CONTRIBUTION TO 3RD I.S.S.C. (Sept. 1967)

Subject—Environmental Conditions

"A Correlation of Environment with Ship Service Speed"

by
Y. YAMANOUCHI
Ship Research Institute

Introduction

A committee was organized in 1963 in the Ship Building Research Association of Japan to study on the winds and waves as the environment to the ship, and completed few works mainly on the statistical investigation of winds and waves. The source material is the 'Marine Meteorological Data', observed and reported to the Meteorological Agency by Japanese Ships. Some of the results were reported to I.S.S.C. Committee Nr. 1 Environmental Conditions, and also were published by this association [1, 2] and by the Ship Research Institute [3], which has been closely co-operating to this Committee.

This contributioh is also an abstract of the results obtained by this Committee in 1966 (SR-91-II), in co-operating with the Ship Research Institute, to which this author worked as the chairman.

Purpose of Study

The average condition of the winds and waves which are expected to be encountered by a ship on her way, will be deduced from the statistics like the ones just above mentioned, as soon as the period of season and the route on the ocean which are to be adopted by this ship are fixed. Then the average behavior of the ship in this environment, as the ship oscillation, stress induced on the hull, or the increment of the shaft horse power will be estimated statistically if the response charactor of these behavior of the ship are known. Now, most of these characteristics can be estimated, experimentally in model basin or theoretically by computations, if the speed of advance of the ship is given.

While, the ship is not sailing on her designed sea speed. Because of the severe oscillations by the winds and waves, the resistance increases and the propulsive efficiency decreases, and results to reduce the speed. Moreover, because of the apprehension of the damages on the cargo by large accelerations of severe oscillations, buckling of deck plate, damage of hatch by shipping of water on the deck, damage on shell plate by emergence and slamming of the bottom, deterioration of the propellerp erformance and damages by racing of the screw propeller, the captain cuts down the power of engine and reduce the ship speed deliberately.

Thus the speed reduction is one of the most conspicuous responses of the ship to the environment, and can not be ignored in estimating the short or long term distribution of the stresses, the various expected values of oscillations or the sea margin, and to set up the optimum route in crossing the ocean. The incidental decrease of speed on account of the rough weather can be estimated experimentally or theoretically, however the deliberately reduction of the speed can not be presumed at this stage, because this is brought mainly by the captain's subjective decision, based on his knowledge, experience and to his synthetical judgement as the captain. (Of couse in future this should be done more rationally and objectively, however at present, this is the case.) Accordingly at present, one of the presumably most suitable way, to get the general information on the speed reduction of the ship in the sea, is to extract the general tendency from the accumulation of the result of the voyages in relation to the severeness of winds or waves. Already a typical pattern of this speed reduction of a certain type of ship in rough sea was given by E. V. Lewis [4] and R. W. James [5] through log book analysis.

We also made this analysis in this way, but not through the analysis of log book but from the 'Meteorological Data'. At first log book was investigated carefully [6] and was found that usually the description of the environment in the log book tended to be severer than actually it is, and has very poor correlation with the observed value of winds and waves in the 'Marine Meteorological Data', reported to the Meteorological Agency. While the 'Marine Meteorological Data' includes the report of winds and waves as well as the ship's course fortunately (as the average of 3 hours before the time when the weather was observed,) and the report of winds and waves are more reliable than the description in log book. Especially the wind speed and direction in Marine Meteorological Data are measured by anemometer which is compelled by law to be equipped on the ship and are examined by the Meteorological Agency, and is one of the most reliable item among the weather report. The detailed description of the behavior and conditions of ship in log book are of course so valuable to be given up, however we prefered to take the more reliable value of environment and compensated the less detailed information on the ship's behavior and conditions by the number of data.

Procedure of Analysis

We intended to get this pattern of speed reduction for many groups of ship at once, classified by its type, purpose and dimensions as well as her other designed conditions.

The data source is 830,000 sheets of IBM punched card of 'Marine Meteorological Data' which cover 7 years of 1954–1960. 1,500,000 sheets of IBM card which cover 10 years of 1954–1963 were already stored in magnetic tapes, for the purpose of statistical investigations of winds and waves we performed in previous years, however for our regret, from 1961, when the code was amended following the WMO standard code, they quitted to punch the ship speed and course as these items were not included in WMO standard, accordingly we had to use the data of only 7 years.

The following procedure was adopted in the analysis.

I. Classification of the Ships

1. Identifying the name of the ship by the ship No., using the Guide Book of the Meteorological Agency, the principal dimensions and particulars were collected consulting with the Detail Book of Ships.
2. The ships constructed before 1950 were excluded.
3. As the items to express the difference of seakeeping quality, the next were chosen.

ship length ;

ship speed ; [to standardize the published data, the max. trial speed, that is the most reliable data, was taken as the basis, and constant, different by the purpose and size of the ship was multiplied to express the 0 sea margin speed at 85% MCR]

ship purpose ; classified as in Table 1 and fishing boat and passenger boat were excluded from this analysis.

ship form above the water line; considering the difference of the easiness of shipping water, the difference of the effective freeboard was taken into account as in Table 1.

4. Using these items as above mentioned, ships were classified into 34 groups as in Table 2. Thus among 1,100 vessels that reported the data, during this period, 453 vessels were adopted to be analysed.

Table 1. Code for Ship Purpose and Type

Code	Purpose	Type
0	passenger	—
1	general cargo	shelter decker
2	bulk carrier	flash decker with long f'cle
3	ore carrier	flash decker with f'cle
4	lumber carrier	flash decker with long poop
5	oil tanker	flash decker
6	chemical tanker	three islander
7	fishing boat	well decker
8	fishing carrier	aft bridge type
9	others	—

Table 2. Classification of Ship

Purpose	Type	Length: L	Speed: V	Group No.	Remarks
1, 2, 4	1	$L\leqq 100$		1	
		$100<L\leqq 125$	$11<V\leqq 12.5$	2	
			$12.5<V\leqq 14$	3	
		$125<L\leqq 150$	$12.5<V\leqq 14$	4	
			$14<V\leqq 15.5$	5	
			$15.5<V\leqq 17$	6	
			$17<V\leqq 18.5$	7	
	2	$L\leqq 100$		8	
		$100<L\leqq 125$	$11<V\leqq 12.5$	9	
			$12.5<V\leqq 14$	10	
		$125<L\leqq 150$	$12.5<V\leqq 14$	11	
			$14<V\leqq 15.5$	12	
			$15.5<V\leqq 17$	13	
			$17<V\leqq 18.5$	14	
	3, 4, 5, 6, 7	$L\leqq 100$		15	
		$100<L\leqq 125$	$11<V\leqq 12.5$	16	
			$12.5<V\leqq 14$	17	
		$125<L\leqq 150$	$12.5<V\leqq 14$	18	
			$14<V\leqq 15.5$	19	
			$15.5<V\leqq 17$	20	
			$17<V\leqq 18.5$	21	
		$150<L\leqq 175$	$12.5<V\leqq 14$	22	
			$14<V\leqq 15.5$	23	
	1, 2, 3, 4, 5, 6, 7	$L\leqq 100$		24	(1+8+15)
		$100<L\leqq 125$	$11<V\leqq 12.5$	25	(2+9+16)
			$12.5<V\leqq 14$	26	(3+10+17)
		$125<L\leqq 150$	$12.5<V\leqq 14$	27	(4+11+18)
			$14<V\leqq 15.5$	28	(5+12+19)
			$15.5<V\leqq 17$	29	(6+13+20)
			$17<V\leqq 18.5$	30	(7+14+21)
3, 5	1~8	$150<L\leqq 175$	$12.5<V\leqq 14$	31	
		$175<L\leqq 200$	$14<V\leqq 15.5$	32	
		$200<L$	$15.5<V\leqq 17$	33	
			$15.5<V\leqq 17$	34	

II. Classification of items used in the analysis

In order to correlate the reduction of ship speed with the roughness of the weather, the wave height (and period) might be most appropriate, however the wind speed was adopted as the index to show the severeness of the weather, because the reliability is much higher in wind speed measeured by anemometer than in the wave height by visual observation, as mentioned before. The most serious defect of this data is that this does not include any information on load condition of the ship, which is one of the important factors for seaking quality of the ship. In order to prevent the large dispersion of the results, because of this reason, we devided the ship's route into homeward voyages and outward voyages, as are shown in Table 3.

Table 3. Classification of Ship's Route

Code	Name of Route	Octant	Longitude $L_0L_0L_0$	Ship's couse D_s	Remarks
1	Pacific Route : East Bound	1 2	40.0≦	1, 2, 3	Outward Voyage
2	Pacific Route : West Bound	1 2	40.0≦	5, 6, 7	Homeward Voyage
3	Pacific Route : Total	1 2	40.0≦	1~8	
4	South Route : East Bound	2	<40.0	1, 2, 3, 8	Homeward Voyage
5	South Route : West Bound	2	<40.0	4, 5, 6, 7	Outward Voyage
6	South Route : Total	2	<40.0	1~8	

Remarks

$L_0L_0L_0$: expression of longitude in tenth of degree (100 is omitted for 100~180°)

D_s: Ship's course (true) made good during the three hours preceeding the time of observation (0~8)

Q : Octant of the globe (0~8)
1: (0~90°N, 90°W~180°W)
2: (0~90°N, 180°E~90°E)

The Code of wind speed, ship's course and ship's speed used are as follows.

Code	Wind Speed		Ship's Course D_s	Ship's Speed V_s
	Beaufourt Scale	f f		
0	—		Position was not Changed	0
1	0~3	00, 01~10 kt	NE	1~ 3 kt
2	4	11, 12~16	E	4~ 6
3	5	17~21	SE	7~ 9
4	6	22~27	S	10~12
5	7	28~33	SW	13~15
6	8	34~40	W	16~18
7	9	41~47	NW	~21
8	10	48~	N	22~24
9			unknown	over 25

The analysis was performed for 5 groups of relative angle of ship's course to the wind direction, namely head, bow, beam, quarter and follow, adjusting the difference of wind direction and the ship's course.

Results

The statistics were performed by an electronic computor (CDS 3600/3200 at C. Ito Electronic Computing Service Co., Ltd.), and output were printed on more than 1000 sheets that is for every group of ship, route and relative wind direction. Each output shows the distribution of occurrence of reduced ship's speed for each wind speed. Moreover, the mean ship speed and the standard deviation were computed for each wind speed. Examples of the plot of this results are shown in Fig. 1, Fig. 2 and Fig. 3∼10.

At first, the class interval of 3 kt for the ship's speed, the most important item in this analysis, looked too large to get a good estimate of the mean reduced speed. This was investigated statistically and was found that as far as the number of data is moderately large, the effect of this interval is rather unexpectedly small, the standard error of the mean reduced speed being adversely proportional to the square root of the data number, and being effected more by the variance of the speed itself, than the variance because of this class interval.

Figs. 3∼10 show examples of the relation of the mean speed reduction to the wind speed. About 200 figures like these were drawn, and each has its own meaning and application indepently each other. However by comparing these figures, the effect of the items such as the purpose, type, length, speed and so on, used in classifying the ships, and also the items as the ship route and relative directions to the winds, used in the analysis, will become clear as follows.

(1) Usually in head seas (winds) the speed reduction starts from the lowest wind speed, and the amount of decrease is the largest for the same wind speed among various relative directions. (Fig. 3∼10)

(2) Generally the bow sea comes next, and the amount of reduction decreases by the order of beam sea and quartering sea. (Figs. 3∼10)

(3) In the following sea, for the moderate wind speed, the ship speed increases than for the calm sea for most of the cases. The reduction of speed starts from rather high wind speed, but with comparatively small amount.

These (1)∼(3) show that most of them look very much like the pattern which was shown by E. V. Lewis [4]. However the wind speed, where the captain seems to cut down the power did not appear clearly. (Figs. 3∼10)

(4) For large sized ship about 200 m, the speed reduction is larger in beam seas against the general tendency for moderate sized ships as above mentioned. (Fig. 10)

Then as a next step of comparison, the average V_T of reduced speed V_R, for all relative wind direction, over whole range of wind speed was computed, and assuming the mean speed V_1 for 0∼10 kt (Code 1) wind as the 0 sea margin speed, the ratio $\Delta V_T/V_1$, ($\Delta V_T = V_T - V_1$) and reduction $\Delta V_R = V_1 - V_R$ were compared by groups and the following tendency were noticed.

(5) The difference of freeboard appeared to effect very slightly on the speed down, although the ship with smallest freeboard appeared most sensitive to rough sea. This suggests that the shipping of water might not be the most leading criterion to make the captain cut down the power, and the speed. (Fig. 11)

(6) Comparing the ship of length $125 < L \leqq 150$ m, with various design speed, the group of ship with moderate speed $14 < V \leqq 15.5$ kt looks like most sensitive to the rough sea. Generally however, as the design speed increases, this means, as the ship becomes finer, the speed reduction decreases, or becomes less sensitive to rough sea. (Fig. 12)

(7) Comparing the ship with different length, the ship with length around 150 m and with speed $12.5 < V \leqq 14$ kt or $14 < V \leqq 15.5$ kt appeared rather sensitive to speed reduction, in spite of the general tendency of the decrease of speed reduction by the increase of the length. (Fig. 13)

(8) As mentioned before, the load condition was one of the most difficult items to be identified from this 'Data', and so in this investigation, the voyages were divided by

the route. The result shows that for all routes, the speed for outward-bond is larger than that for homeward-bond and shows that the load is fuller for homeward-bond than for outward-bond.

The comparison of speed down by load condition was difficult, because of the large scatter for outward-bond, presumably because of the scatter of load condition, however for South Route, the speed down appeared larger for full load condition than for light load condition.

As already mentioned, the variance namely the scatter of the ship speed for the same wind effect much more on the estimate of the mean of the reduced speed than the class interval of 3 kt. As the cause of this scatter, the following can be counted.

a) Scatter of the seakeeping quality of the ships, classified in one group, because of the scatter of the principal dimensions and other design conditions,
b) scatter of load conditions of ships of one group on the same route, same course,
c) scatter of the captain's judgement to cut down or to adjust the power,
d) scatter of the performance of hull and engine by the different period of time after the last docking, and the years after construction,
e) scatter of the performance of engine, or the steering system including the auto-pilot system.
f) Besides, a rather large scatter is supposed to be caused by the difference of the wave climate as the wave direction, height, period or the existence of the swell at the same wind, as can be presumed by the wind and wave statistics as we investigated in previous year. In these results, there appeared a lots of problems that should be investigated more precisely relating to the environments in designing a ship with good seakeeping quality. Here however just the results are shown. Further discussions will be reported in future.

In conclusing this note, this author sincerely wishes to propose to ISSC, to make a proposal to WMO to add the ship speed and course to the items to be punched on IBM card of 'Marine Meteorological Data'. This will make this 'data' more valuable for us naval architects, giving a good information on the behavior of ships as well as the environment. (In this case, two colums of puched card are desirable to be used to express the ship speed by knots, expecting the appearance of high speed, higher than 30 kt, merchant vessels in near future.)

References

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[2] "Statistical Investigation on the Winds and Waves on the North Pacific Ocean", Shipbuilding Research, Vol. 8, No. 1, June 1966, JSRA. Chart was published separately as "Winds and Waves on the North Pacific Ocean (1954-1963)", March 1966, JSRA. [in Japanese]

[3] Yamanouchi, Y., Unoki, S. & Kanda, T.: "On the Winds and Waves on the Northern North Pacific Ocean and South Adjacent Seas of Japan as the Environmental Condition for the Ship", Papers of Ship Research Institute No. 5, March 1965.

[4] Lewis, E. V.: "Log Analysis", E.T.T. Report No. 708, Nov. 1958. Second Summer Seminar "Ship Behavior at Sea", on June 1958, at S.I.T.

[5] James, R. W.: "Application of Wave Forecasts to Marine Navigation" Hydrographic Office Special Reports No. 1, July 1957.
James, R. W.: "General Notes on Ship Routing", E.T.T. Report No. 708, Nov. 1958, Second Summer Seminar "Ship Behavior at Sea", on June 1958 at S.I.T.

[6] "Report on the Investigation of Improvement of Ship Performance" "Investigation on Sea Margin", Investigation Memo No. 46, March 1966, JSRA. [in Japanese]

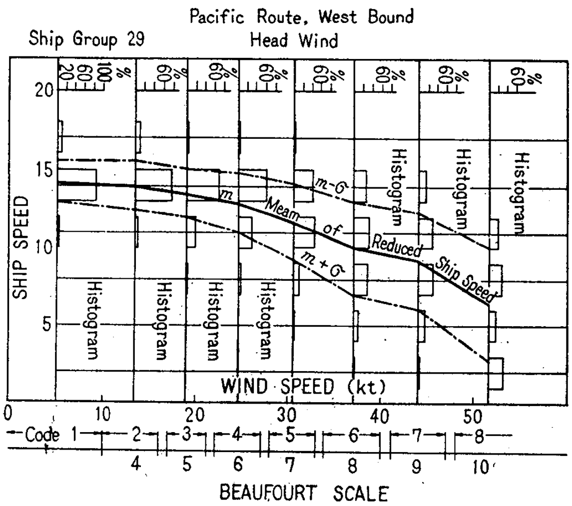

Fig. 1. An Example of the Results

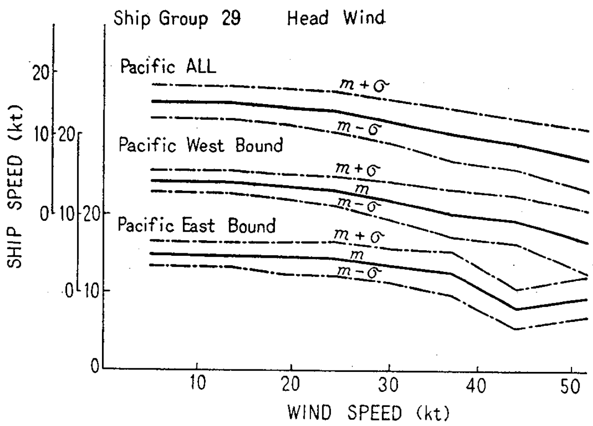

Fig. 2. Mean of Reduced Speed for each Caurse

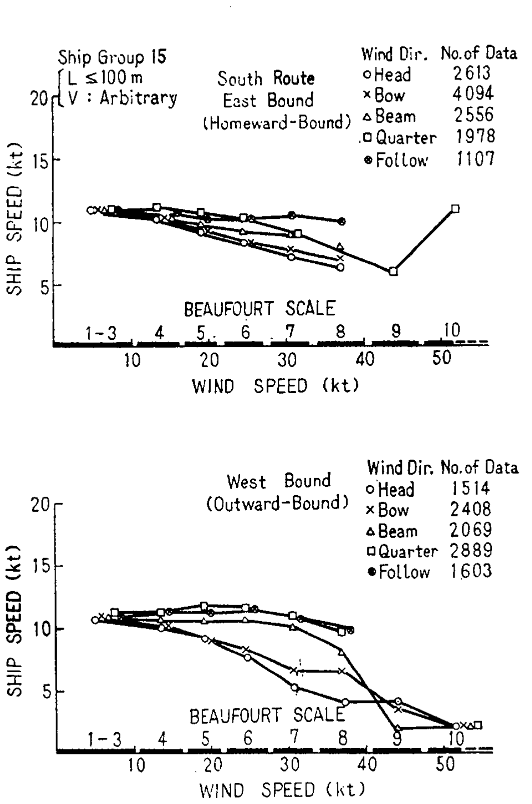

Fig. 3. Examples of Pattern of Speed Reduction

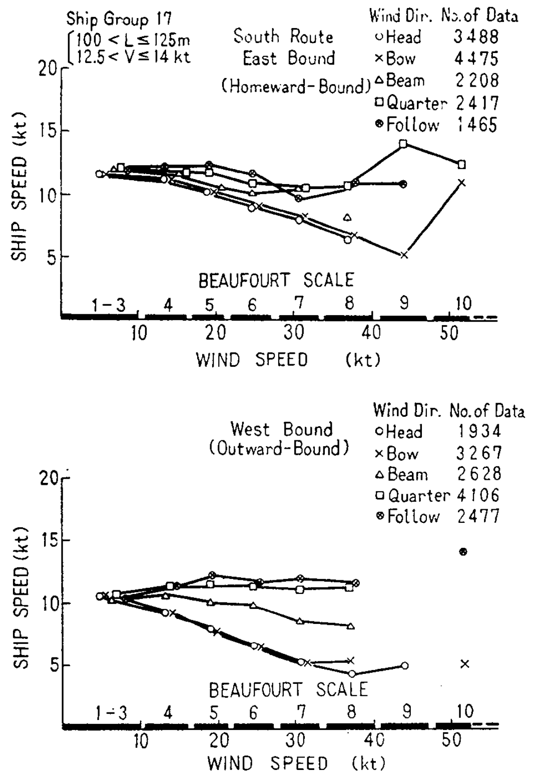

Fig. 4. Examples of Pattern of Speed Reduction

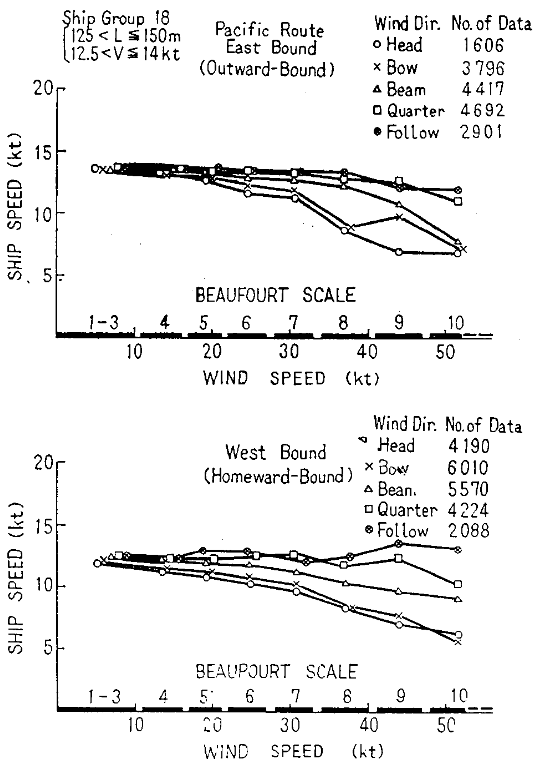

Fig. 5. Examples of Pattern of Speed Reduction

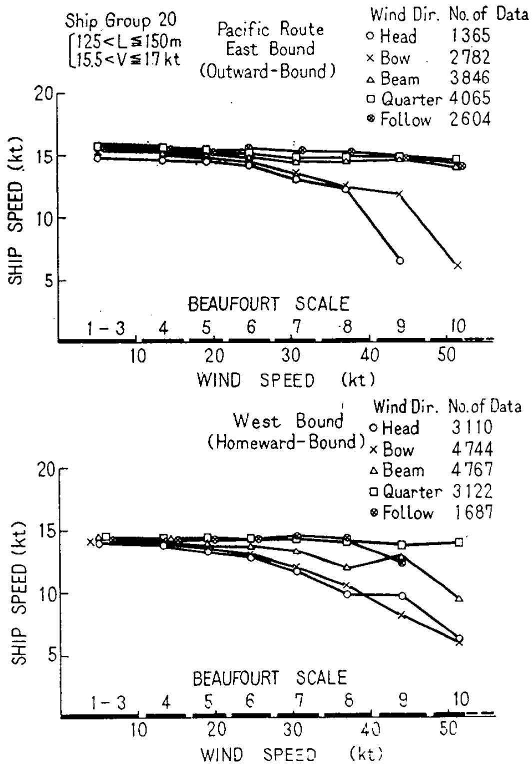

Fig. 6. Examples of Pattern of Speed Reduction

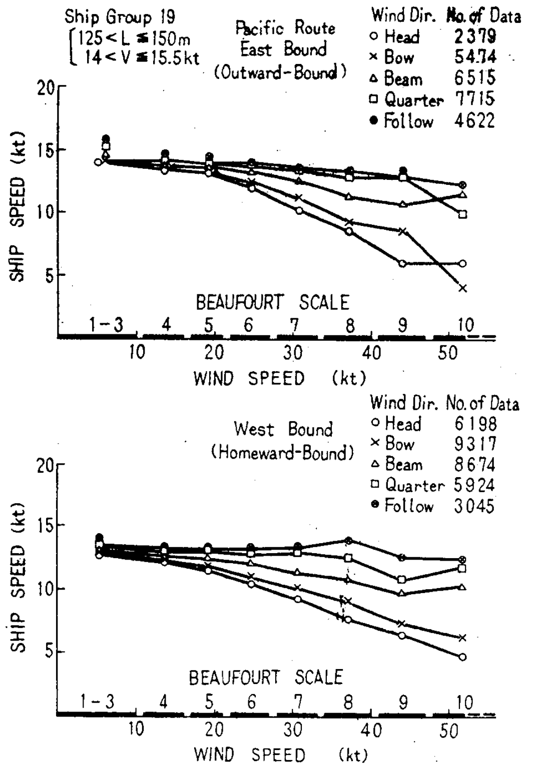

Fig. 7. Examples of Pattern of Speed Reduction

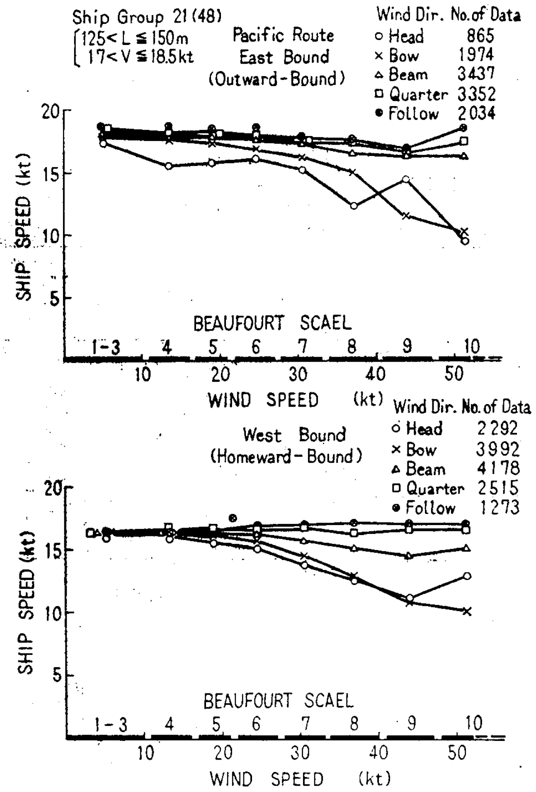

Fig. 8. Examples of Pattern of Speed Reduction

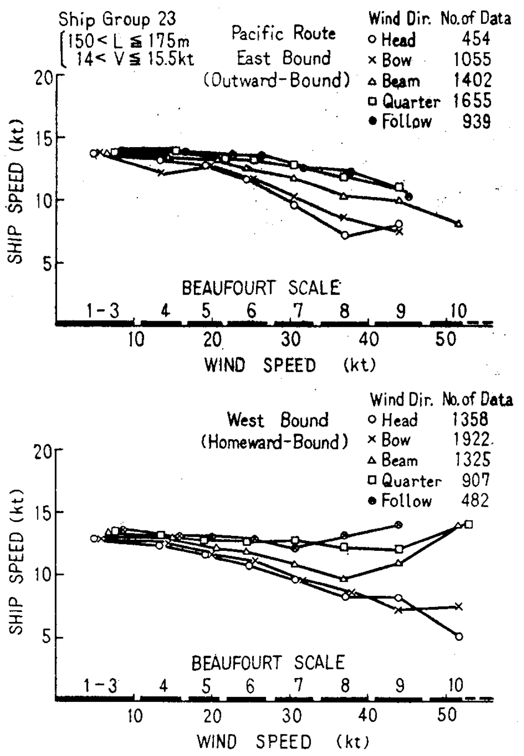

Fig. 9. Examples of Pattern of Speed Reduction

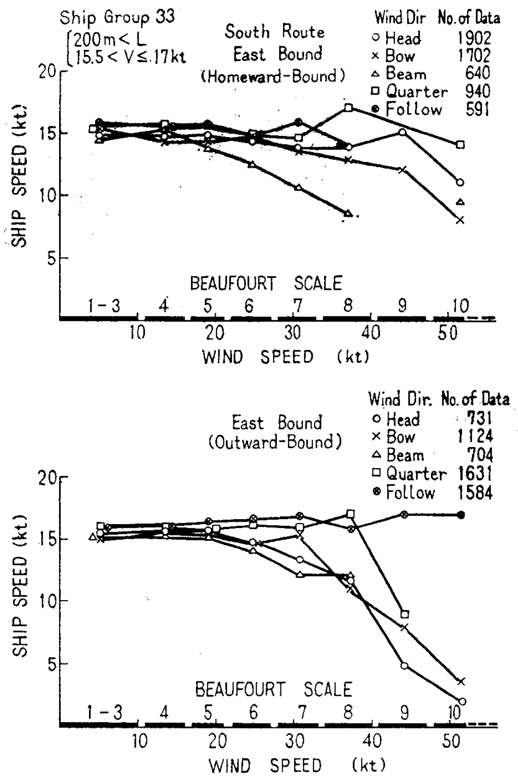

Fig. 10. Examples of Pattern of Speed Reduction

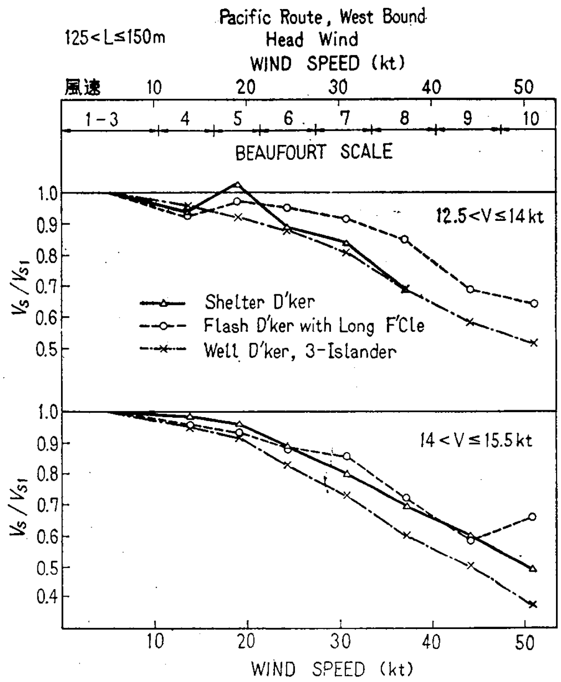

Fig. 11. Difference by Freeboard

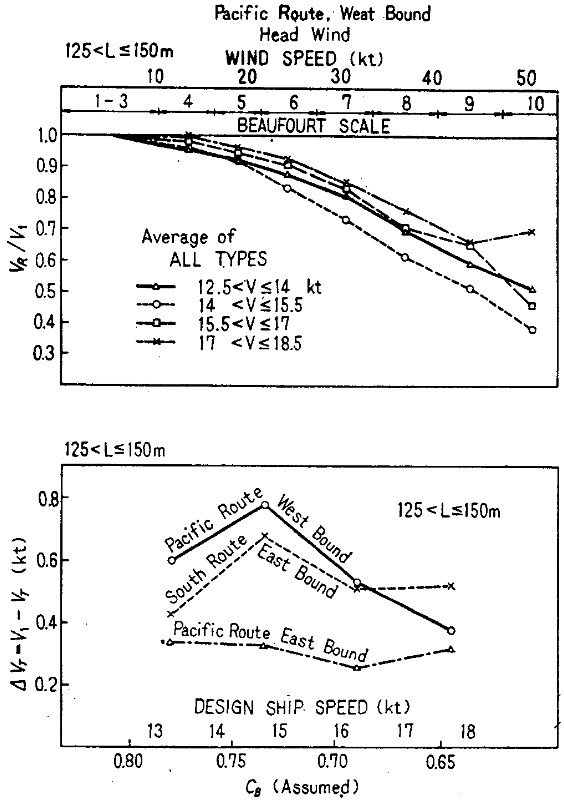

Fig. 12. Difference by the Design Speed

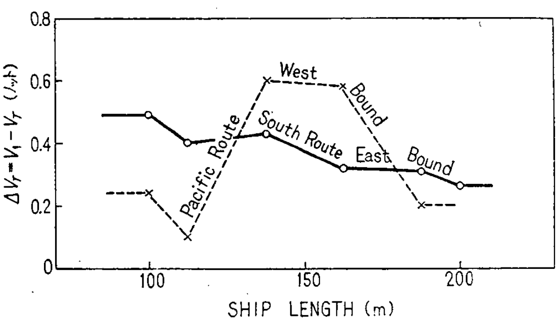

Fig. 13. Difference by Ship Length