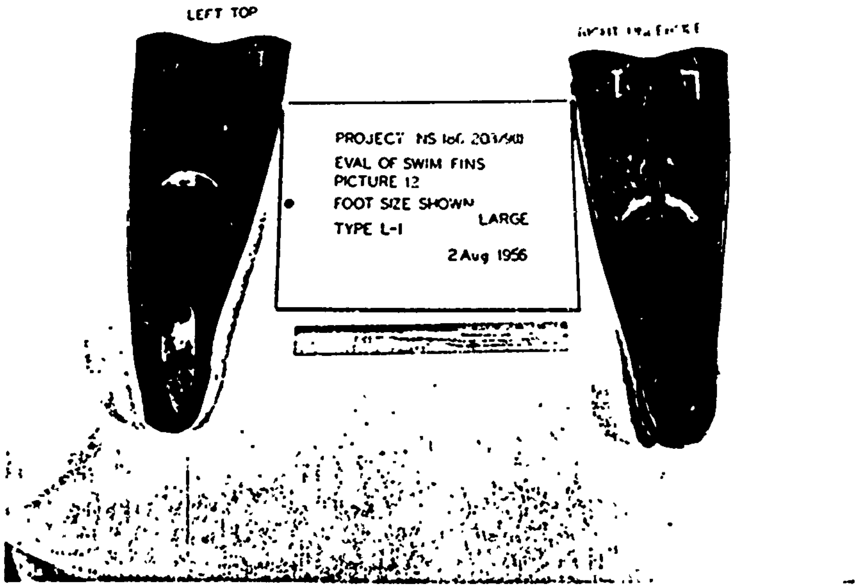

MEDIAL EDGE

FIG 11 FIN K-1


LEFT TOP
PROJECT NS 1oC 203/5O
EVAL OF SWIM FINS
PICTURE 12
FOOT SIZE SHOWN
LARGE
TYPE L-1
2 Aug 1956

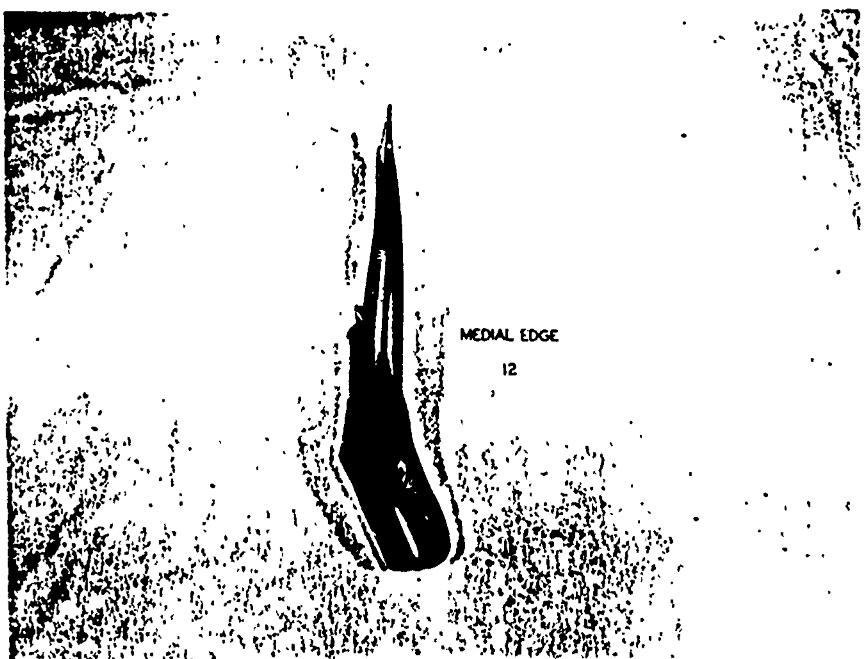
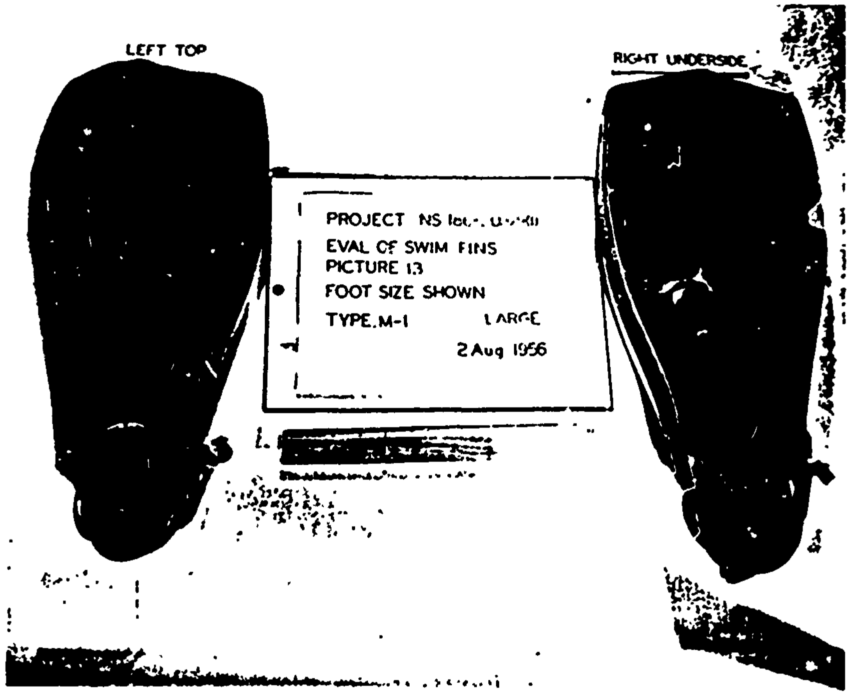

MEDIAL EDGE
12

FIG 12 FIN L-1


LEFT TOP
RIGHT UNDERSIDE
PROJECT NS
EVAL OF SWIM FINS
PICTURE 13
FOOT SIZE SHOWN
TYPE.M-1 LARGE
2 Aug 1956

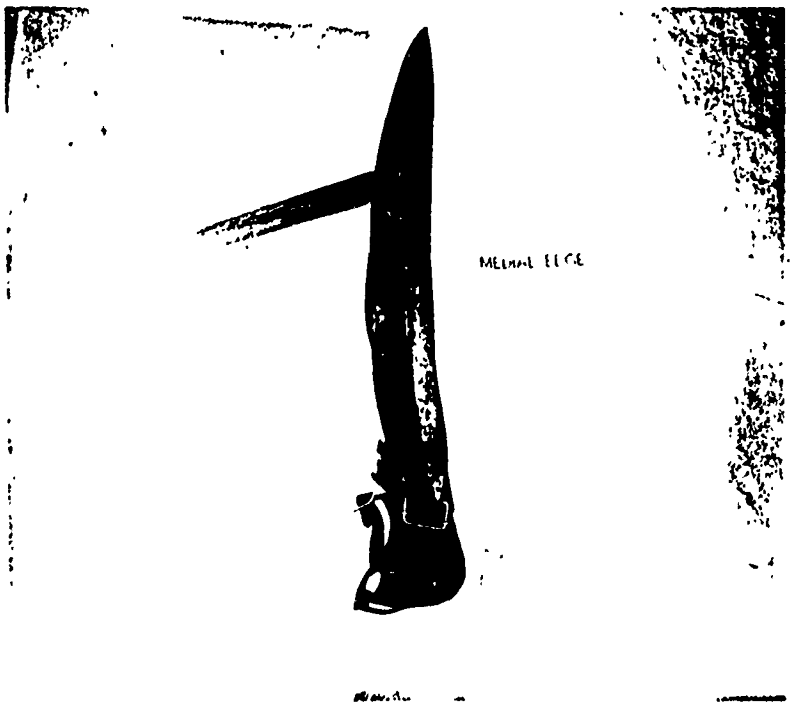
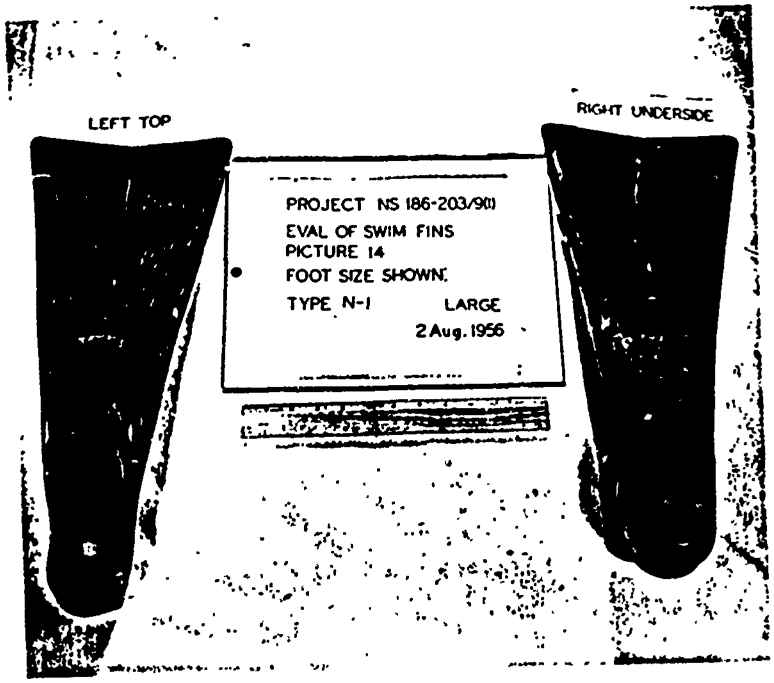
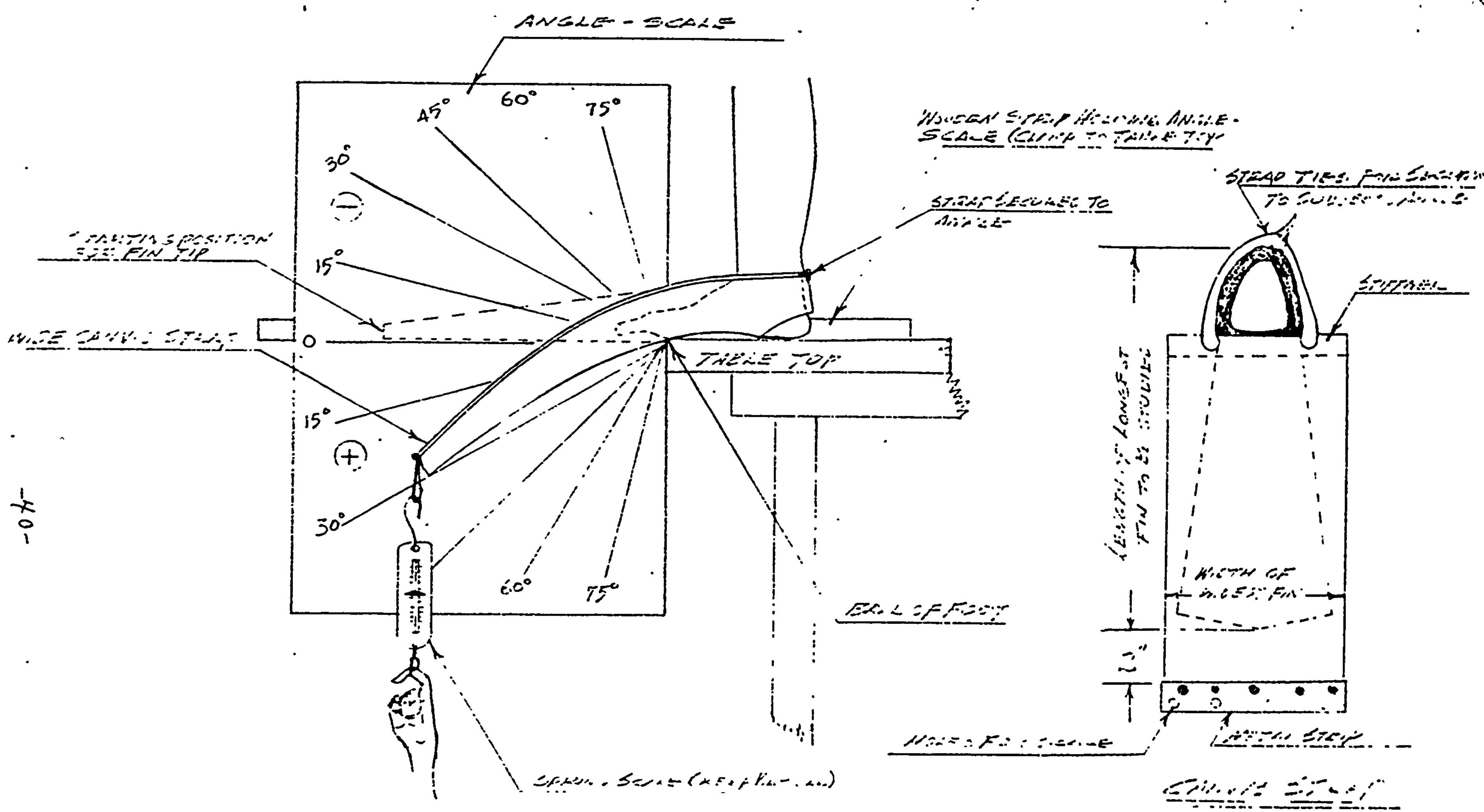


FIG. 13 FIN M-1

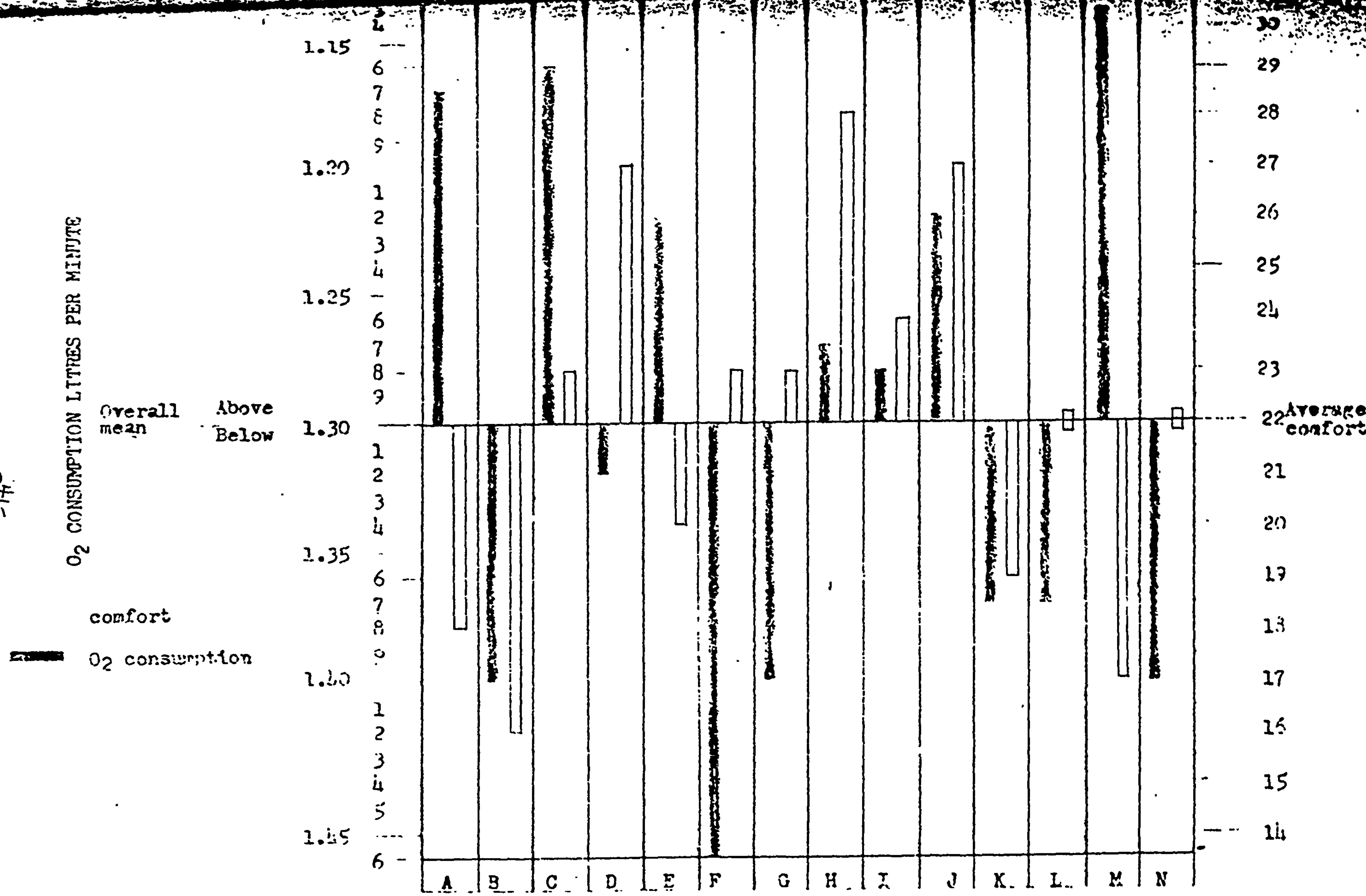

LEFT TOP
RIGHT UNDERSIDE
PROJECT NS 186-203/901
EVAL OF SWIM FINS
PICTURE 14
FOOT SIZE SHOWN:
TYPE N-1 LARGE
2 Aug. 1956


MEDIAL EDGE

FIG 14 FIN N-1



MEASUREMENT OF FIN STIFFNESS
FIGURE 5



O_2 CONSUMPTION LITRES PER MINUTE
Overall mean
Above
Below
comfort
O_2 consumption
1.15
1.20
1.25
1.30
1.35
1.40
1.45
A
B
C
D
E
F
G
H
I
J
K
L
M
N
30
29
28
27
26
25
24
23
22 Average comfort
21
20
19
18
17
16
15
14

FIGURE 15

SUBJECTS COMMENTS CONCERNING FINS

Note: This represents a summary of the relevant statements obtained on Data forms No. 4 in response to question #15. ("If you wish, use other side to say in your own words what was good or bad about this fin, offer suggestions, etc.")

FIN A. 1. Make foot size smaller, but leave blade same size.
2. For fleet use the boot socks would invainably get lost, and the fin is just too large for good performance.

FIN B. 1. These fins had a very bad drag on my up-stroke and I had to put a lot of power in the down-stroke to keep up with the 8-pound force.

FIN C. 1. Fin was generally good, but size was too small.
2. This fin had a tendency to wobble through the water. This is probably due to size.

FIN D. 1. (No comments)

FIN E. 1. Need larger foot size.
2. Very good fin.

FIN F. 1. Not quite enough power.

FIN G. 1. Nothing good about this fin.
2. Rubber in blade too soft for size of fin.

FIN H. 1. Fins too heavy.
2. Learned more about kick style and std. kick.
3. Foot size should be smaller.

FIN I. 1. Too small.
2. Good fin in performance.

FIN J. 1. Fin's are good for power.
2. Good fins.
3. Decreased the amplitude of my kick because apparently I have been working against the inertia of the trapeze.
4. This fin is much too large and cumbersome. It seemed like most of my work went into returning the fin to kick position. Could not keep a constant kick rate.

* 8 of 12 subjects used foam neoprene "boot sox" with this fin

FIN J. 5. This fin was excellent in fit, comfort and power.
6. This fin is an excellent fin if you could get different foot sizes and keep the same web.

FIN K. 1. Good fit.
2. Too small in area.
3. Had to work too hard.
4. This fin seems inefficient in the water - "slips".
5. Heel strap broke when putting it on.
6. Didn't seem to be getting any power.

FIN L. 1. Too small.
2. "Wobbled" in water.
3. Fin web too small-no power.
4. There did not seem to be any position or kick style suitable for swimming with these fins.
5. No power from kick.

FIN M. 1. Heel piece not adequate-needs improvement.
2. Heel would not stay in place.
3. Heel piece came off.
4. Good power-not enough comfort to say they are good for swimming.
5. Would be better with full heel or (regular) heel strap.

FIN N. 1. Had to work too hard-no power.
2. Fins seemed to "slip".
3. Buckle came off heel strap fitting-need better heel arrangement. *
4. Shoe design would be better. *

* Full shoe is provided in this make, but it was not studied.

SWIM-FIN EVALUATION (PROJECT NS186-203/9(1)
DATA-FORM NO. 2: PHYSICAL CHARACTERISTICS OF FINS

1. Designator letter ____________ 2. Name ____________________

3. Model ____________________ 4. Acquired ________________

5. Manufacturer ____

6. Sizes made ____

7. Sizes under study
Designator numbers.
Shoe size

8. General Description:

a. Size ____________

b. Color ____________

c. Type of rubber ____________ d. Stiffening ____________

e. Distinguishing features ____________________________

____

____________________________ f. Fit ____________

9. Specific Measurements: ______________________________

a. Linear measurements

SIZE:						
1) Width of footspace						
2) Length of footspace						
3) Length of fin						
4) Width at widest point						
5) Maximum thickness						
b. Surface area sq. in.						

c. Weight

1) Air
___lb.___oz.

2) Water
___lb.___oz.

3) Buoyancy
Neg.___Pos.___

Neutral______

d. Curvature: _____ degrees of ____ in diam. circle.

(9,d)	(9,a,3) 1,1)

e. Angles

1) Plantar or dorsal offset ________

2) Angles at end of fin ________

3) Medial or lateral offset ________

(9,e,1)) (9,e,2),3))

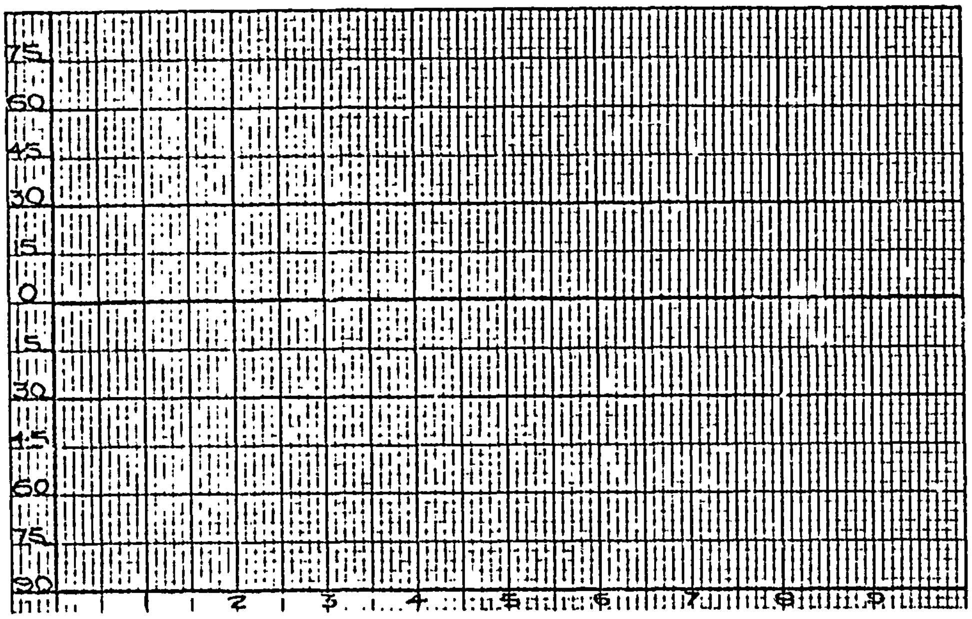
10. Stiffness Index

Designator letter _____ No. _____ Size _____ of fin used.

+ (UP)

DEGREES

- (DOWN)



POUNDS

11. Mishaps ____

____

____________________ ________________ Hours of use ____________

12. Condition at end of study ____________________________

____

____________________________________ Total hours of use ____________

SWIM-FIN [illegible]

DATA-FORM NO. 4

SUBJECT'S IMPRESSION OF FINS (Self-interview)

(Fill in blanks, cross out words not applicable, check, etc.)

NAME: ____

FIN USED: (/) ____________________________________

DATE(s) of run(s) _________________________ (Baseline, Comparison)

SIZE

1. Size used ____ 2. Satisfactory? ____ 3. If no, need (larger, smaller) size? ____ 4. Used boot socks? ____

GENERAL COMFORT

5. Excellent ____
   Good ____
   Fair ____
   Poor ____
   Very Poor ____

6. If less than good, was this because of fit? ____

7. Chafed or rubbed ____ Pinched ____
   Caused blisters ____ Slipped or slid ____
   Pressed on bones ____ Turned on foot ____
   Cramped toes ____ Tended to come off ____
   Other ____

PERFORMANCE

8. Swimming seemed (easier, harder, about same) than/as usual.

9. Caused unusual fatigue? ____ General ____ Legs ____ Feet ____ Ankles ____ Certain muscles? ______________________.

10. Had to alter normal kick style to get most out of them? ____.
11. Walking in these fins was (difficult, rel. easy).

OVERALL IMPRESSION

12. Compared to this fin is:

	A	B
Better		
About same		
Worse		

(A = baseline fin ____________.
B = fin usually used ____________)

13. Think it would be better with more practice? ____

14. Satisfied to use it from now on? ____.

15. If you wish, use other side to say in your own words what was good or bad about this fin, offer suggestions, etc.

METHOD OF MEASURING OXYGEN CONSUMPTION

Note: Time does not permit description of this method in complete detail. It is basically the same as that used in studies reported in E.D.U. FORMAL REPORT 14-54, Oxygen Consumption in Underwater Swimming and E.D.U. FORMAL REPORT 1-55, A Trapeze Swim-Ergometer.

The salient features of the method as used in this study are as follows:

BASIC PRINCIPLE

The subject uses a closed circuit oxygen rebreathing scuba. As the subject consume oxygen, more must be added to the system. The volume added is essentially equal to the volume consumed (the subject's oxygen consumption).

The oxygen is supplied from a small, calibrated "run cylinder" which is equipped with an accurate gage. The pressure-drop in the cylinder is directly proprotional to the volume of oxygen supplied. The pressure is recorded periodically. The pressure drop is translated into volume by multiplying it by the calibration factor for the cylinder (volume releaced per unit of pressure-drop). Application of correction factors yields the value for volume corrected to standard conditions.

APPARATUS

The Lambertsen T-4 oxygen scuba was employed. The facemask was replaced with a mouthpiece to reduce the likelihood of leaks. The demand valve which automatically supplies oxygen when the breathing bag flattens on inspiration was left intact. The normal oxygen supply cylinder and regulator were placed with a hose to a supply manifold outside the tank.

The supply manifold arrangements include: (1) a large oxygen cylinder, (2) a small, carefully calibrated "run cylinder" immersed in a water both with thermometer, (3) a large, accurate pressure gauge, and (4) a regulator to reduce pressure to the supply hose.

PROCEDURE

1. Oxygen is supplied from the large cylinder while the subject dons the scuba, purges it, and settles down.

2. The large cylinder is shut off and the system is checked for leaks.

3. When the subject has started swimming, the small run cylinder (previously charged from the large cylinder and allowed to equilibrate its temperature is opened. (The

subject is watched closely to note any leaks of oxygen from the breathing circuit. If any significant leak is noted, the run is repeated).

4. The gage is read each minute during the run. (Water bath temperature is also recorded periodically). At certain intervals, the subject is instructed to take a full breath. (This brings the system up to a standard volume, and it is done at such a time that the cylinder temperature and pressure can sterilize before the next pressure reading).

5. The pressure readings are plotted against time. A "line of best fit" is then drawn on the graph to represent the mean rate of pressure drop during the "steady state" portion of the run. In drawing the line, most emphasis is placed on the period beyond the first 5 minutes of the run and on the points which represent readings after the full breaths.

6. The pressure drip over a set interval is measured from the drop-rate line. To obtain the oxygen consumption value in terms of liters of oxygen per minute corrected to standard conditions (STPD), the drop value is multiplied by a single factor which is derived from; (1) the calibration factor of the cylinder (see note), (2) the factor for reducing the period of observation to "per minute", (3) and a factor for connecting from ambient (water bath) temperature to zero degrees centigrade. Separate factors were calculated for temperatures in one degree C. intervals over the necessary range.

NOTE:

The "cylinder calibration factor" was obtained by applying the following procedure: (Actually, the factor is for the gage and manifold as well as for the cylinder all high pressure parts involved in the actual runs are included in the calibration procedure). The procedure is repeated several times to insure accuracy.

1. Charge cylinder and attach to manifold.
2. Allow to cool to room temperature.
3. Read pressure accurately.
4. Bleed cylinder into large, well-calibrated spirometer. (Bleed to zero pressure).
5. Assure that cylinder and spirometer are at same temperature, which must be same as that during initial pressure reading.
6. Read volume delivered to spirometer.
7. Correct volume to dry gas volume at ambient temperatue and 760 mm Hg.
8. Divide volume by total pressure-drop to determine volume per p.s.i drop.