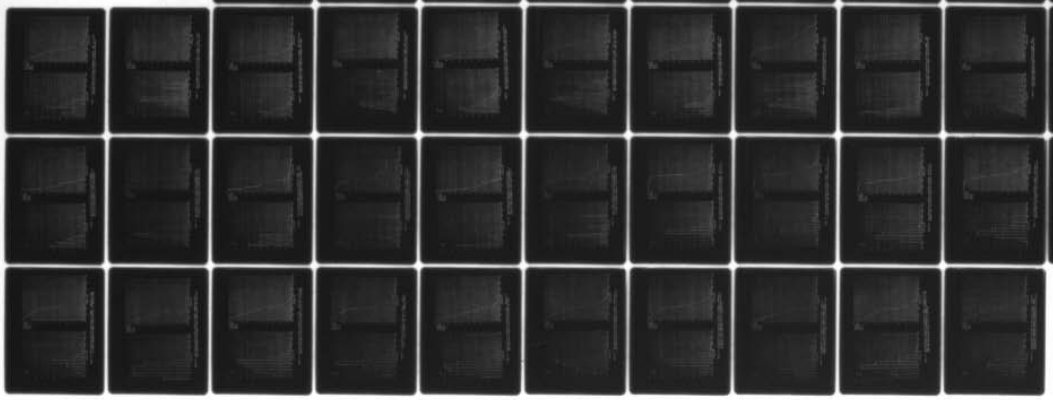
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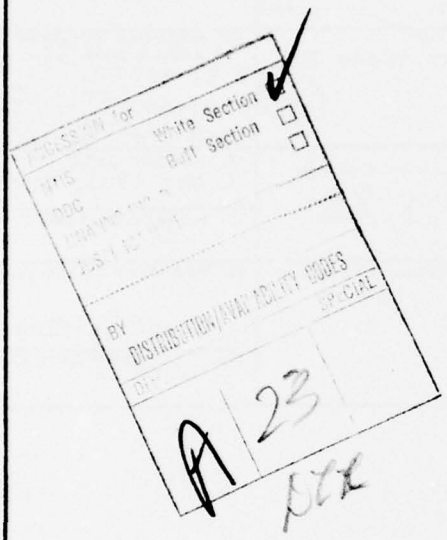
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
In a previous technical memorandum "Mathematical Model of FLIR Performance" of 19 Oct 1972, a set of equations was developed which permits one to calculate acquisition, classification and identification ranges for ship targets when viewed by an airborne forward looking infrared (FLIR) imaging device. One of the inputs to the model is the length of the target. This technical memorandum provides statistical data that enable one to determine the length of ship targets that a FLIR must be designed to acquire, classify and identify

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at operationally useful ranges if it is to be effective against any pre-selected percentage of the number or tonnage of the world's ships. Ship population distributions and ship tonnage distributions according to length are plotted in the form of histograms and curves of cumulative frequency of occurrence. Data are presented in various combinations for U.S., U.S.S.R. and world merchant and naval combatant and support vessels.



NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA 18974

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30 Mar 1973
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TECHNICAL MEMORANDUM NADC-202149:NEM

Subject: Naval and Merchant Ship Length Distributions

References:
(a) NAVAIRDEVCEN Tech Memo NADC-20203:PMM "Mathematical Model of FLIR Performance" of 19 Oct 1972
(b) R. V. Blackman (Editor), Jane's Fighting Ships, 1971-72 edition, McGraw-Hill Book Company
(c) U.S. Department of Commerce, Maritime Administration, Office of Subsidy Administration, Division of Trade Studies and Statistics table "Merchant Fleets of the World Frequency Distribution," (unpublished) of 31 Dec 1971
(d) U.S. Department of Commerce, Maritime Administration publication "A Statistical Analysis of the World's Merchant Fleets," 1972
(e) Lloyd's Register of Shipping Statistical Tables 1971

I. INTRODUCTION

Under AIRTASK A360360C/001B/3F32340604, operational and system analyses and state-of-the-art technology surveys and projections are being performed at NAVAIRDEVCEN as a first effort in the development of FLIR (forward looking infrared) imaging devices which would be affordable in large quantities and optimized for the missions of single-place attack aircraft. In reference (a) a method was developed for calculating target acquisition, classification and identification ranges as functions of target size, orientation and effective thermal contrast, atmospheric conditions, and FLIR sensor altitude, resolution and sensitivity. The purpose of this technical memorandum is to provide statistical data on the sizes of ship-type targets in a format that is compatible with the mathematical model. That is, the data contained herein will enable one to determine the size of ship targets that a FLIR must be designed to acquire, classify, and identify at operationally useful ranges if it is to be effective against any preselected percentage of the number or tonnage of the world's ships. The resulting ship size data will serve as inputs to the mathematical model. (The term "ship" is generally understood to mean

a large seagoing vessel and is so used herein, although certain smaller vessels of tactical interest which are listed in reference (b) are also included.)

II. METHOD AND RATIONALE

Data from references (b) and (c) were used to construct histograms and cumulative distribution curves illustrating the number and tonnage of the world's ships as functions of ship length. Thirty-eight groupings of U.S., Soviet, and the world's military and merchant ships were considered for which data are given in figures 1 through 38. In the histograms, the height of each column indicates either the number of ships or the total tonnage that falls within the corresponding ship length interval indicated on the abscissa. The cumulative distribution curves are the integrals of the histograms over ship length expressed as percentages normalized to 100 percent. The integrations were performed from longer to shorter ship lengths in order that the ordinates may be interpreted as the percent statistical probability that the length of a ship will exceed any given amount.

To illustrate the use of these data, if it is desired to design a FLIR that will be able to identify, say, 70 percent of the world's naval combatants at operationally useful ranges, the appropriate curve (figure 19) indicates that the FLIR must be designed to identify ships as small as 85 feet in length at those ranges. However, to talk in terms of a percentage of the number of ships could be somewhat misleading. Basing a distribution solely on ship numbers results in large and small ships being given equal statistical weight. Since a large ship may be considered to be a more important potential target than one of the more numerous smaller vessels, the data were also plotted with the number of ships in each length interval multiplied by the respective tonnages of the ships in that interval. That is, the sum of the tonnages of the ships in each length interval were plotted as a function of ship length to yield a distribution that gives greater statistical weight to the larger ships. The latter type of distribution may be a better guide for the FLIR designer specifying what lengths of ships an effective FLIR must be able to identify at operationally useful ranges. If the FLIR designer uses the tonnage distributions, his design requirements are not as stringent as they would be if he were to use the distributions according to number. For instance, as mentioned above, 70 percent of the number of the world's naval combatants exceed 85 feet in length as shown in figure 19. But figure 20 shows that 70 percent of the world's combatant tonnage comprises ships exceeding 330 feet in length.

III. NAVAL SHIPS

Reference (b) is a compilation of data on ships of 55 of the world's navies, describing individually most of the military vessels in the

world. From the individual ship data for the U.S. and Soviet navies, the necessary length and tonnage data were extracted to plot the length distribution of 1660 U.S. ships (not including Coast Guard vessels) and 2215 Soviet ships. These distributions are shown in figures 1 through 6.

Completion of these distributions indicated to the author that the time required to study the other 53 navies in a like manner would be excessive. A shorter approach was employed by separating the types of ships tabulated in reference (b) into two groups, "combatants" and "support ships." The combatants comprise the 21 types described in table I. These ships have silhouettes which are easily distinguishable from those of merchant ships and have lengths and tonnages which are relatable meaningfully to their types. Representative lengths and tonnages were assigned to each type of ship as shown in tables II and III. These values may be considered to be the most probable lengths and tonnages that would characterize ships of the respective types. Tables II and III also tabulate the extreme values of length and tonnage for each type. The extreme values are based on individual ship data given in reference (b) for all 55 navies.

The representative lengths and tonnages for each type were based on data on individual ships of the two or three countries owning the largest number of the ships of that type. For many types of ships, the U.S. and Soviet navies own the majority of these ships, for instance, 332 of the 539 destroyers (type 9). In the case of the 23 fleet minelayers (type 14), Spain (with six) and Denmark (with four) were taken as the sources of representative data. After representative values of length and tonnage were assigned to each type, distributions were estimated for any country or group of countries by merely using the number of ships of a given type, as tabulated in reference (b), and multiplying that by the appropriate value of length or tonnage. The numbers of ships of each type owned by the U.S. Navy, the Soviet Navy, and the 55 world's navies, respectively, are shown in table IV.

Individual ship data for the U.S. and Soviet navies were used to construct the distributions of combatant ships given in figures 7 through 12; representative length and tonnage values (for the same navies) were used to construct the distributions shown in figures 13 through 18. The comparison of the two sets of figures illustrates the distortion resulting from using the representative values to estimate the distributions for these two countries. The distortion was considered to be acceptable for the purposes of this study, and world distributions were estimated from the representative values and illustrated in figures 19 and 20.

The reader should be aware that both the individual ship data and the representative value distributions are based on incomplete populations. The individual ship data in reference (b) could not be fully utilized because the data were not complete for all vessels. When the combatants were considered by type, some vessels did not fall into any of the categories and thus were omitted. There are more U.S. combatants in the distributions based on individual ship data than in those based on representative values because some ships that reference (b) had listed as "miscellaneous" in the summary table on which the representative value distributions were based were assigned to specific combatant types by the author.

IV. MERCHANT SHIPS

Published data concerning merchant ships usually identify their sizes in terms of "gross tonnage" rather than length. Sources such as references (d) and (e) base all their groupings on gross tonnage. Reference (d) has no length data and reference (e) gives length data only on ships greater than 6000 gross tons. For instance, in the case of oil tankers, reference (e) lists the ages and tonnages of 6292 ships of 100 gross tons and upwards, but the lengths of only the 3260 ships of 6000 gross tons and upwards. Although the length of a ship is related to its gross tonnage, curves for the various types of merchant ships were not available to enable the author to estimate lengths based on the tonnage data.

The data in reference (c) were used as the source of merchant ship length distributions shown in figures 21 through 28. These data do not cover ships operating on the Great Lakes and special types such as cable ships, icebreakers, trawlers, and those belonging to the military forces. The data are based only on merchant ships of 1000 gross tons and over.

The total number of merchant ships listed in reference (c) is 20,544. Reference (e) lists 55,041 merchant ships of which 23,613 are over 1000 gross tons and 31,428 are between 100 and 1000 gross tons. Apparently more than half of the world's merchant ships are between 100 and 1000 gross tons, and these do not appear in reference (c). The ship population distributions in figures 21, 23, 25 and 27 are thus biased heavily towards the larger ships. However, according to reference (e), only 4.4 percent of the world's gross tonnage is in the form of ships between 100 and 1000 gross tons, so the tonnage data from reference (c) used to construct figures 23, 24, 26 and 28 give a more accurate picture of the length distributions than the ship population data do.

V. NAVAL AND MERCHANT SHIP COMPOSITES

Ship population distributions were plotted of certain combinations of the naval and merchant ship distributions given in the odd-numbered figures 1 through 27. The tonnage distributions (even-numbered figures) could not be combined since the naval tonnage is a weight measurement (displacement tonnage) and the merchant ship tonnage is a volume measurement (gross tonnage).

The data of figures 1 and 21 were combined in figure 29 to show the U.S. Navy combatants and support ships and the U.S. merchant fleet. Figure 30 gives a similar composite distribution for the USSR, and figure 31 shows the combined distribution of U.S. and Soviet ships together. Figures 32, 33, and 34 show the combatant and merchant ship composite distributions and figures 35, 36 and 37 combine the estimated combatant distributions with the merchant ship distributions for the two countries. Figure 38 combines the estimated world combatant distribution with that of the world's merchant ships.

VI. ACKNOWLEDGEMENT

The author would like to express her appreciation for the cooperation of Mr. James White of the Maritime Administration in providing the merchant ship data and for the assistance of Messrs. Paul M. Moser and Glenn J. Jadney in the preparation of this memorandum.

Nancy E. MacMeekin

NANCY E. MACMEEKIN

TABLE I

COMBATANT SHIPS OF THE WORLD'S NAVIES

TYPE DESCRIPTIONS

Type	Description
1	Large Aircraft Carriers
2	Light Aircraft Carriers
3	Escort Carriers, Helicopter Carriers, Commando Carriers
4	Command Ships, Communications Ships, Amphibious Force Flag Ships
5	Nuclear Powered Submarines
6	Conventionally Powered Submarines
7	Cruisers
8	Leaders, Large Destroyers, Frigates (DLG)
9	Destroyers
10	Destroyer Escorts, Frigates, Escorts (and APD)
11	Corvettes (including PCE)
12	Patrol Vessels, Submarine Chasers (PC)
13	Missile Boats, Torpedo Boats, Fast Gunboats, Fast Patrol Boats
14	Fleet Minelayers, Fast Minelayers, Mine Support Ships
15	Coastal Minelayers
16	Ocean Minesweepers, Fleet Minesweepers
17	Coastal Minesweepers, Mine Hunters
18	Inshore Minesweepers, Minesweeping Boats
19	Motor Launches, Motor Patrol Craft, River Gunboats
20	Landing Ships
21	Landing Craft

TABLE II

COMBATANT SHIPS OF THE WORLD'S NAVIES

OVERALL LENGTHS (FEET)

Ship Type	Minimum	Maximum	Representative
1	812	1123	965
2	695	865	754
3	592	744	604
4	117	684	553
5	252	448	378
6	70	350	261
7	489	689	636
8	417	565	530
9	280	440	400
10	205	438	318
11	184	275	214
12	111	228	162
13	20	164	94
14	172	456	291
15	99	221	200
16	171	244	194
17	97	153	142
18	50	120	112
19	20	231	70
20	204	522	312
21	37	225	136

TABLE III

COMBATANT SHIPS OF THE WORLD'S NAVIES

FULL LOAD DISPLACEMENT TONNAGE

(LONG TONS)

Ship Type	Minimum	Maximum	Representative
1	33,000	90,000	60,000
2	20,000	33,000	24,000
3	12,000	29,000	18,000
4	643	23,000	15,000
5	2,640	9,000	6,000
6	81	3,600	1,700
7	6,000	22,000	15,000
8	3,600	9,200	7,100
9	1,500	5,200	3,700
10	960	4,000	2,200
11	650	1,400	880
12	140	780	400
13	50	245	88
14	790	9,000	2,000
15	230	1,250	750
16	530	1,400	720
17	150	510	300
18	25	235	150
19	6	865	50
20	750	8,300	3,700
21	10	1,100	380

TABLE IV

COMBATANT SHIPS OF THE WORLD'S NAVIES

POPULATIONS

(NUMBER OF SHIPS)

Type	U.S. Navy	Soviet Navy	World's Navies
1	27	0	29
2	0	0	6
3	7	2	16
4	12	0	14
5	96	83	189
6	56	318	623
7	23	26	74
8	33	0	51
9	232	100	539
10	198	130	707
11	0	0	152
12	1	270	589
13	37	450	1622
14	1	1	23
15	0	0	34
16	80	185	416
17	14	135	626
18	1	0	350
19	80	120	1945
20	57	125	401
21	100	75	651
Total	1055	2020	9057

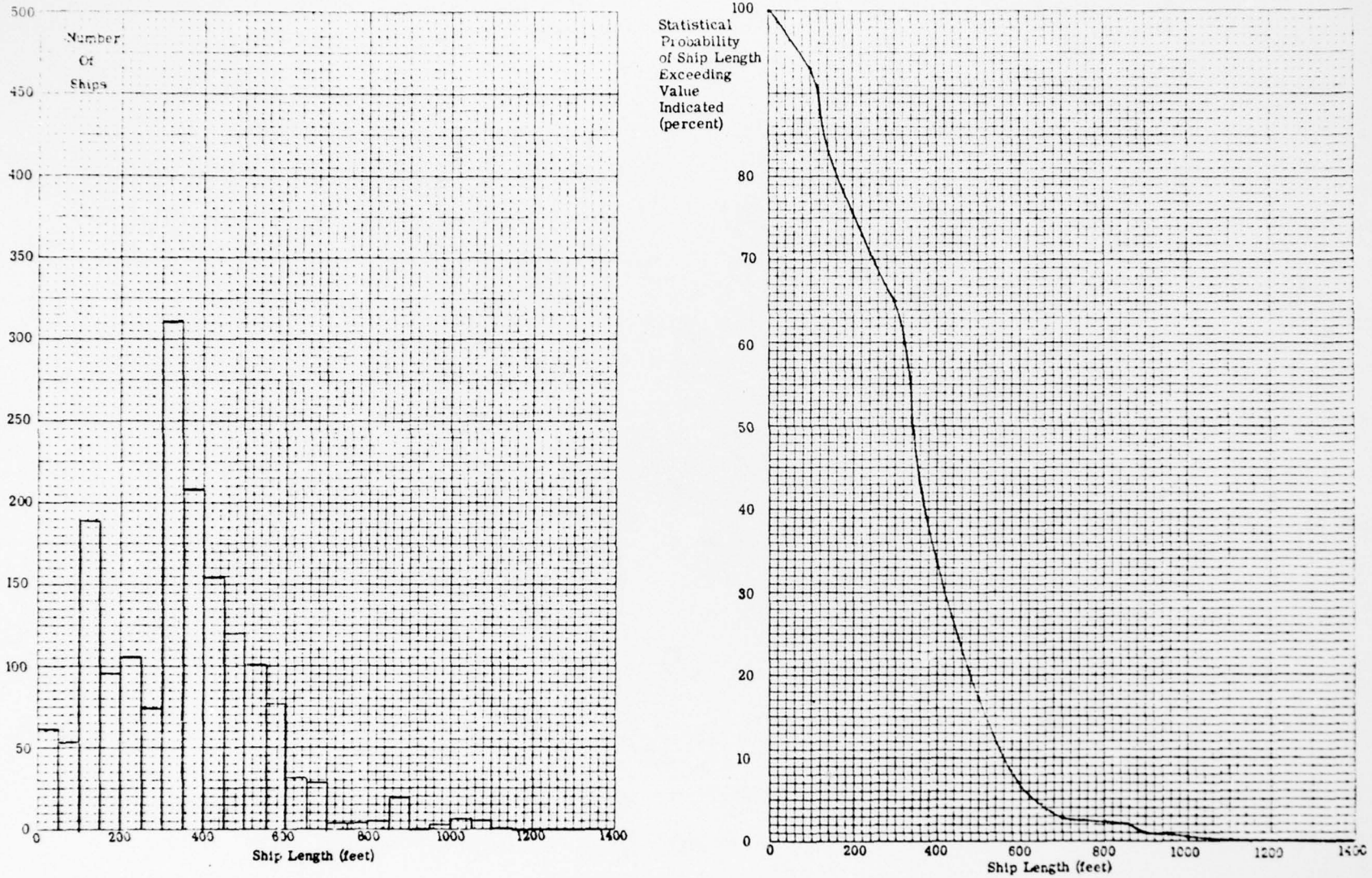


Figure 1. Ship Population Distribution According to Length: 1660 U.S. Naval Combatant and Support Vessels (based on individual ship data)

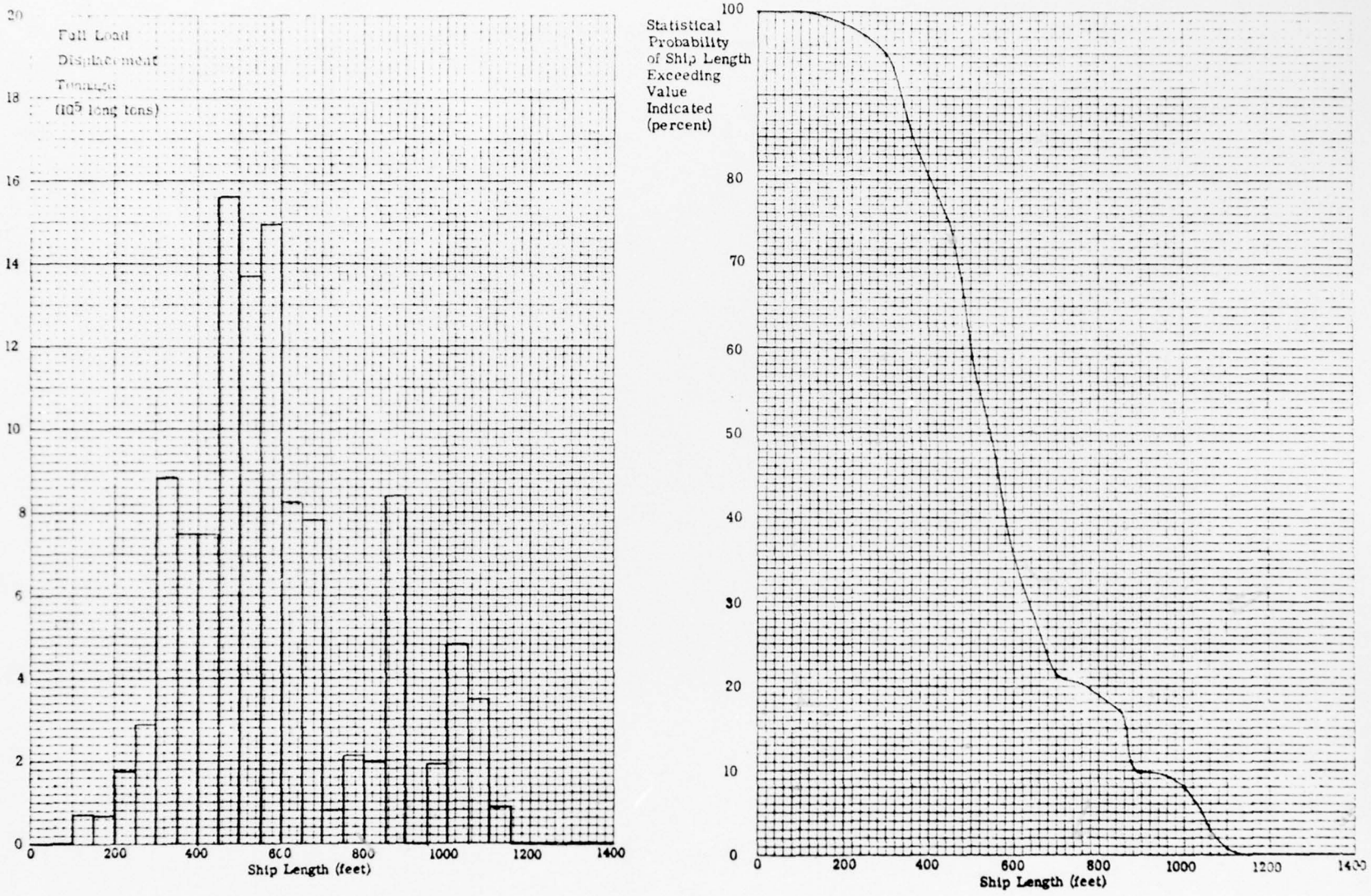


Figure 2. Ship Tonnage Distribution According to Length: 1660 U.S. Naval Combatant and Support Vessels (based on individual ship data)

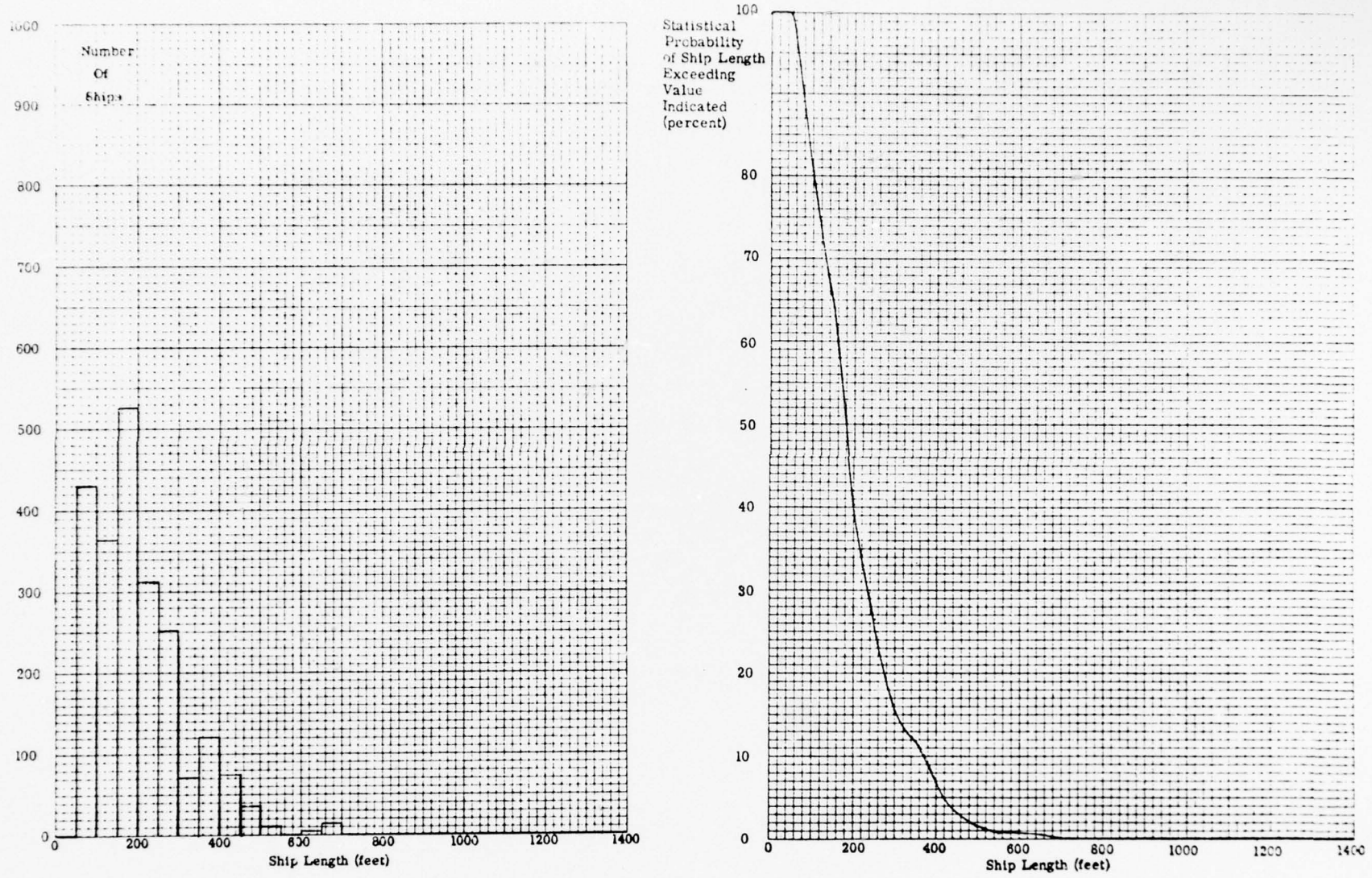


Figure 3. Ship Population Distribution According to Length: 2215 Soviet Naval Combatant and Support Vessels (based on individual ship data)

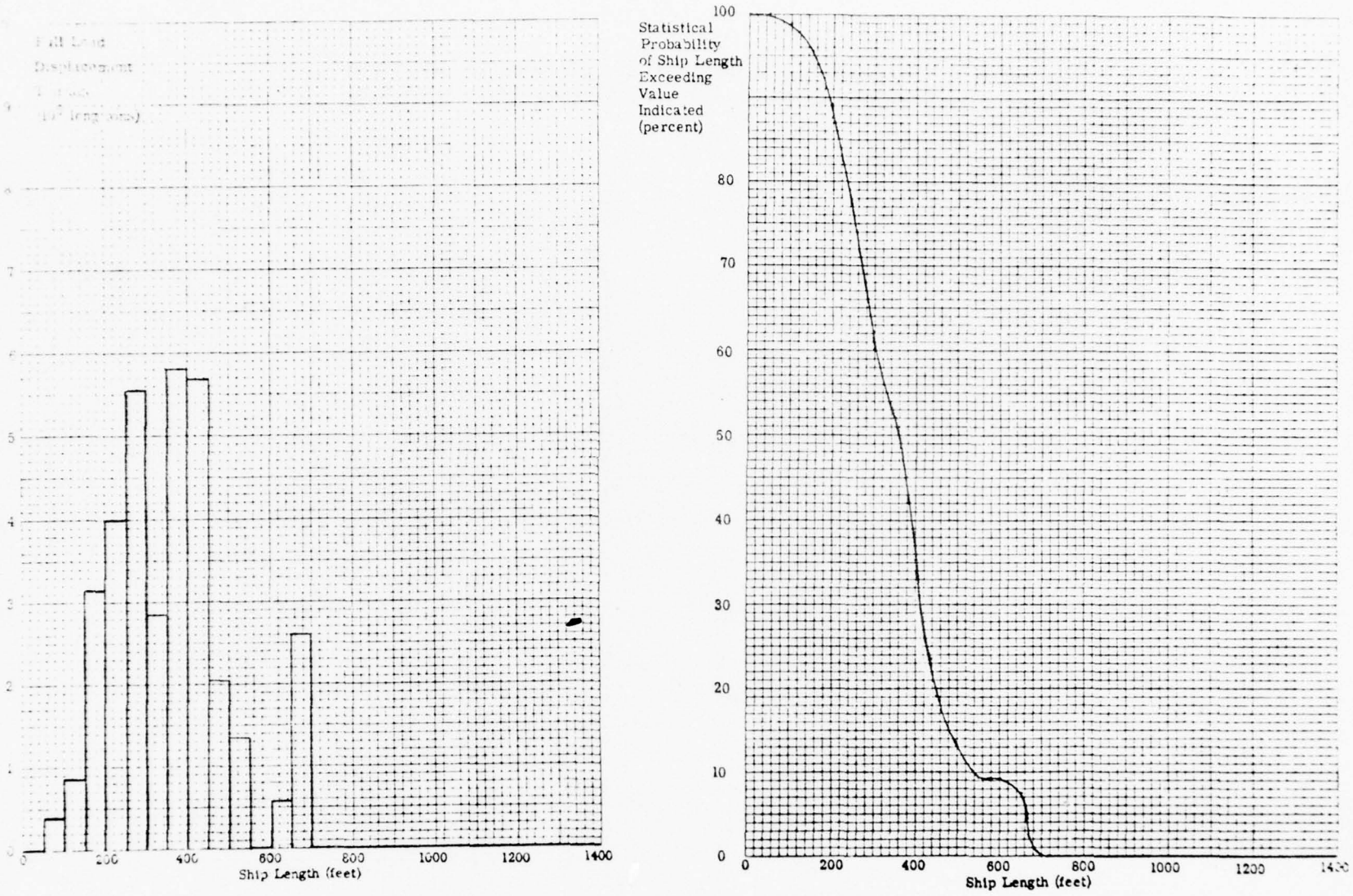


Figure 4. Ship Tonnage Distribution According to Length: 2215 Soviet Naval Combatant and Support Vessels (based on individual ship data)

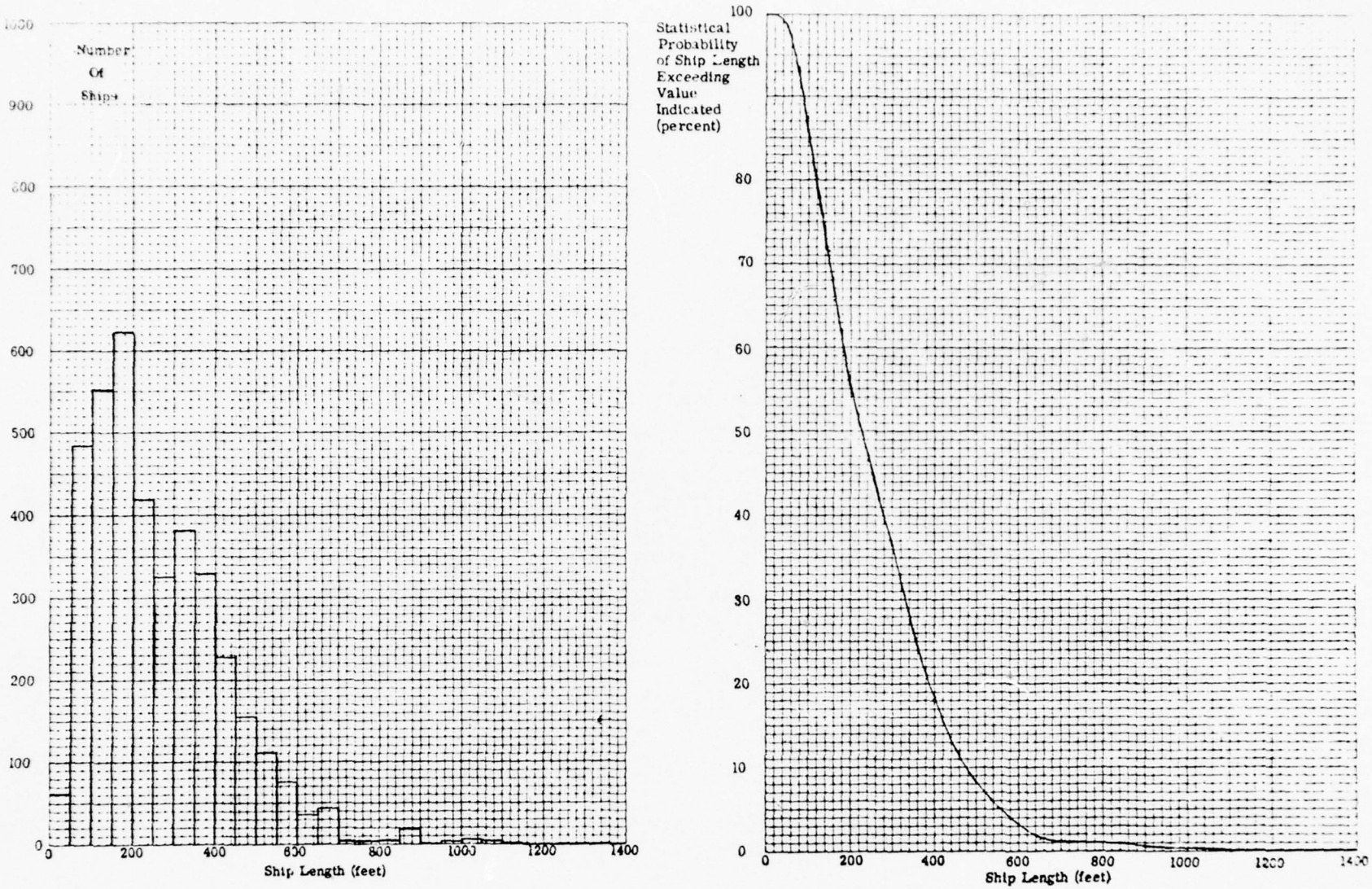


Figure 5. Ship Population Distribution According to Length: 3875 U.S. and Soviet Naval Combatant and Support Vessels (based on individual ship data)

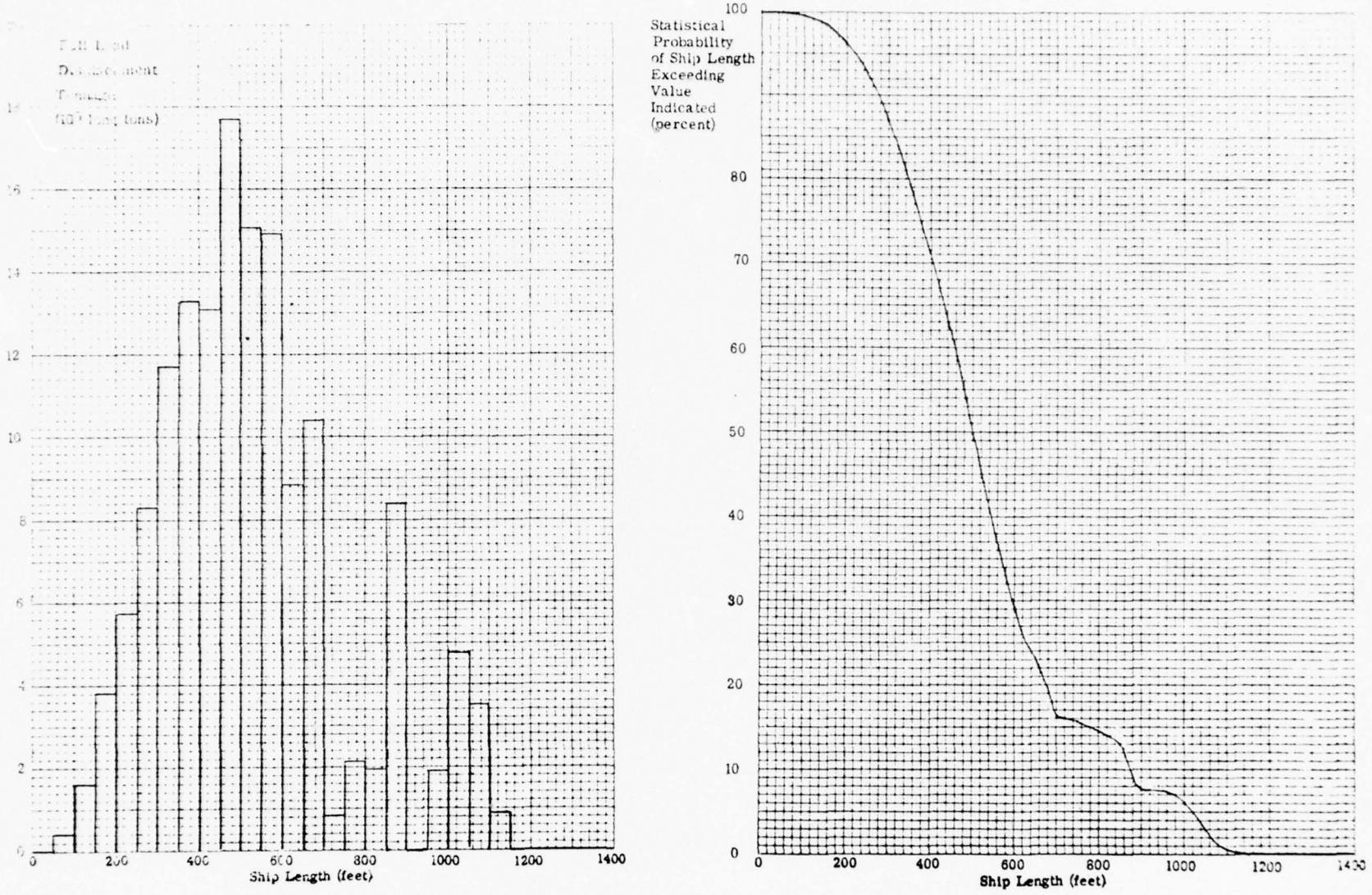


Figure 6. Ship Tonnage Distribution According to Length: 3875 U.S. and Soviet Naval Combatant and Support Vessels (based on individual ship data)

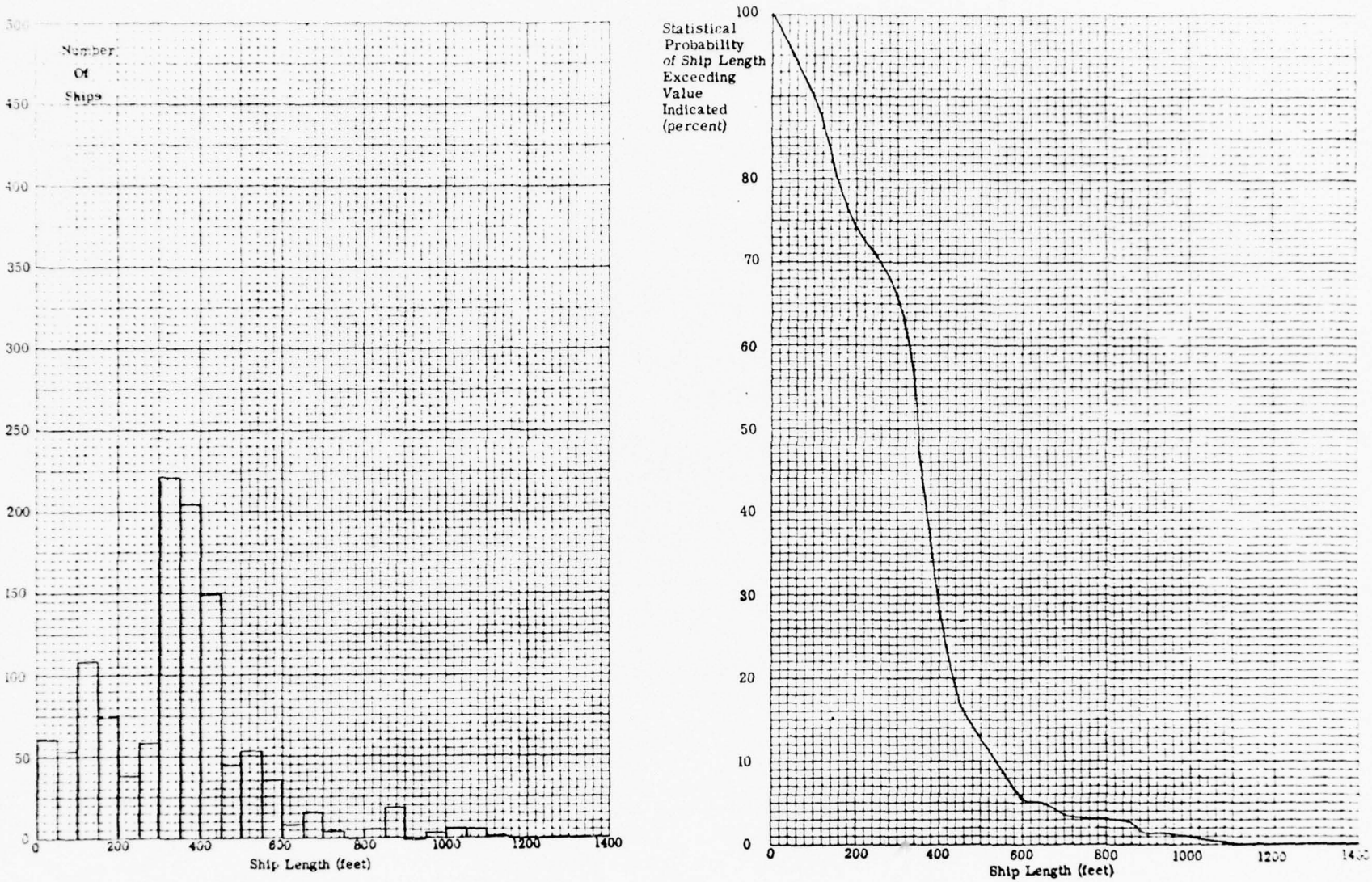


Figure 7. Ship Population Distribution According to Length: 1173 U.S. Naval Combatants (based on individual ship data)

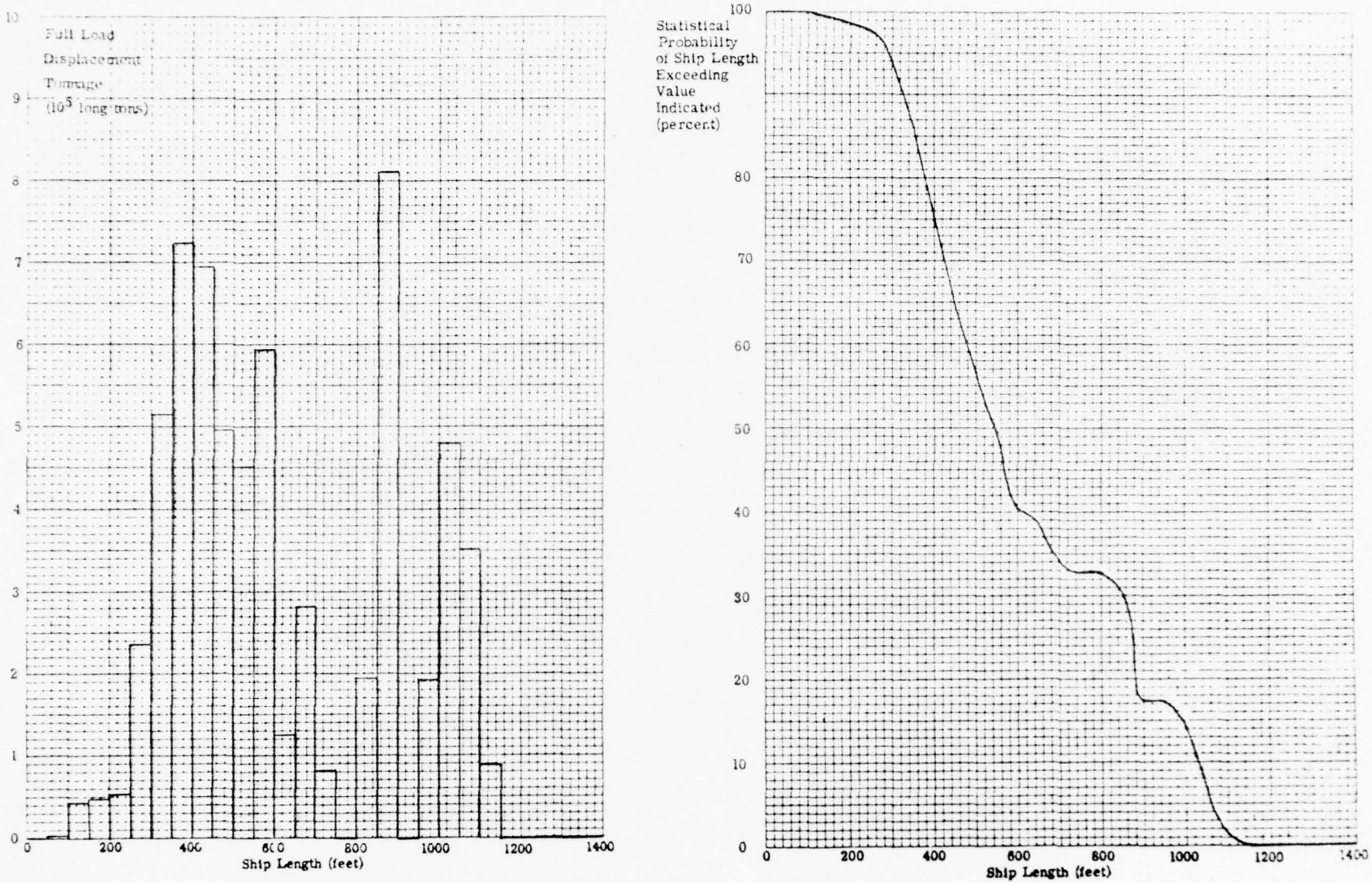


Figure 8. Ship Tonnage Distribution According to Length: 1173 U.S. Naval Combatants (based on individual ship data)

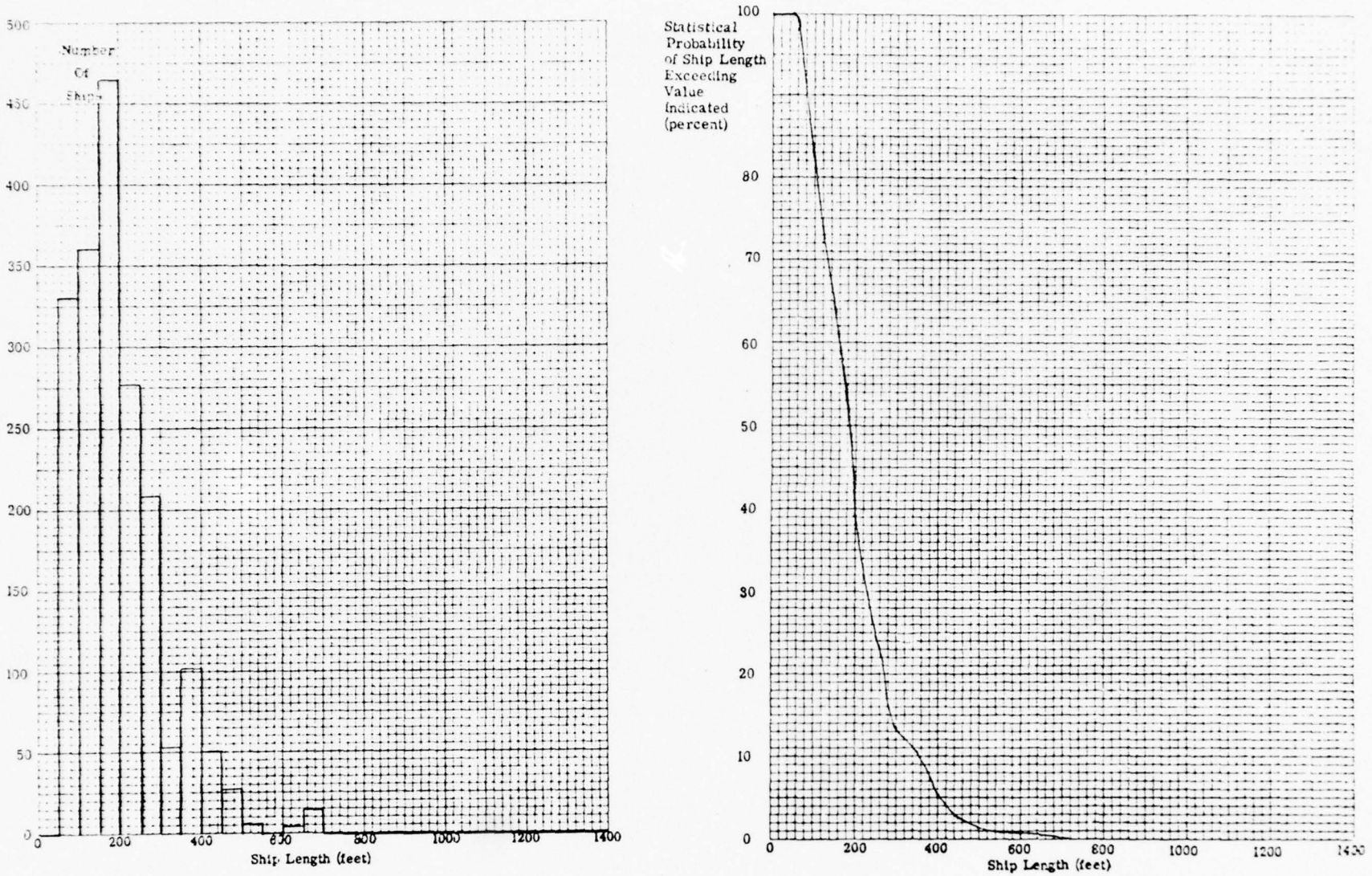


Figure 9. Ship Population Distribution According to Length: 1895 Soviet Naval Combatants (based on individual ship data)

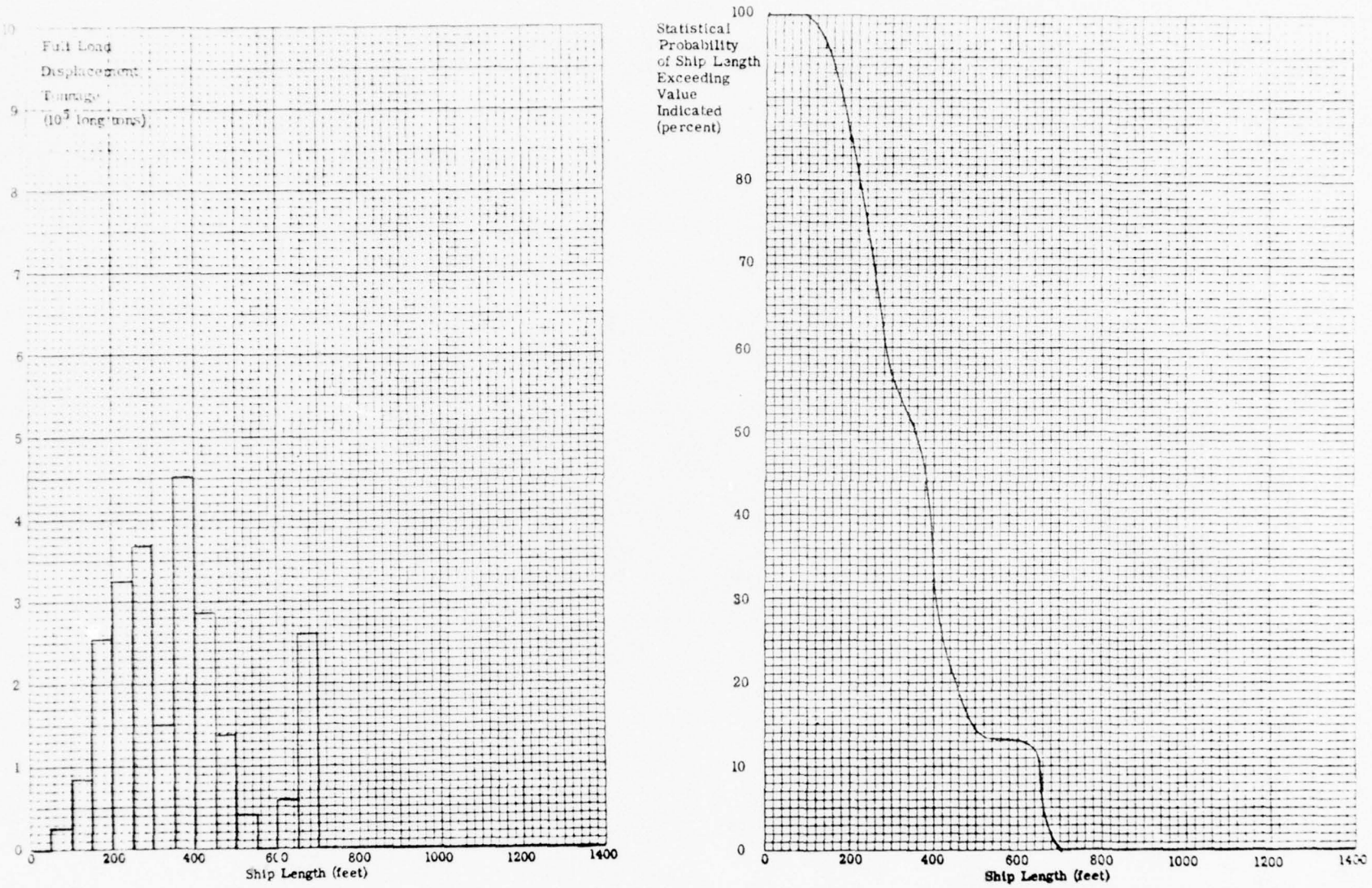


Figure 10. Ship Tonnage Distribution According to Length: 1895 Soviet Naval Combatants (based on individual ship data)

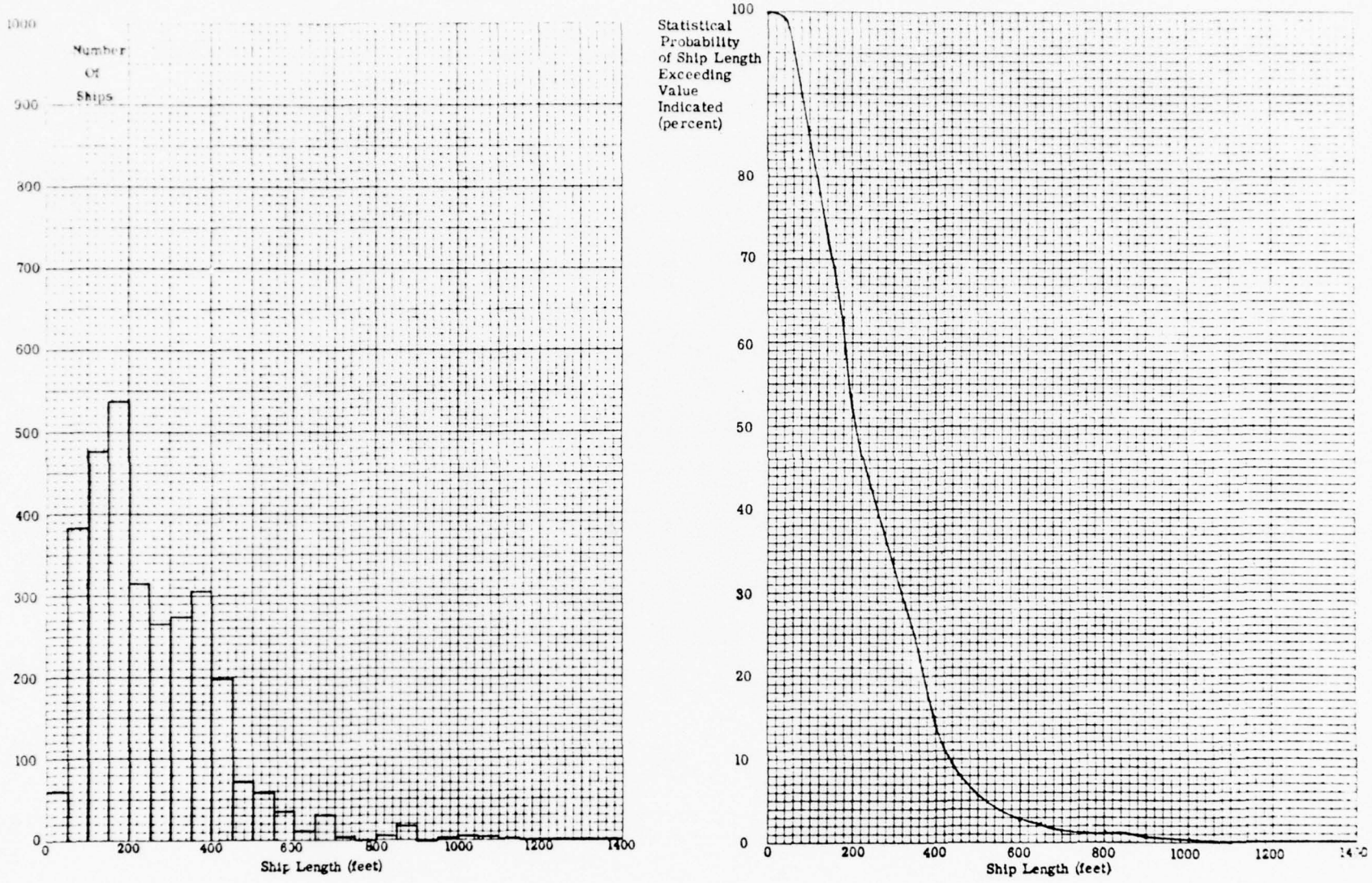


Figure 11. Ship Population Distribution According to Length: 3068 U.S. and Soviet Naval Combatants (based on individual ship data)

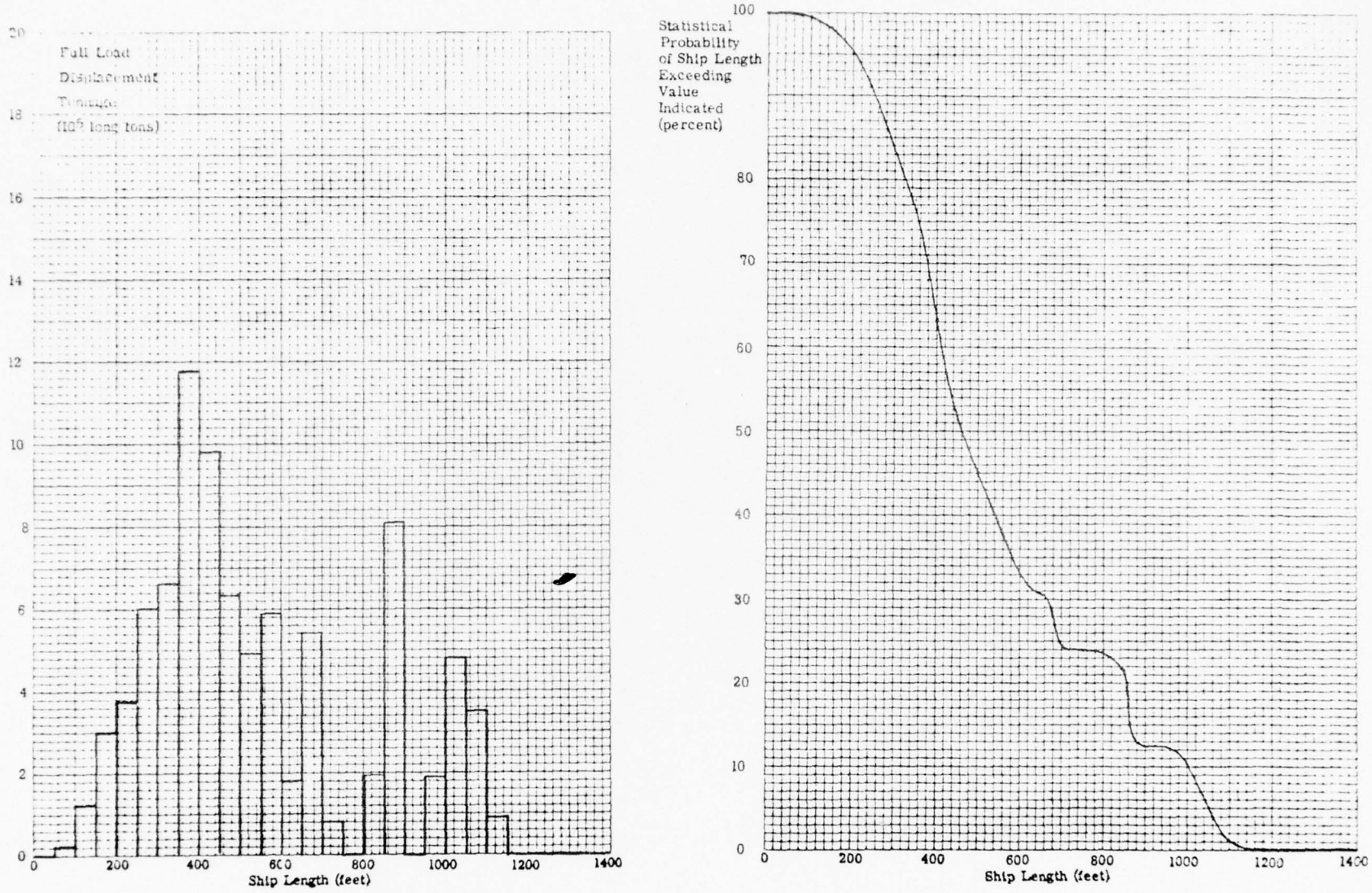


Figure 12. Ship Tonnage Distribution According to Length: 3068 U.S. and Soviet Naval Combatants (based individual ship data)

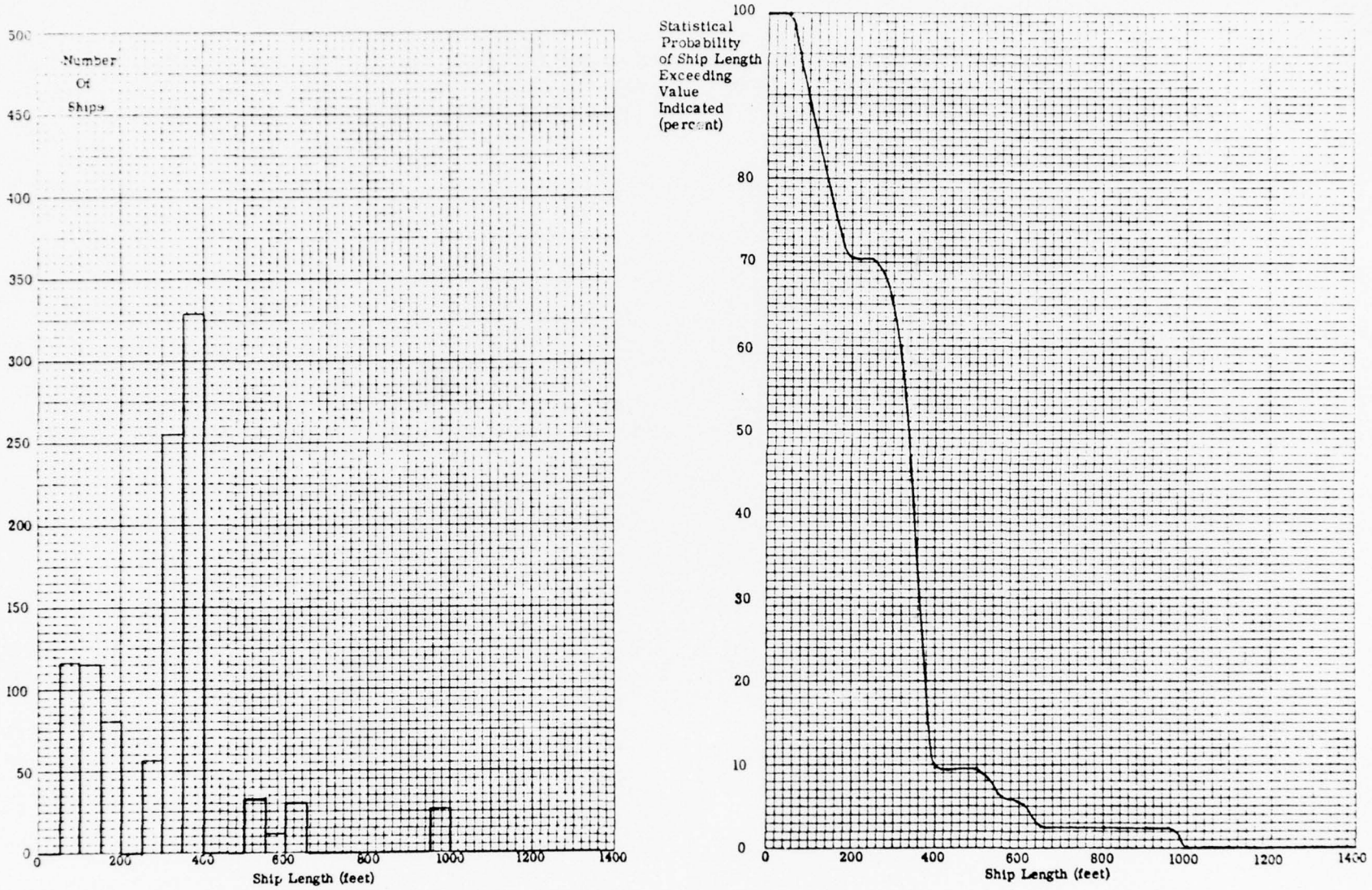


Figure 13. Ship Population Distribution According to Length: 1055 U.S. Naval Combatants (based on representative values of length estimated for each type of ship)

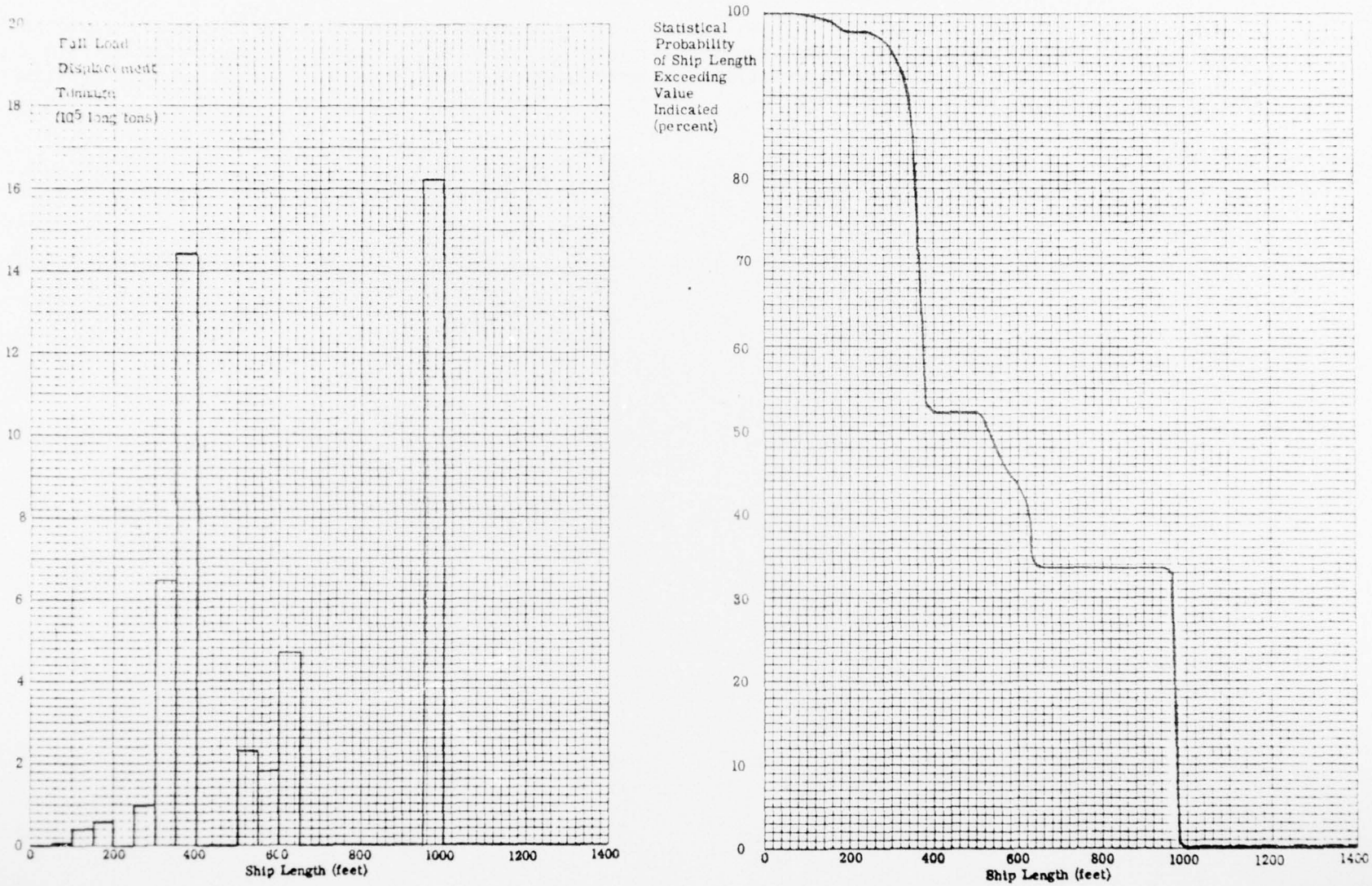


Figure 14. Ship Tonnage Distribution According to Length: 1055 U.S. Naval Combatants (based on representative values of length and tonnage estimated for each type of ship)

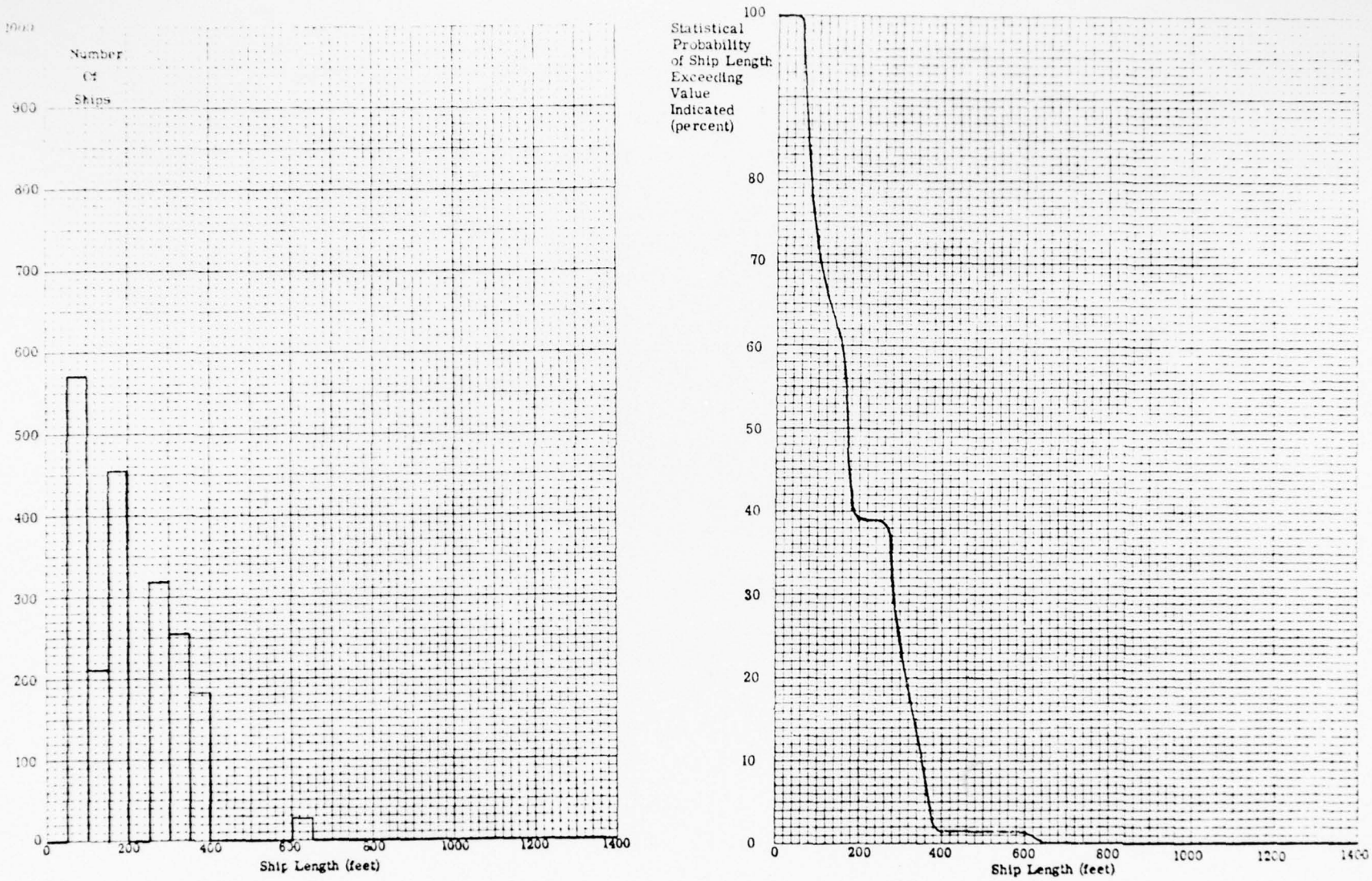
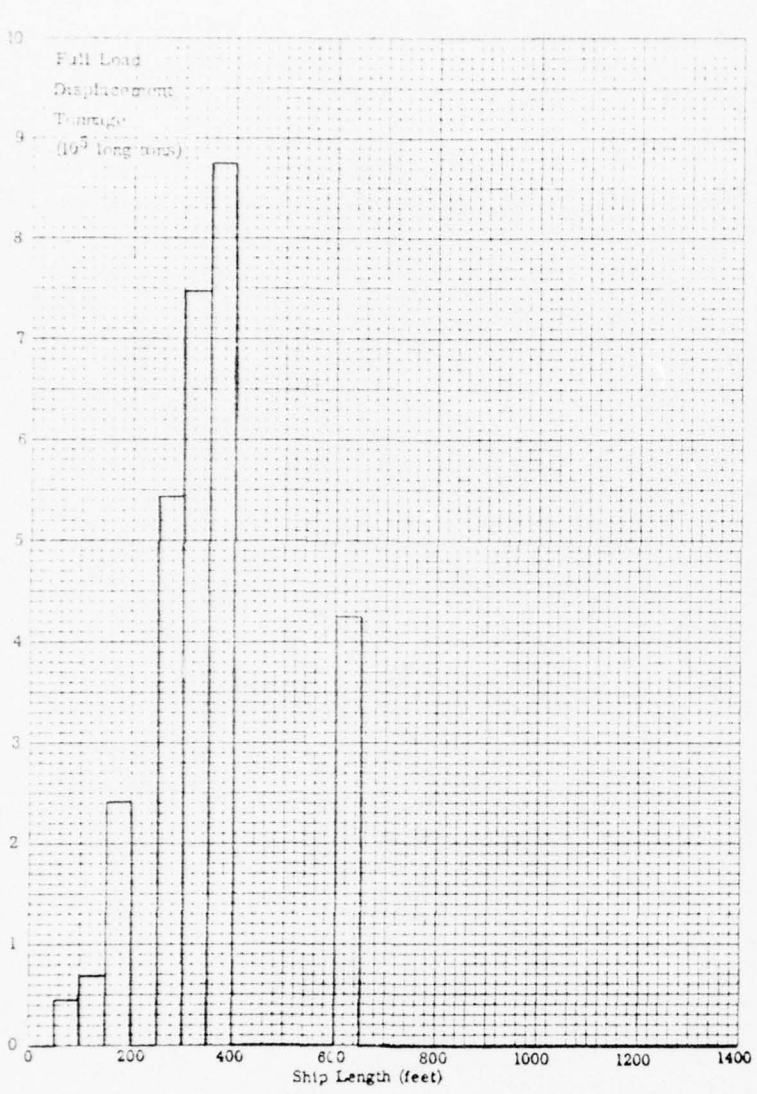


Figure 15. Ship Population Distribution According to Length: 2020 Soviet Naval Combatants (based on representative values of length estimated for each type of ship)



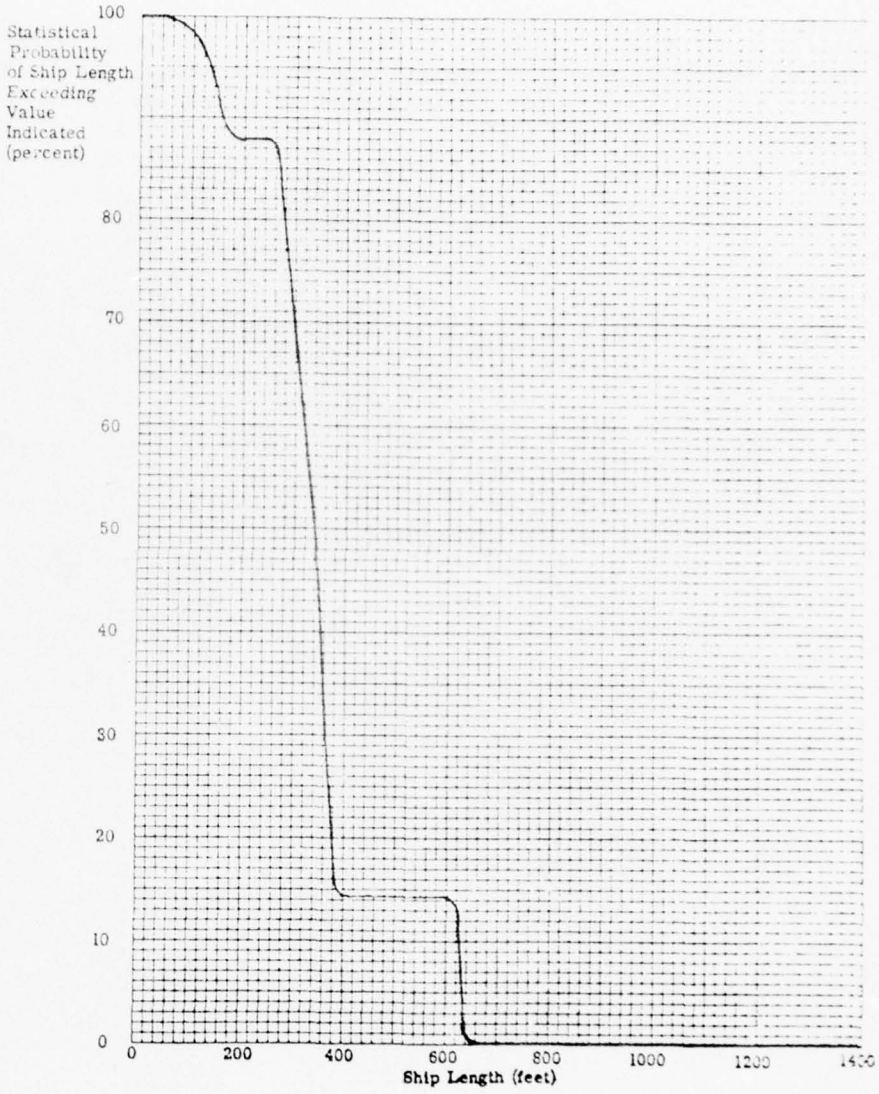


Figure 16. Ship Tonnage Distribution According to Length: 2020 Soviet Naval Combatants (based on representative values of length and tonnage estimated for each type of ship)

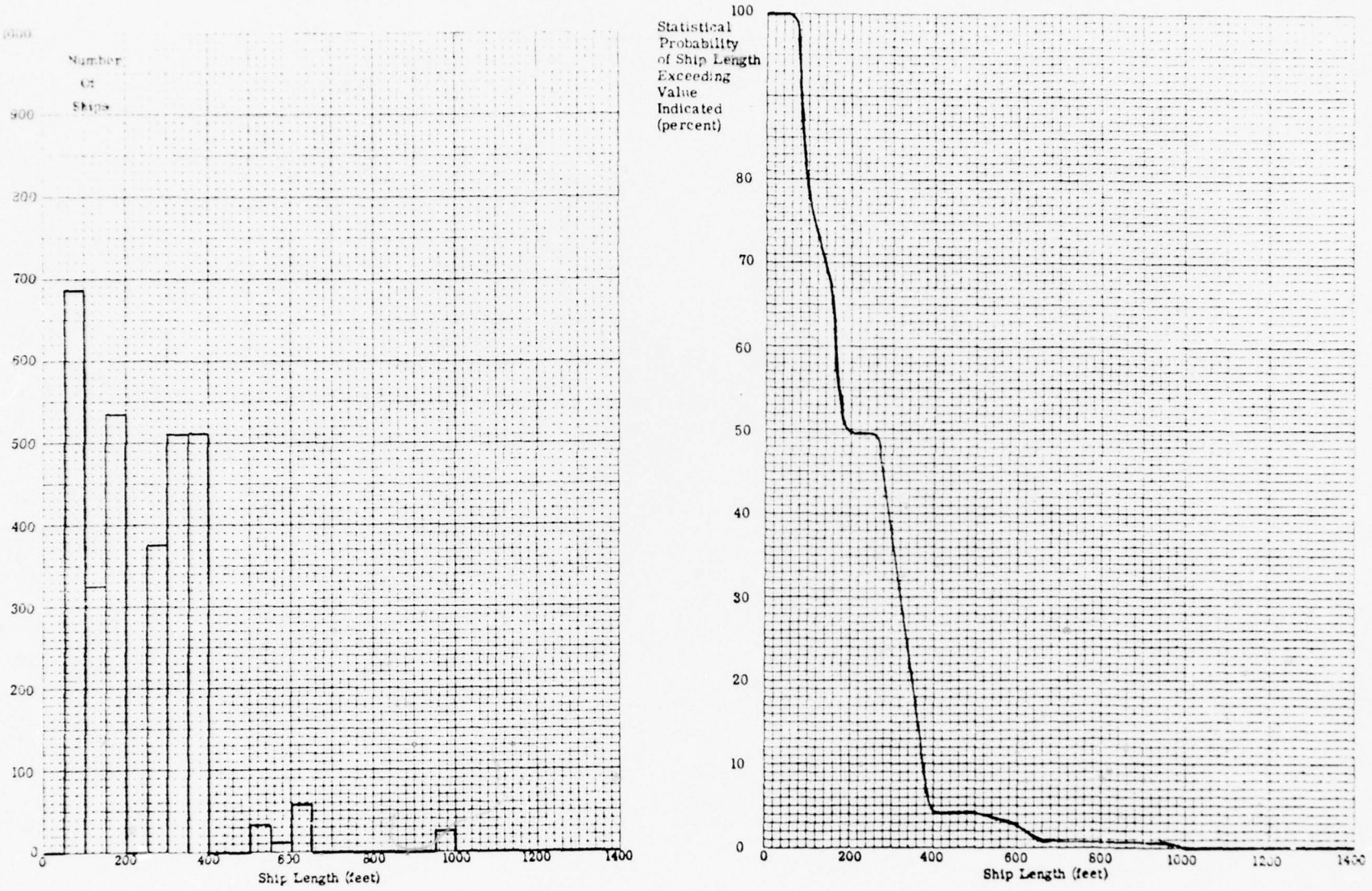


Figure 17. Ship Population Distribution According to Length: 3075 U.S. and Soviet Naval Combatants (based on representative values of length estimated for each type of ship)

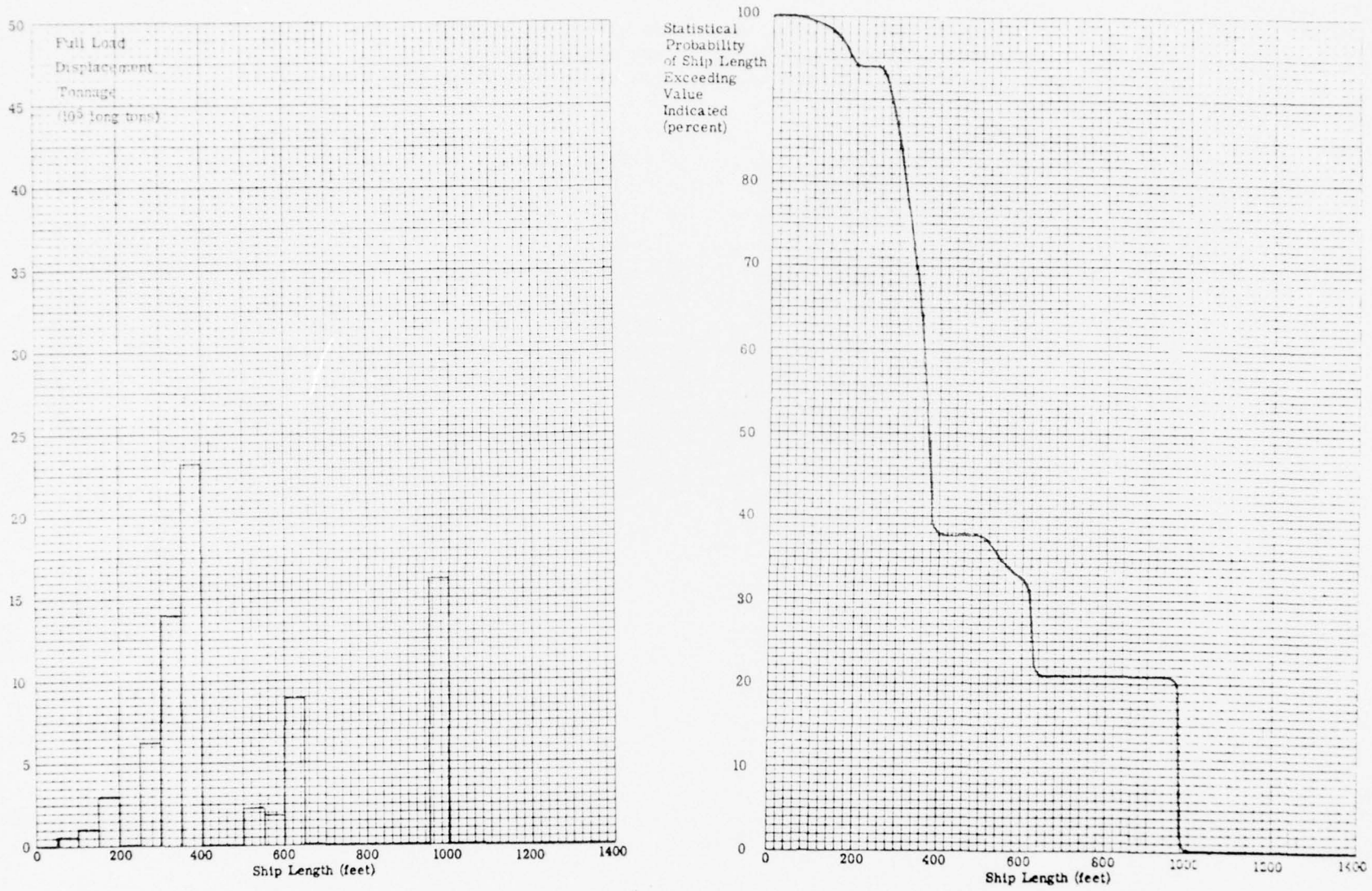


Figure 18. Ship Tonnage Distribution According to Length: 3075 U.S. and Soviet Naval Combatants (based on representative values of length and tonnage estimated for each type of ship)

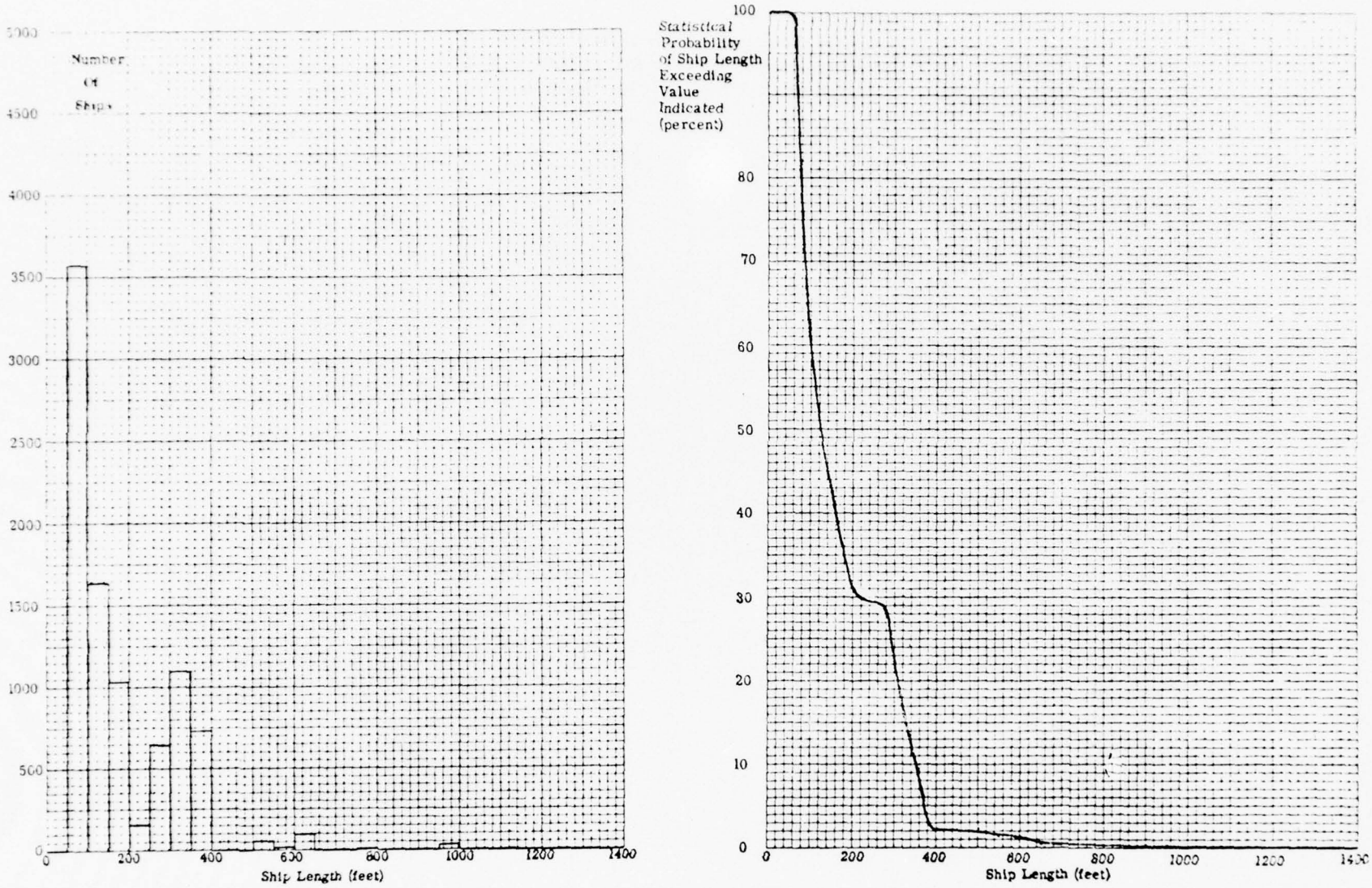


Figure 19. Ship Population Distribution According to Length: 9057 World Naval Combatants (based on representative values of length estimated for each type of ship)

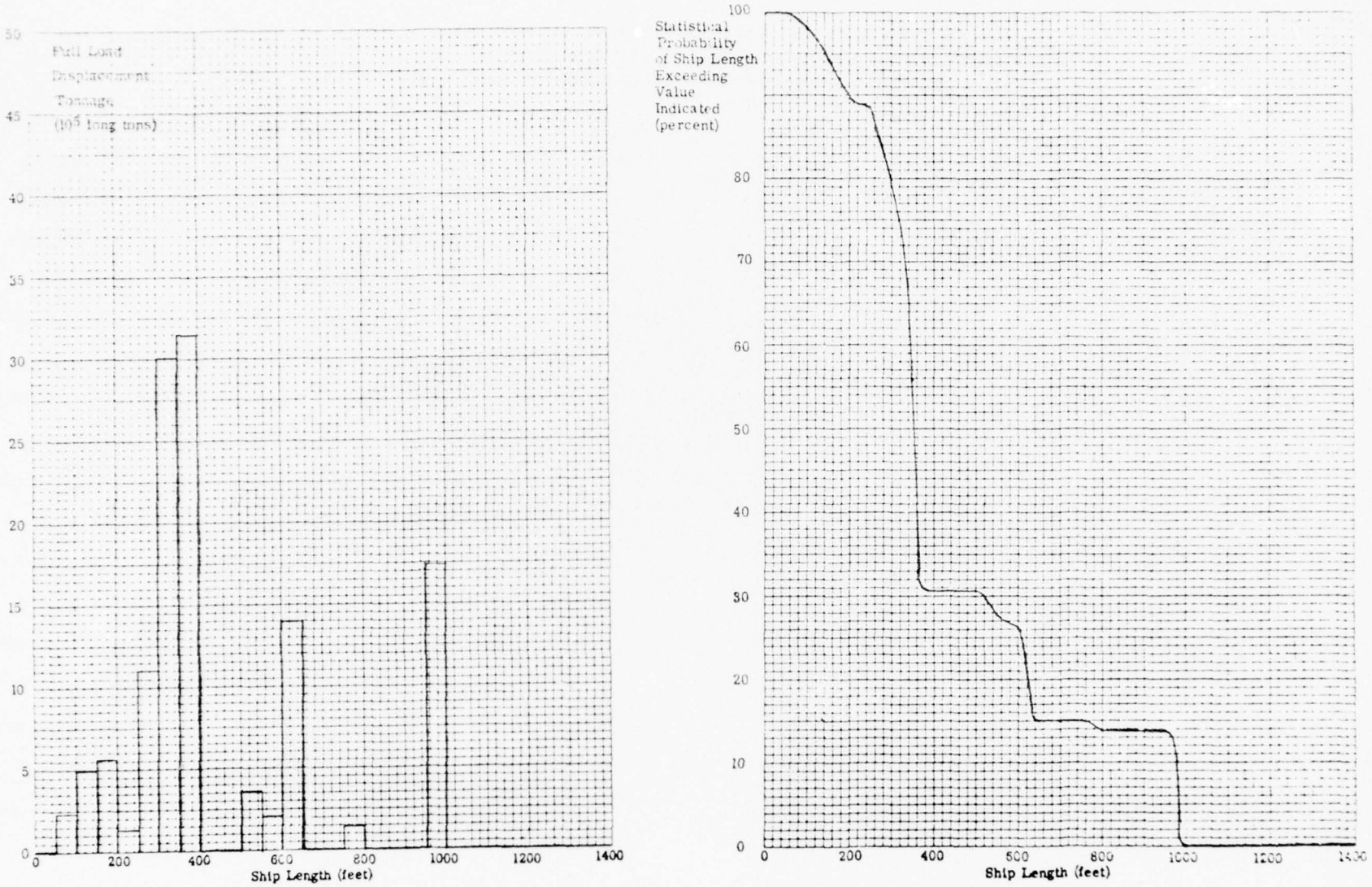


Figure 20. Ship Tonnage Distribution According to Length: 9057 World Naval Combatants (based on representative values of length and tonnage estimated for each type of ship)

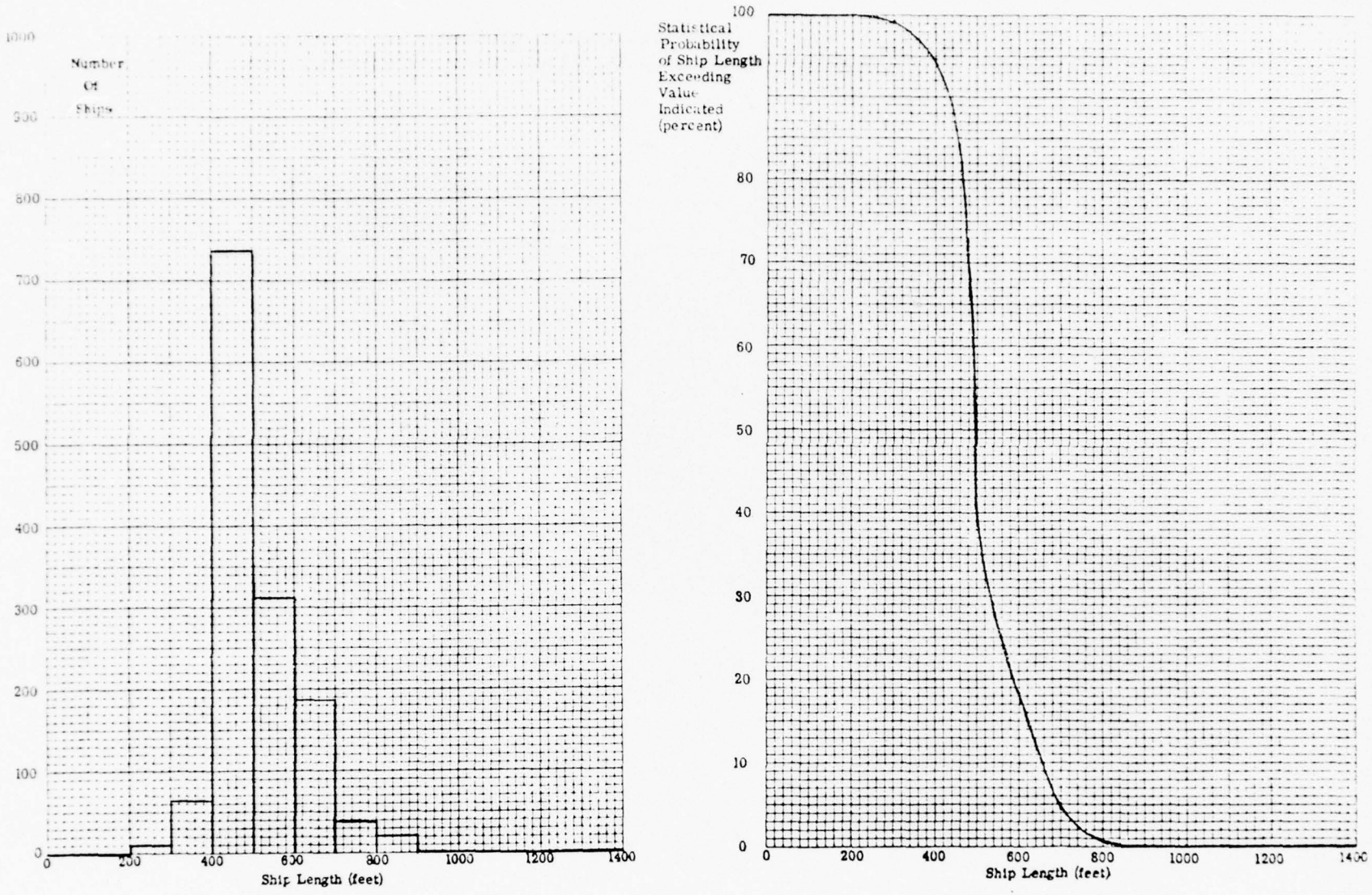


Figure 21 Ship Population Distribution According to Length: 1372 U.S. Merchant Ships (data based on ships of 1000 gross tons and over)

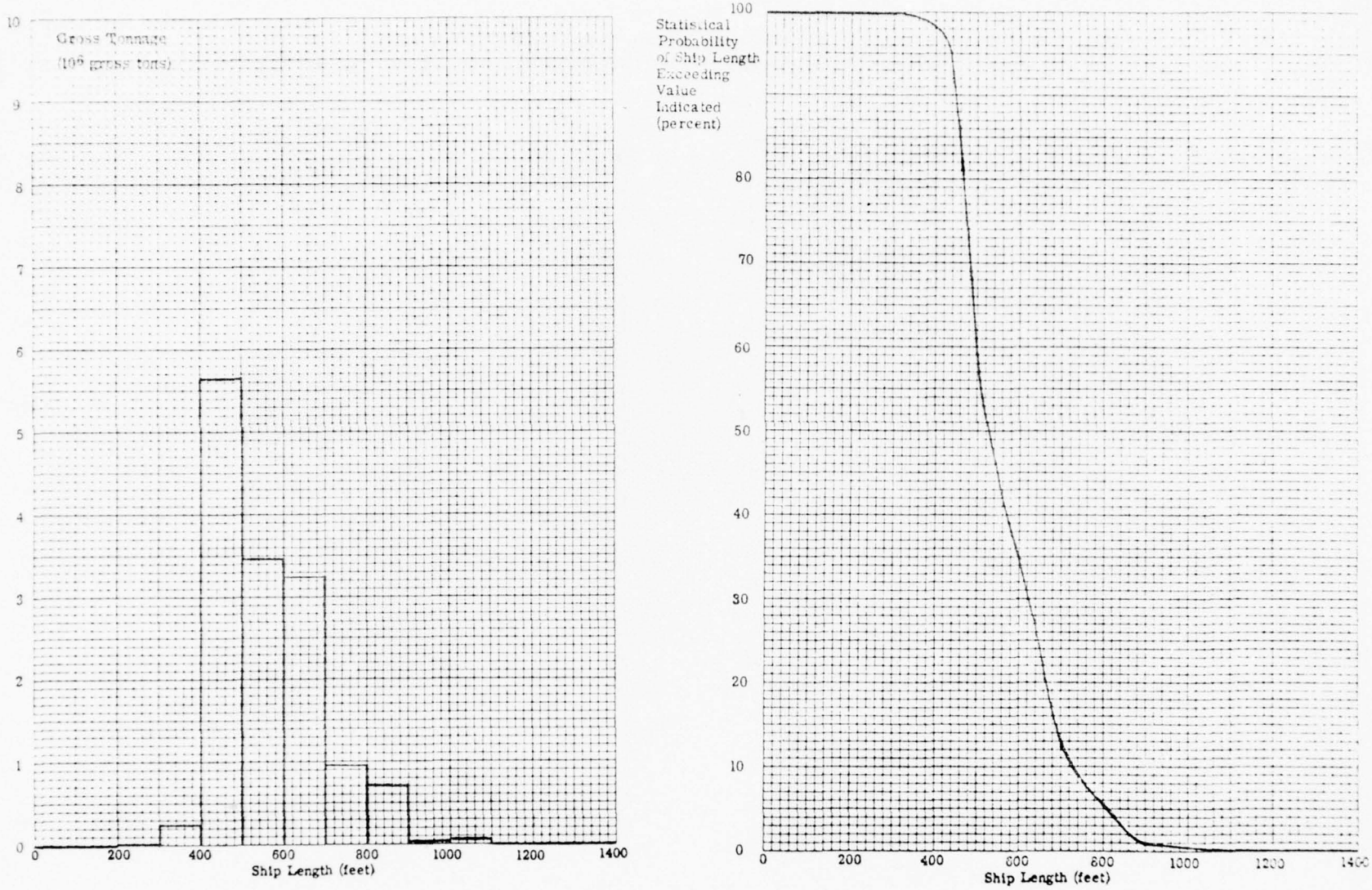


Figure 22. Ship Tonnage Distribution According to Length: 1372 U.S. Merchant Ships (data based on ships of 1000 gross tons and over)

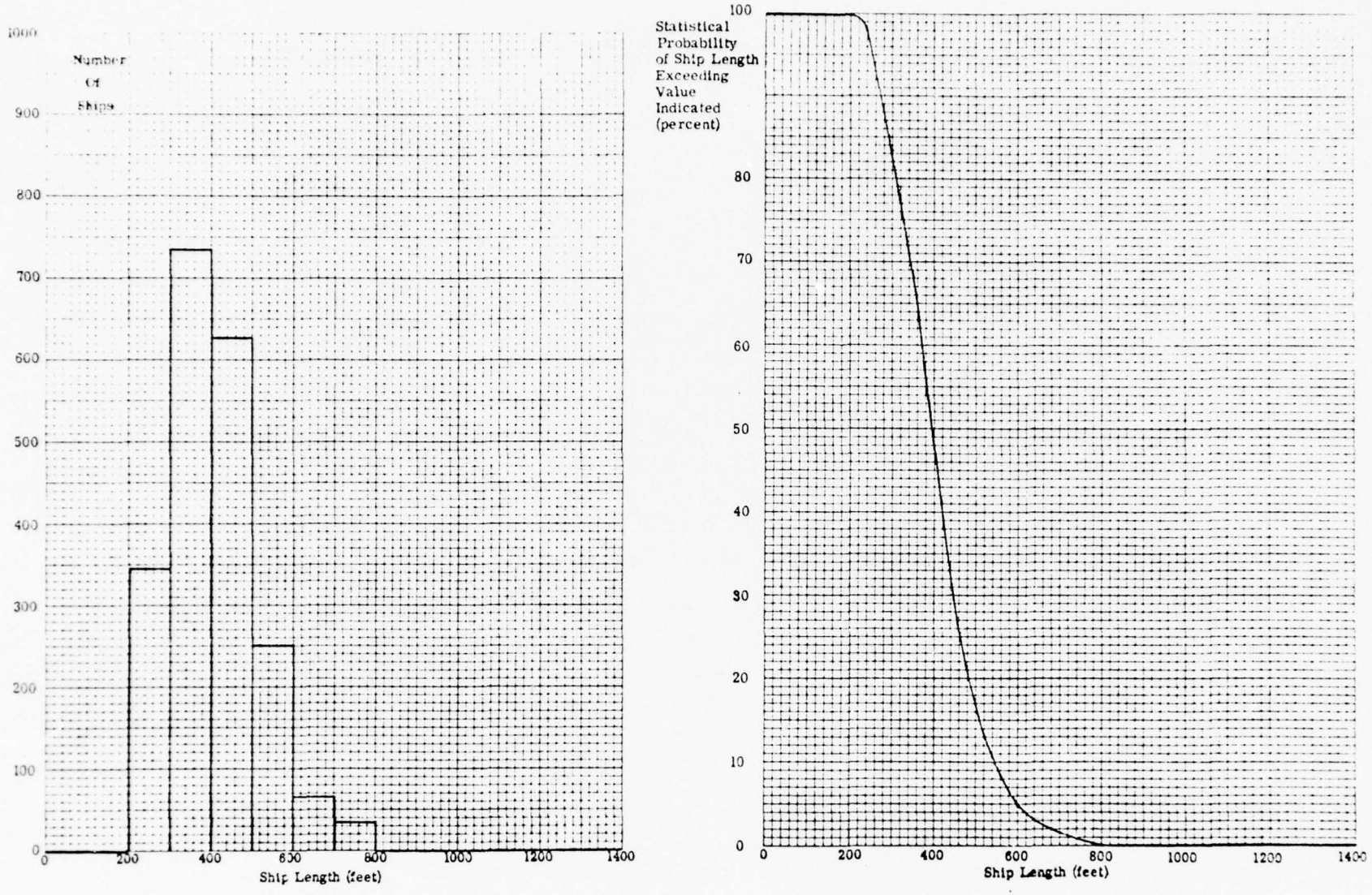


Figure 23. Ship Population Distribution According to Length: 2059 Soviet Merchant Ships (data based on ships of 1000 gross ton and over)

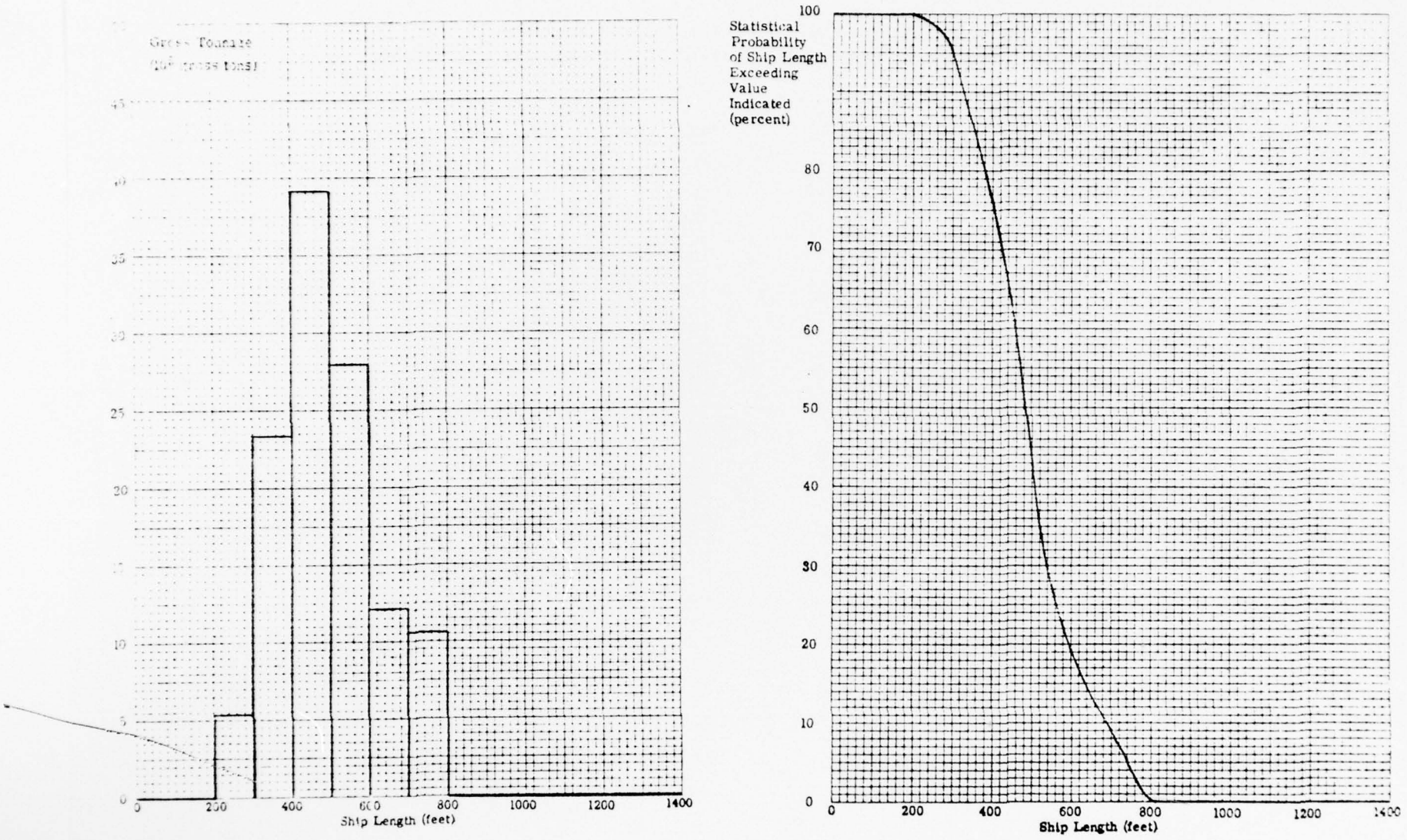


Figure 24. Ship Tonnage Distribution According to Length: 2059 Soviet Merchant Ships (data based on ships of 1000 gross tons and over)

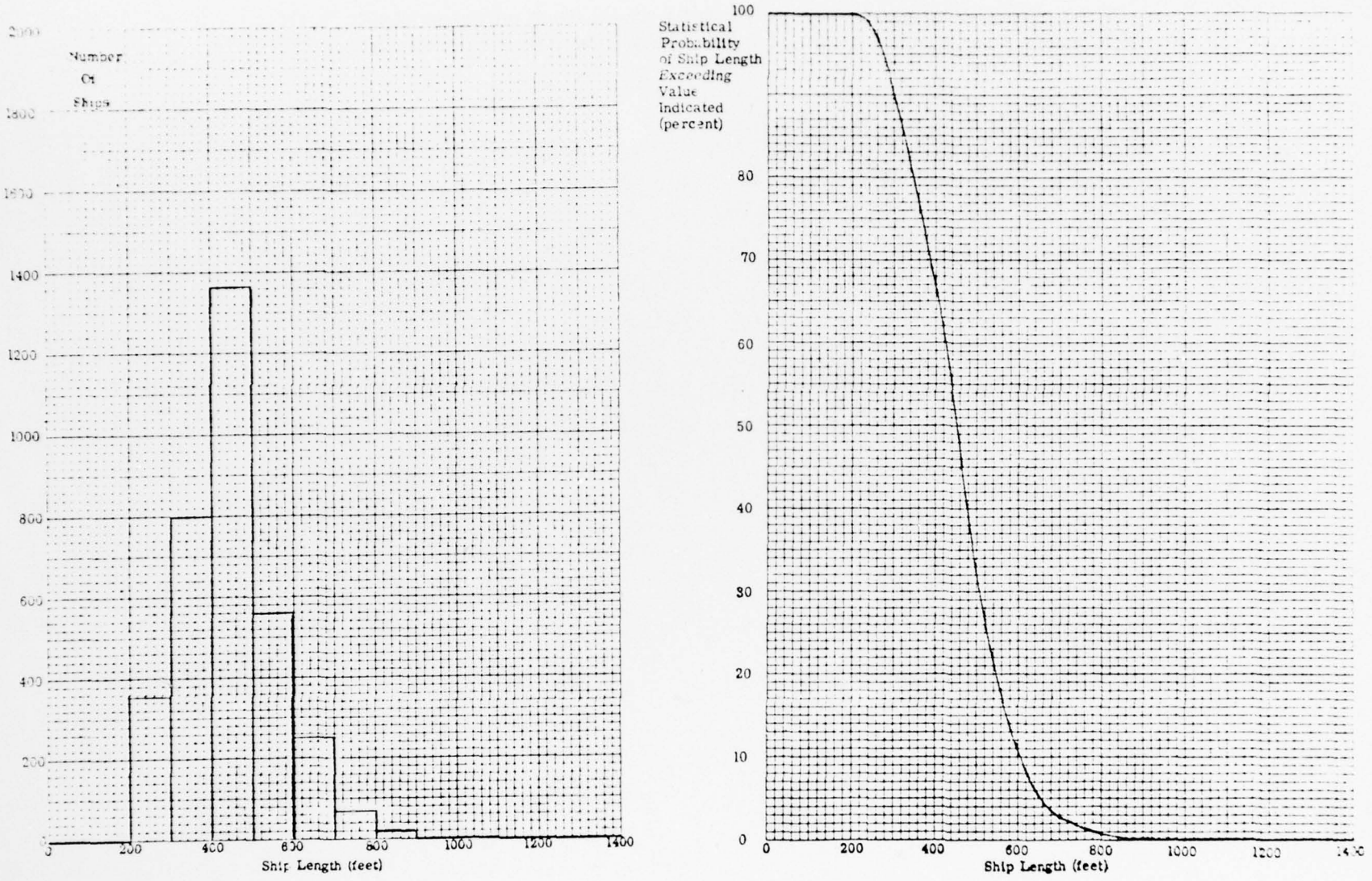


Figure 25. Ship Population Distribution According to Length: 3431 U.S. and Soviet Merchant Ships (data based on ship of 1000 gross tons and over)

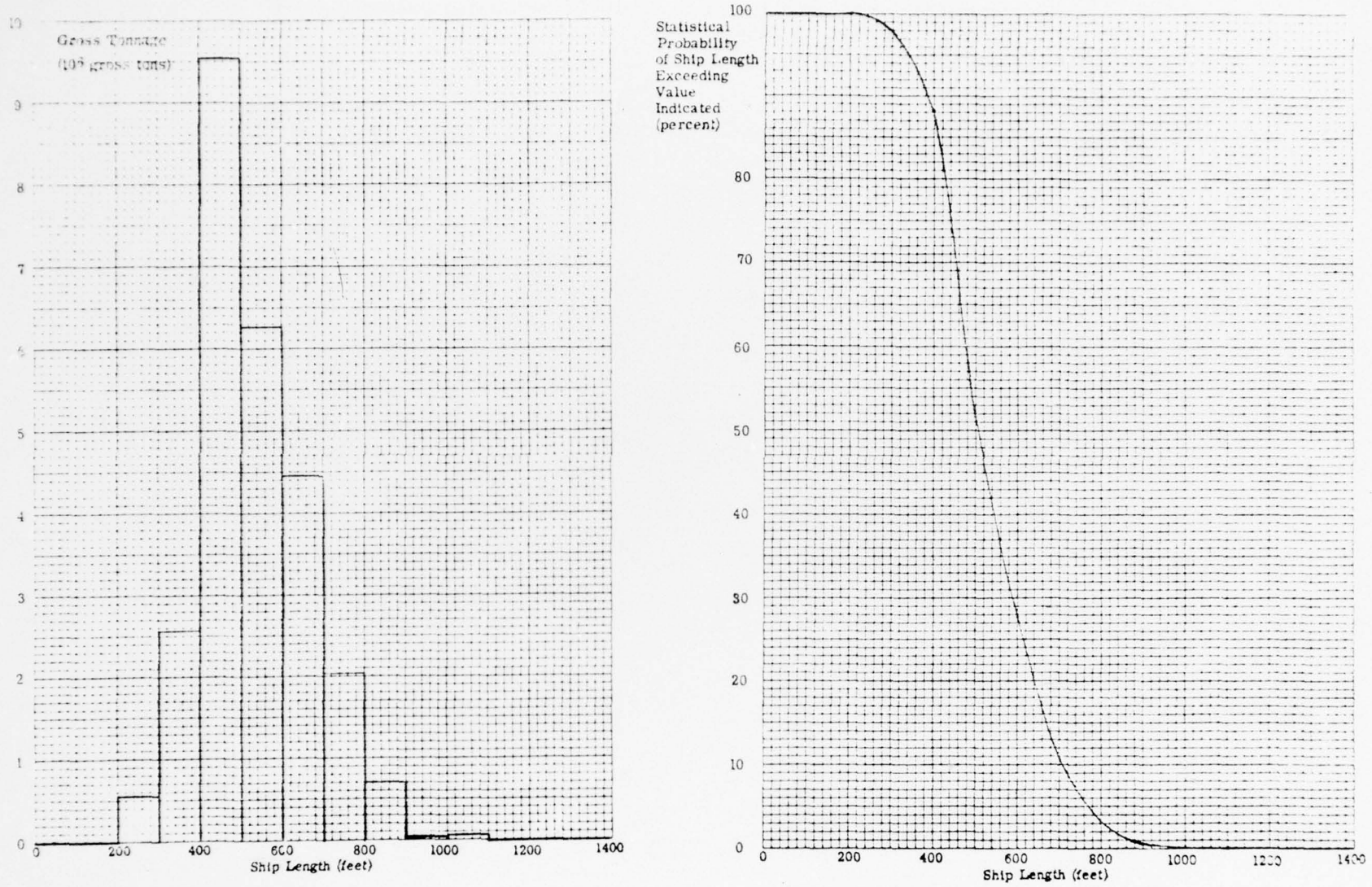


Figure 26. Ship Tonnage Distribution According to Length: 3431 U.S. and Soviet Merchant Ships (data based on ships of 1000 gross tons and over)

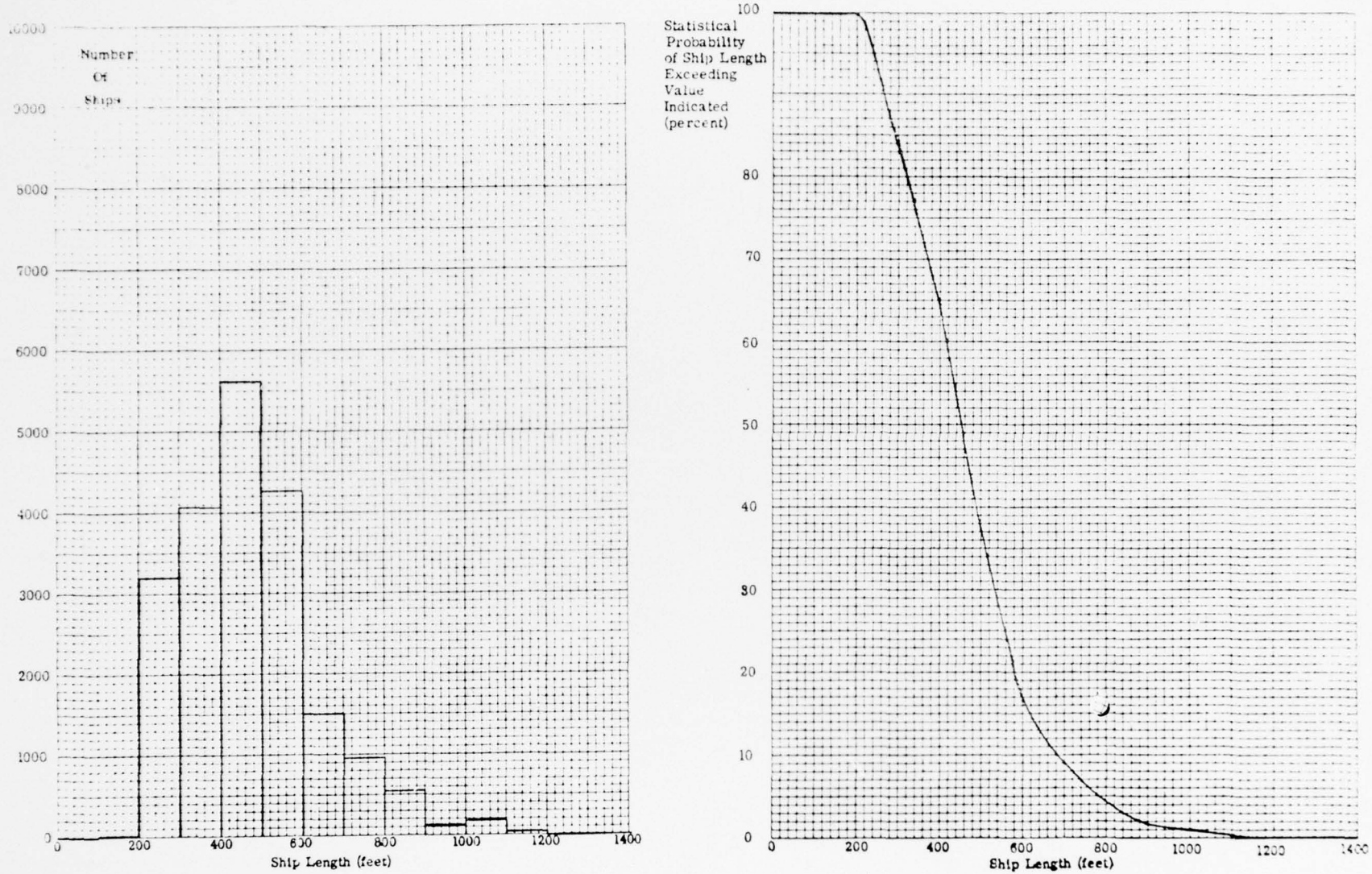
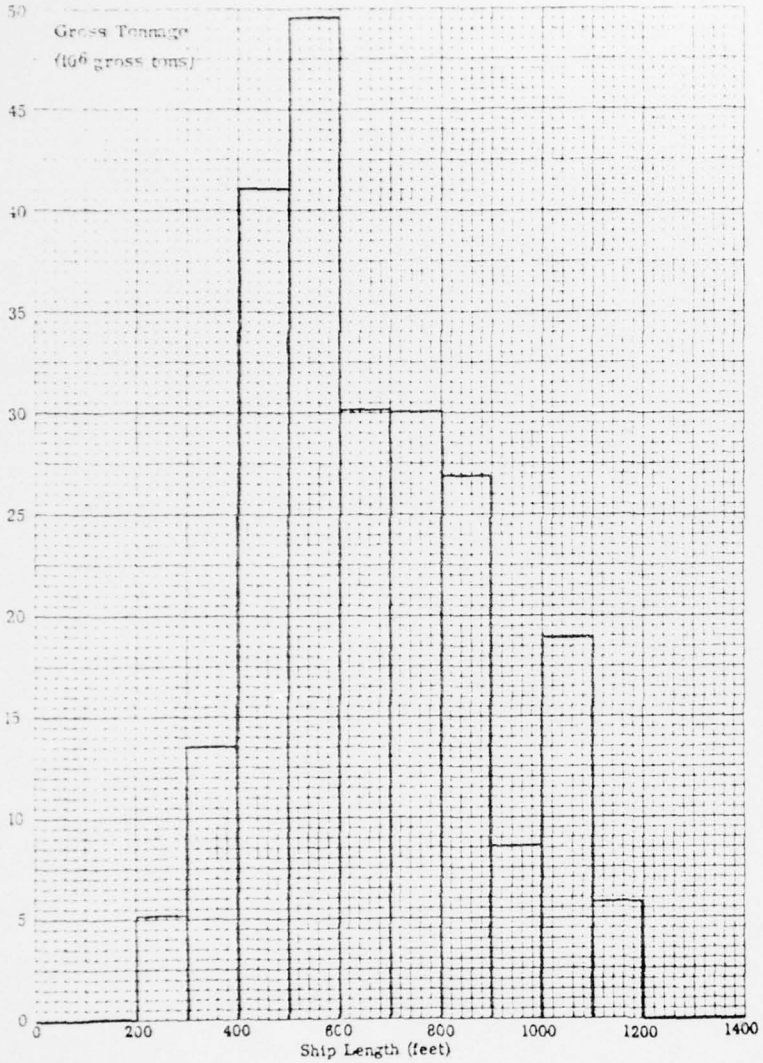


Figure 27. Ship Population Distribution According to Length: 20544 Merchant Ships of the World (data based on ships of 1000 gross tons and over)



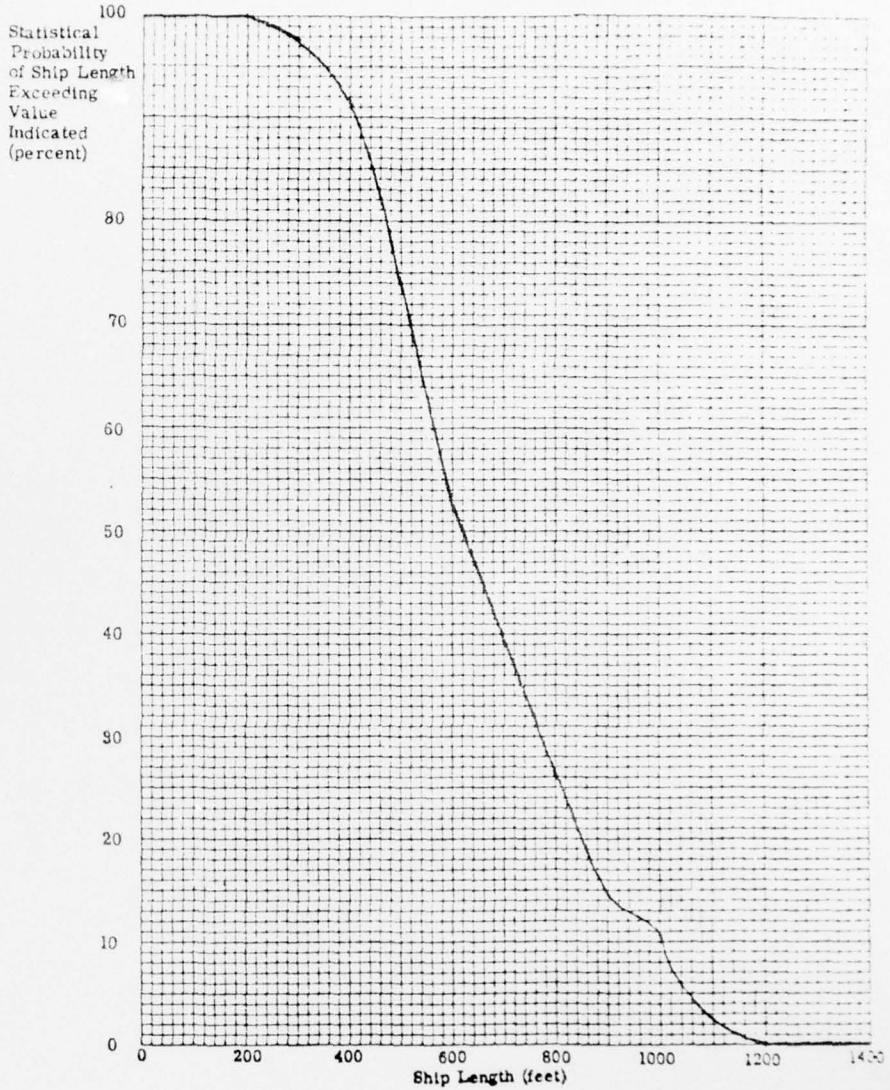


Figure 28. Ship Tonnage Distribution According to Length: 20544 Merchant Ships of the World (data based on ships of 1000 gross tons and over)

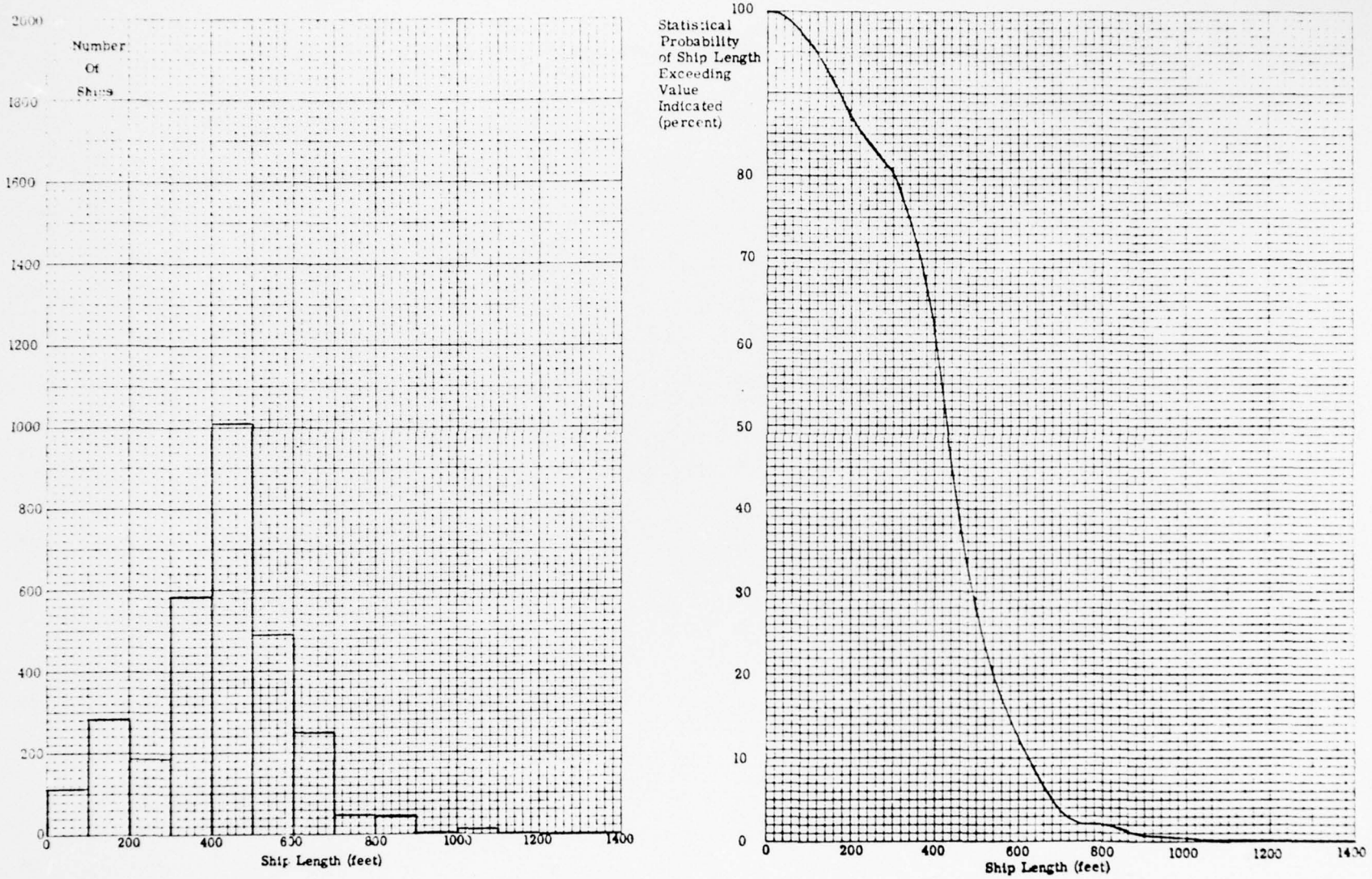


Figure 29. Ship Population Distribution According to Length: Composite of 1660 U.S. Naval Combatant and Support Vessels and 1372 U.S. Merchant Ships

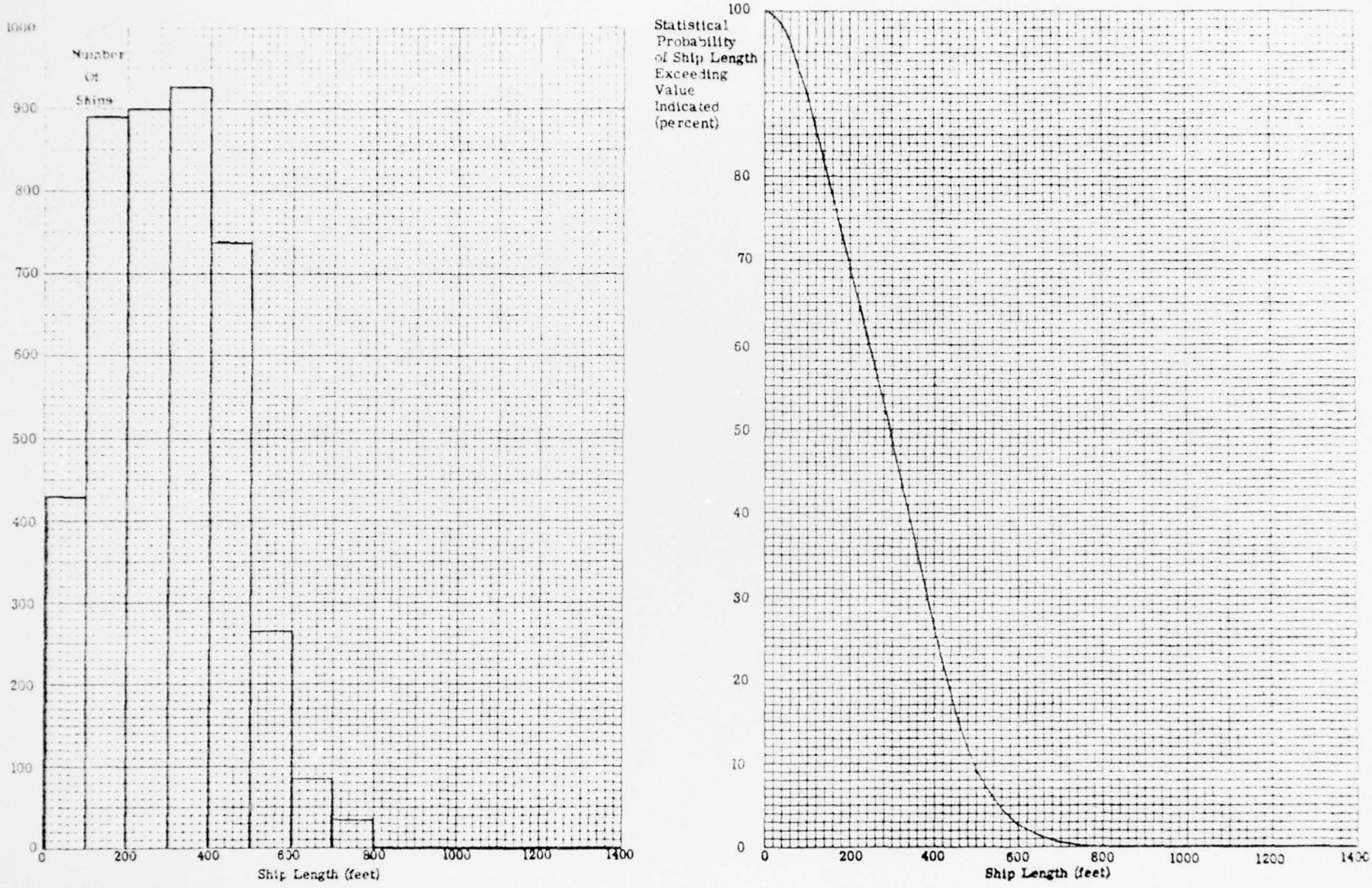


Figure 30. Ship Population Distribution According to Length: Composite of 2215 Soviet Naval Combatant and Support Vessels and 2059 Soviet Merchant Ships

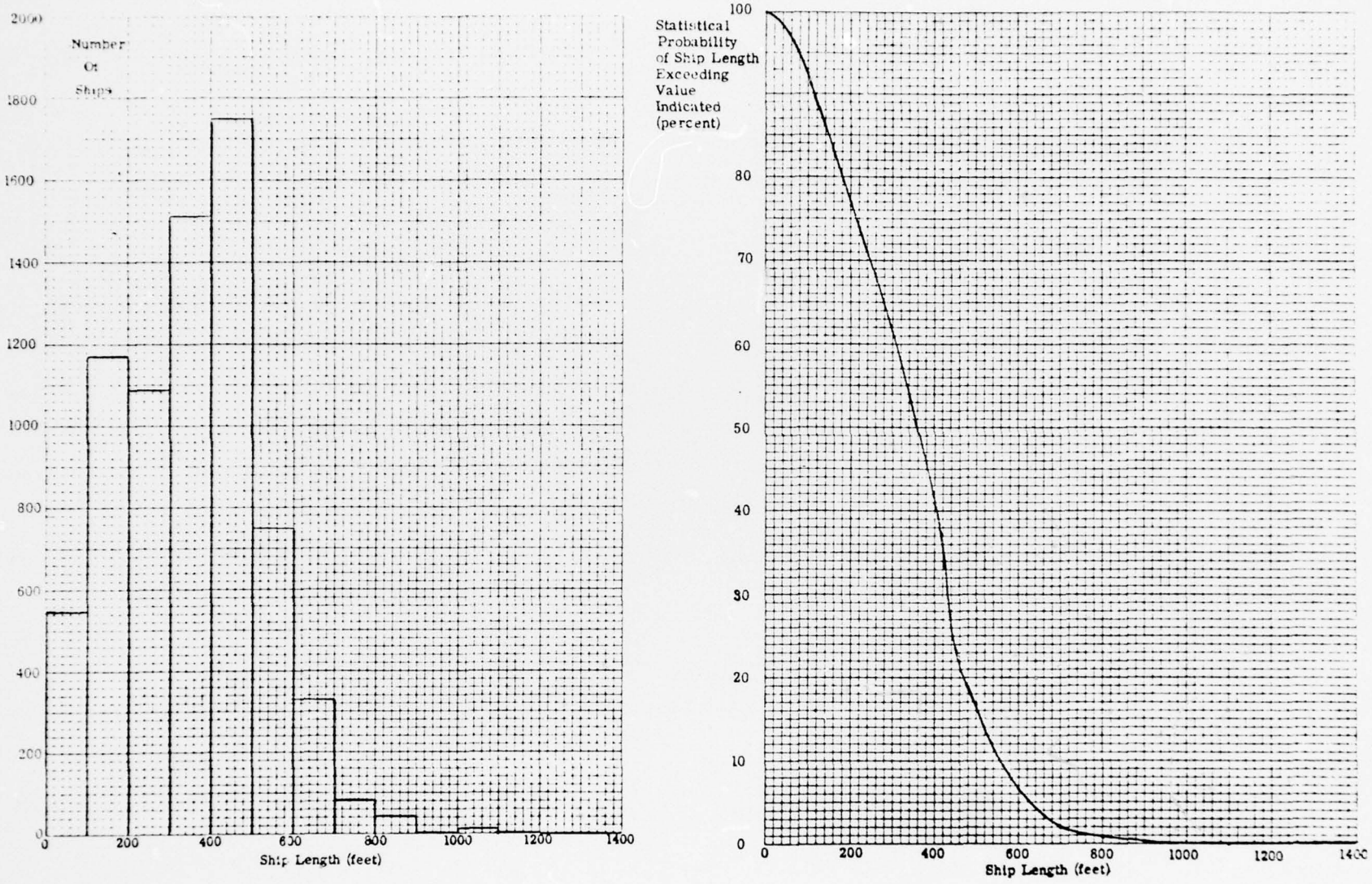


Figure 31. Ship Population Distribution According to Length: Composite of 3875 Naval Combatant and Support Vessels and 3431 Merchant Ships of the U.S. and USSR

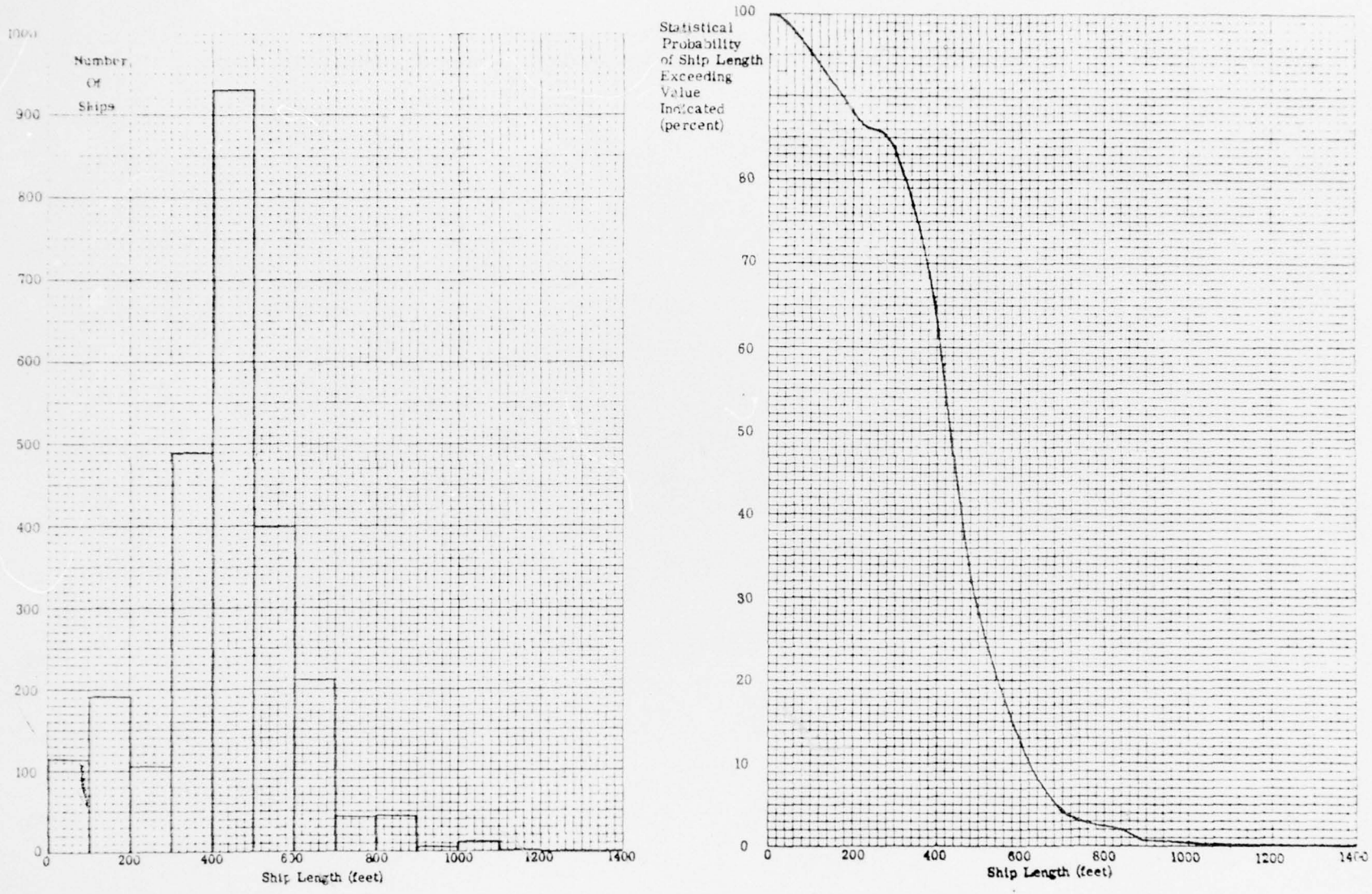


Figure 32. Ship Population Distribution According to Length: Composite of 1173 U.S. Naval Combatants and 1372 U.S. Merchant Ships

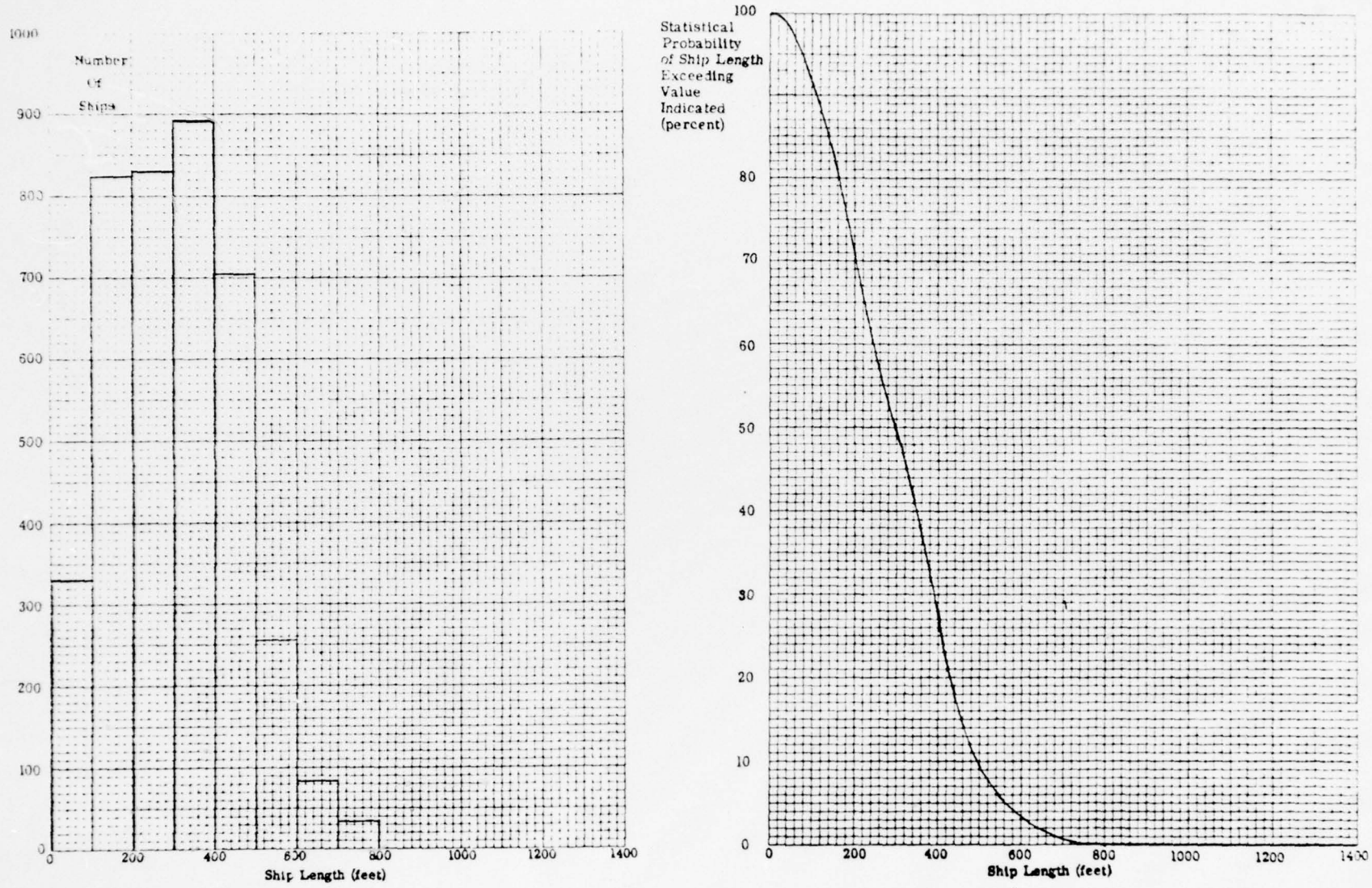


Figure 33. Ship Population Distribution According to Length: Composite of 1895 Soviet Naval Combatants and 2059 Soviet Merchant Ships

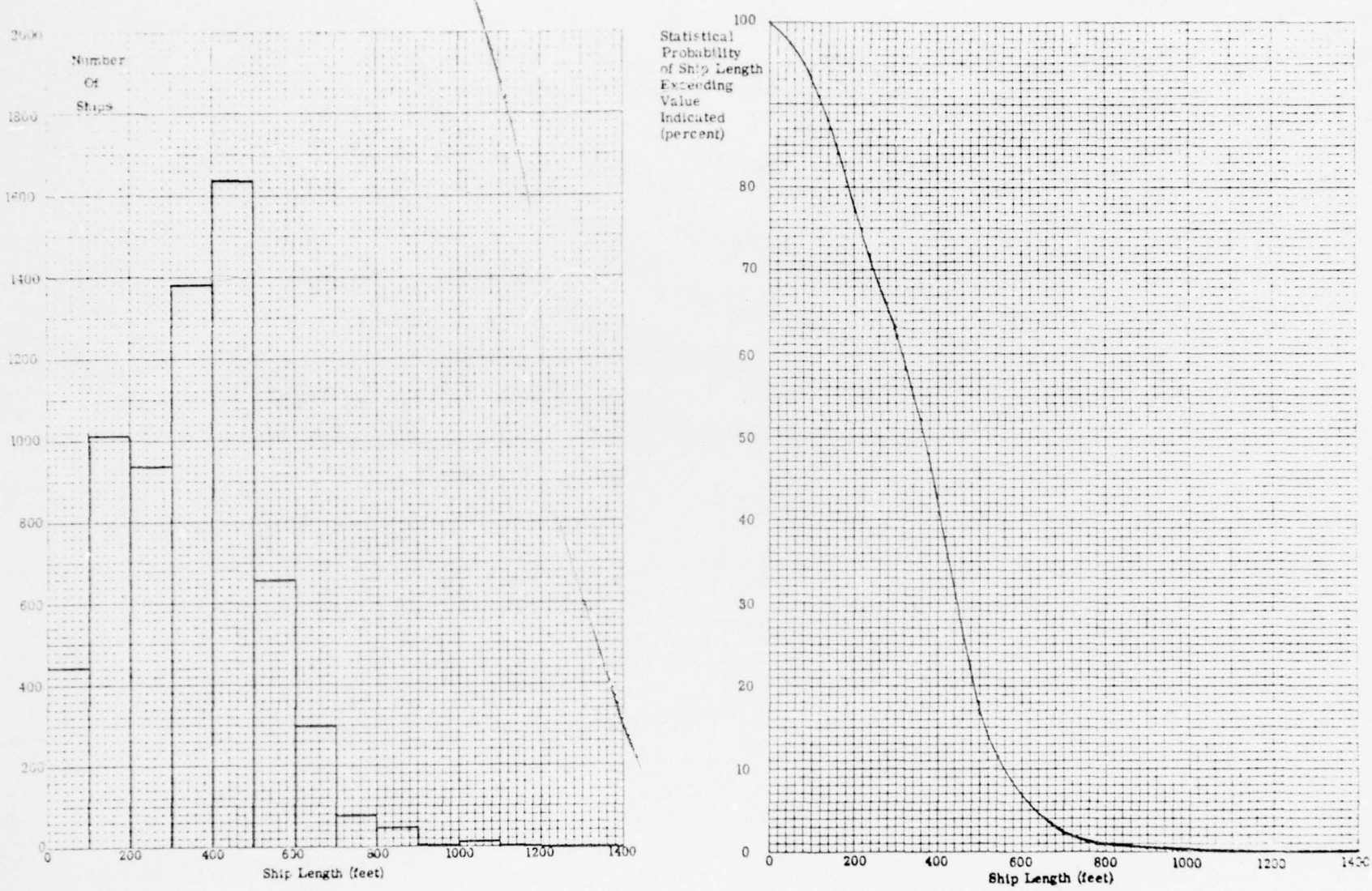


Figure 34. Ship Population Distribution According to Length: Composite of 3068 Naval Combatants and 3431 Merchant Ships of the U.S. and USSR

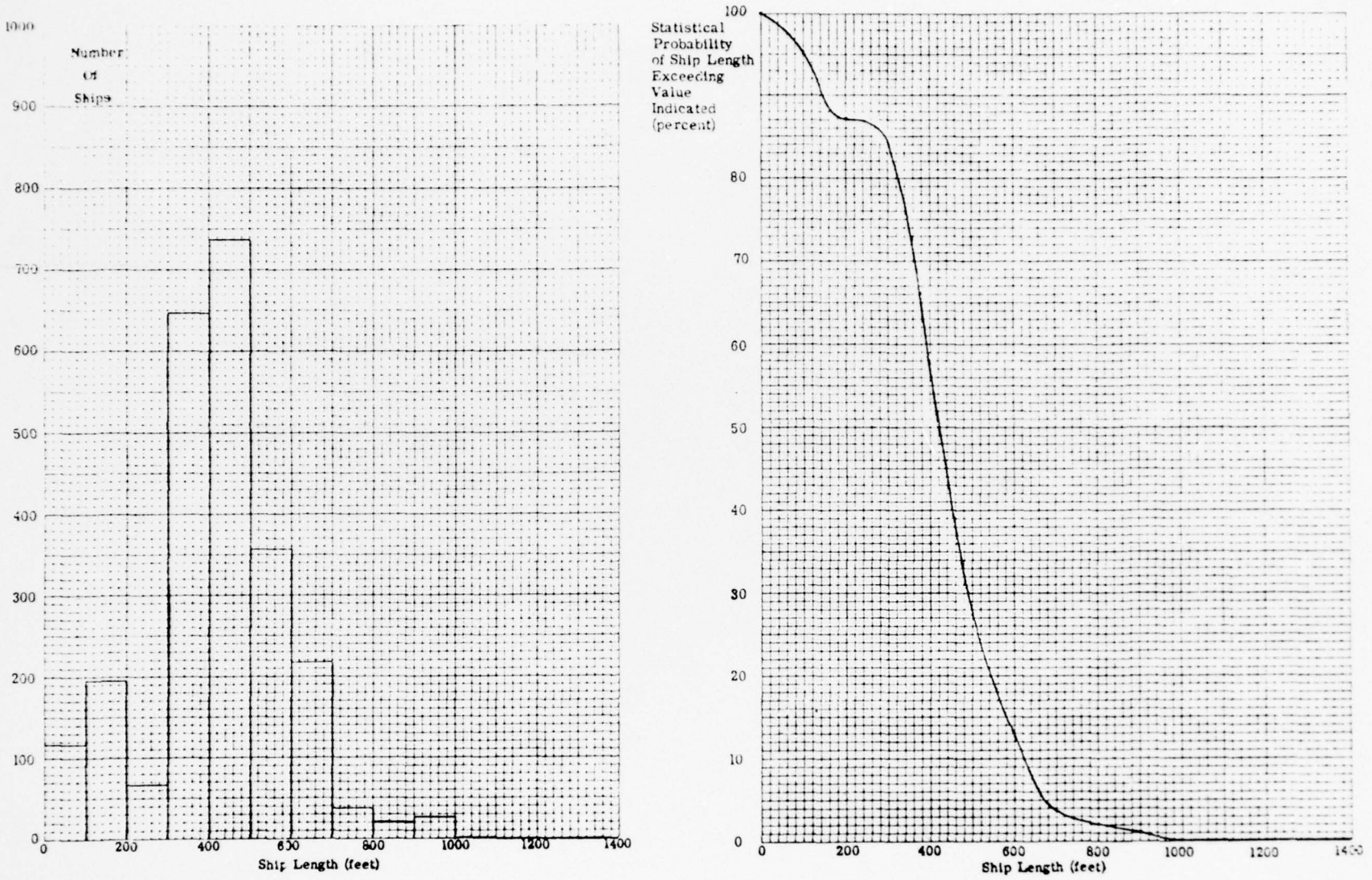


Figure 35. Ship Population Distribution According to Length: Composite of 1055 U.S. Naval Combatants (based on representative lengths estimated for each type) and 1372 U.S. Merchant Ships

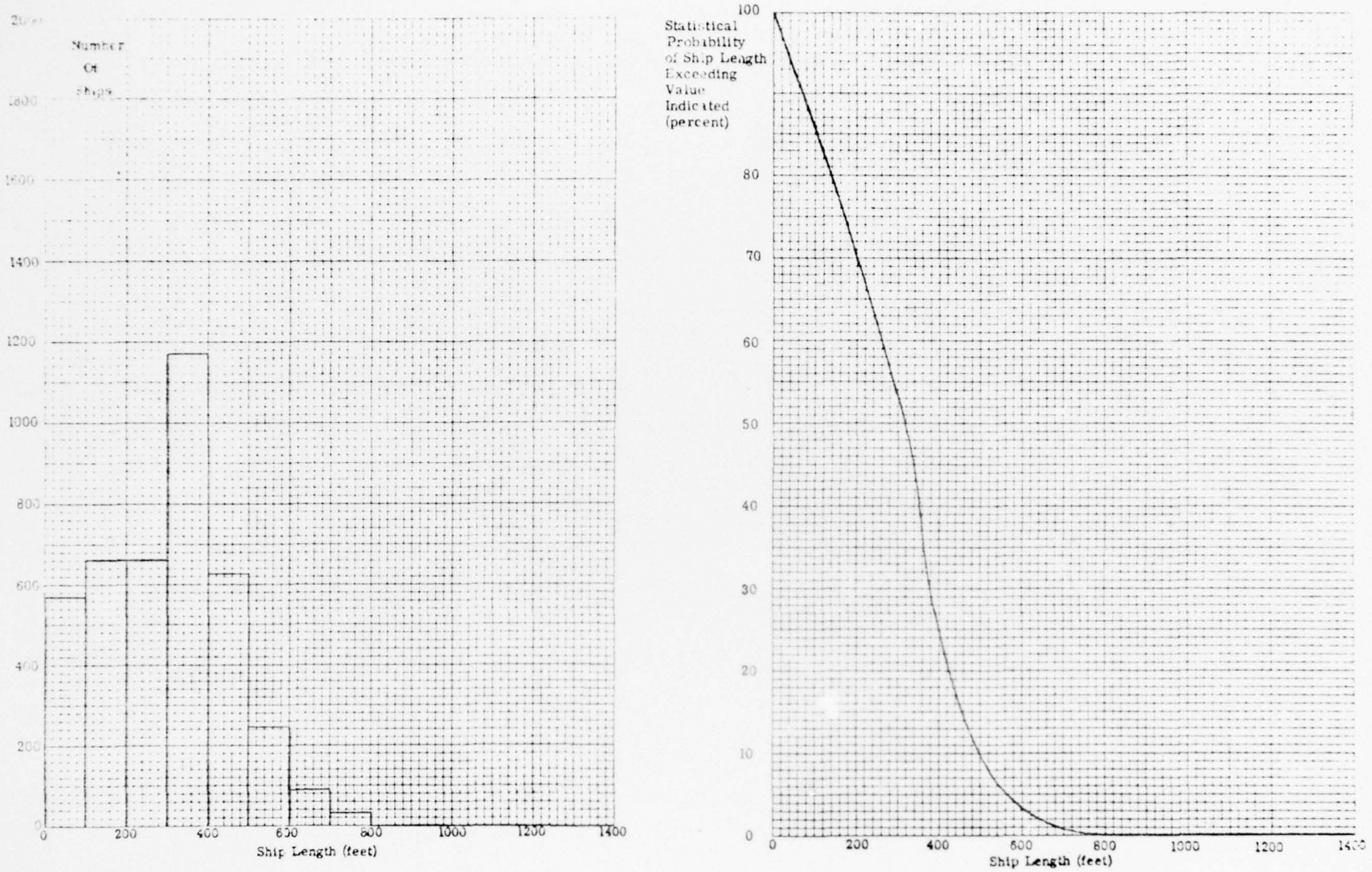


Figure 36. Ship Population Distribution According to Length: Composite of 2020 Soviet Naval Combatants (based on representative lengths estimated for each type) and 2059 Soviet Merchant Ships

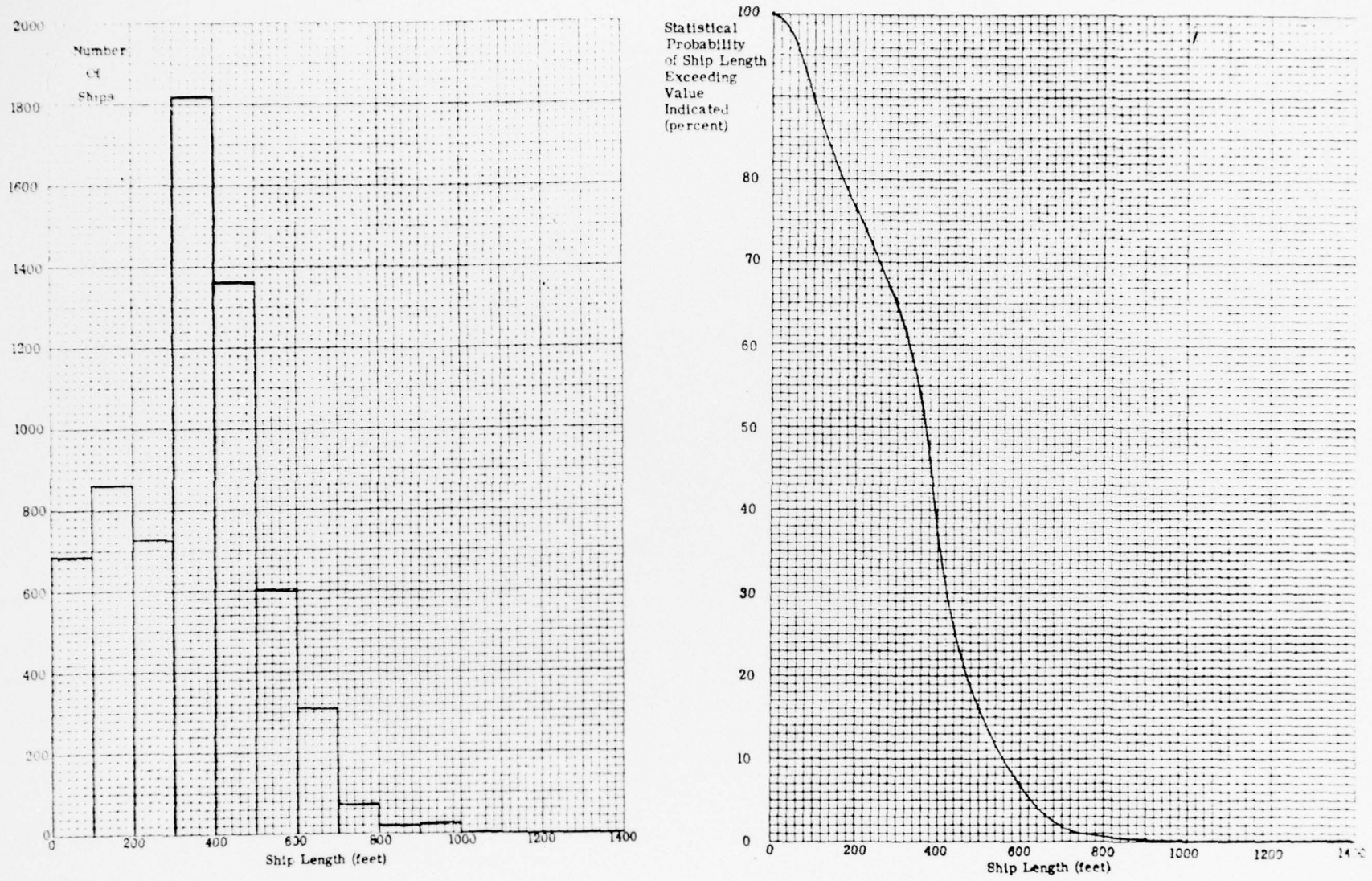
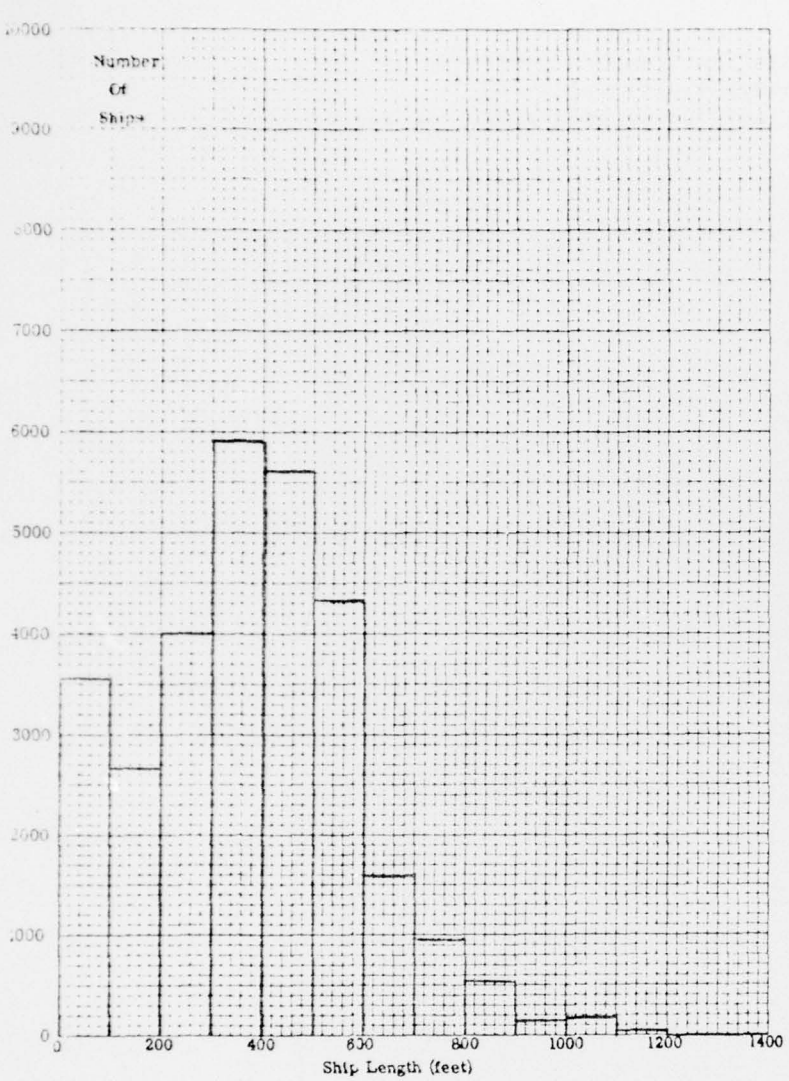


Figure 37. Ship Population Distribution According to Length: Composite of 3075 Naval Combatants (based on representative lengths estimated for each type) and 3431 Merchant Ships of the U.S. and USSR



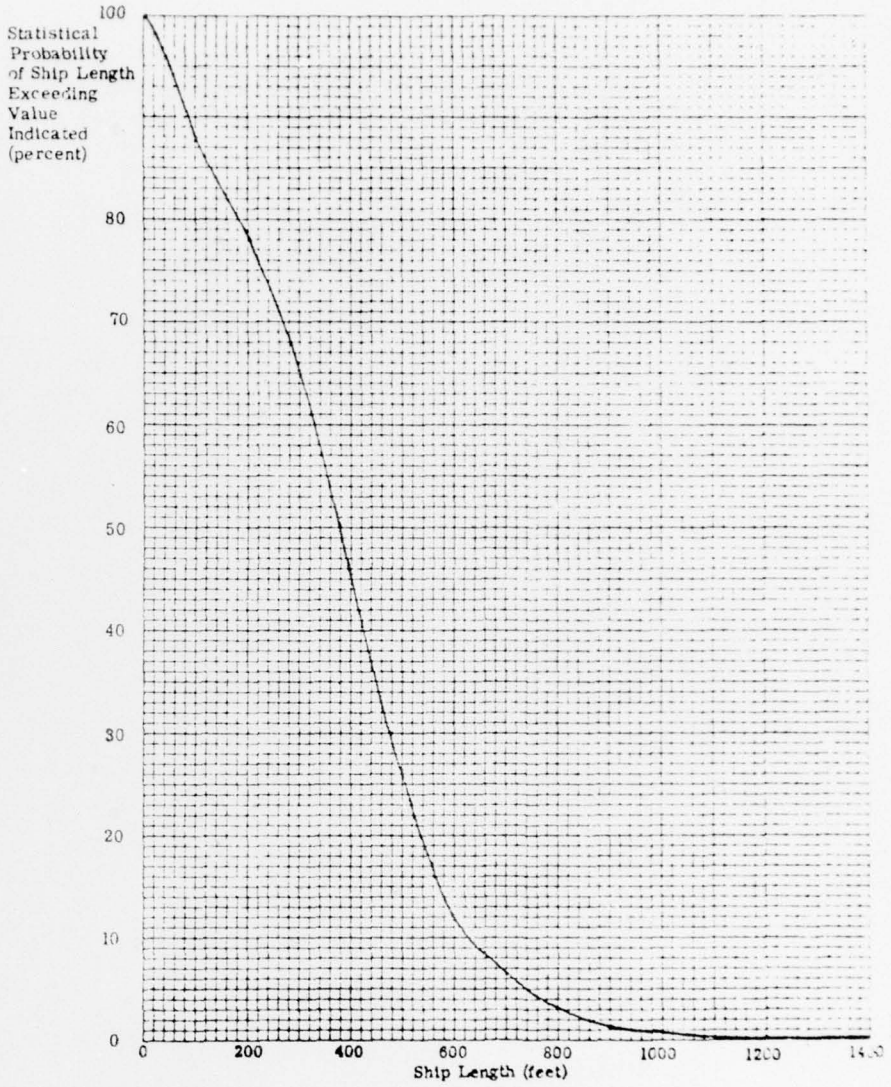


Figure 38. Ship Population Distribution According to Length: Composite of 9057 Naval Combatants (based on representative length estimated for each type) and 20544 Merchant Ships of the World