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The Marine Environment Information Data Bank and suggestion of its use

SUMMARY

The paper presents the Data Bank containing information on stress factors dominating in ship's enviroment and samples of information collected in the bank. Proposals on how to apply the degradation prediction method to materials used in ship equipment are given in Part II of the paper.

The presented method could be helpful in environment aggressiveness assessment, degradation, failure or damage risk assessment, selection of laboratory test type and time for an equipment guaranteed period or required durability, material durability prediction etc.

INTRODUCTION

Knowledge of real stress factors, which electric equipment aboard ships is dependable on, is necessary for proper selection of the equipment, determination of parameters for laboratory tests and eventually for accelerated tests.

Service durability prediction for the equipment can be made not only on the engineering analysis basis but also on that of enviromental conditions. The last approach is frequently even easier to be applied, particularly to reversible processes.

The developed Data Bank connected with the above mentioned problem contains information on enviromental stress factors which directly or indirectly influence the degradation processes of shipboard equipment.

DATA BANK

Humidity (rainfall, precipitation, air relative humidity) is important for material deterioration, base corrosion and coating destruction.

Water penetration rate through paint coatings depends also on temperature and relative humidity. Another destructive factor is solar radiation. Apart from the climatic parameters air pollution (chlorides and SO_2)is also important. Air relative humidity exceeding 80% is corrosion stimulating factor too.

This information was decisive for choice of stress parameters which were taken into account when forming the Data Bank. This permanent and continuously complemented Data Bank contains stress data for the Atlantic and Indian Oceans (data for exposed decks) and aboard-ship registered data. The following files formed the basis for the Data Bank:

- measurements of climatic parameters carried out in the past on typical shipping lines
- pilot books from the years 1951 - 1971
- maritime geographical atlases

Climatic parameters have been measured in various typical ship compartments or areas such as:

- engine rooms (level of: electric generating sets, Main Electric Switchboard-MES)
- wheelhouses
- deckhouses, forecastles, steering gear rooms
- exposed decks.

The climatic parameters i.e. temperature, air relative humidity and their changes were recorded on 33 ships sailing on 10 shipping lines. Total number of measurement days were as follows:

- engine room - MES level	5 740
- engine room - generating set level	3 886
- wheelhouses	4 923
- steering gear rooms	3 084
- deckhouses,forecastles	8 599
- exposed decks	1 253

Agressive factors (chlorides and SO_2) were measured on 20 ships in the same service compartments [1] to [4]. The elaborated records are examplified in Tab. 1.

Calculations have been carried out with the use of computer programs to determine the basic stress parameters.

A graphic program, based on the IEC climate classification system [5], makes it possible to predict the occurence of various stress factors in a chosen ship space (Fig. 1).

Information on stress types are given in a form of a-t-v climatograms (a- humidity, t - temperature, v - relative humidity). Climatogram areas enable to determine the simultaneous occurence frequency of two parameters: temperature and relative humidity. They can be formed from the daily mean values (area 1), the mean values of daily extreme values (area 2) and the absolute values (area 3).

Tab. 1. Temperature and relative humidity distributions (data collected from 47964 measurements recorded during 95928 hours, not accounting for climatic zones). *Compartment: deckhouse*

[°C] Temp. \ Hum. [%]	0 4	5 9	10 14	15 19	20 24	25 29	30 34	35 39	40 44	45 49	50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99
-10,0 ÷ (- 8,1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-8,0 ÷ (- 6,1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-6,0 ÷ (- 4,1)	C	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
-4,0 ÷ (- 2,1)	0	0	0	0	0	0	1	0	0	0	1	1	0	0	3	3	26	1	0	0
-2,0 ÷ (- 0,1)	0	0	0	0	0	0	0	1	0	0	0	0	0	9	6	12	33	20	11	4
0,0 ÷ 1,9	0	0	0	0	0	0	0	0	0	0	1	0	0	15	18	38	73	23	35	14
2,0 ÷ 3,9	0	0	1	0	2	3	0	0	0	1	1	5	34	7	30	54	127	62	14	5
4,0 ÷ 5,9	0	0	0	5	1	2	2	9	4	2	5	16	50	31	49	139	138	57	28	12
6,0 ÷ 7,9	0	0	0	0	2	2	6	19	13	6	28	23	47	60	99	233	74	51	35	22
8,0 ÷ 9,9	0	0	0	7	0	5	11	14	12	29	33	46	82	38	112	110	100	80	81	43
10,0 ÷ 11,9	0	0	0	3	5	5	19	24	26	66	72	56	64	87	119	107	78	65	58	33
12,0 ÷ 13,9	0	0	0	6	7	12	18	49	87	81	64	54	78	163	141	183	240	153	48	67
14,0 ÷ 15,9	0	0	0	3	4	10	28	69	82	90	69	100	140	174	175	400	258	146	106	107
16,0 ÷ 17,9	0	0	0	2	9	29	47	78	59	97	129	162	253	261	229	299	247	201	114	96
18,0 ÷ 19,9	0	0	0	0	10	43	100	57	87	143	145	173	305	365	317	371	457	428	292	96
20,0 ÷ 21,9	0	0	0	4	12	35	80	93	117	179	242	198	370	582	447	602	640	399	187	73
22,0 ÷ 23,9	0	0	0	3	15	47	82	118	186	220	290	291	511	643	457	667	440	348	173	78
24,0 ÷ 25,9	0	0	0	2	17	57	101	195	237	275	317	319	502	501	677	657	589	429	166	93
26,0 ÷ 27,9	0	0	1	3	13	62	126	226	261	209	229	286	348	488	459	541	537	430	202	167
28,0 ÷ 29,9	0	0	2	6	18	37	136	166	194	172	162	277	410	406	588	589	456	466	401	219

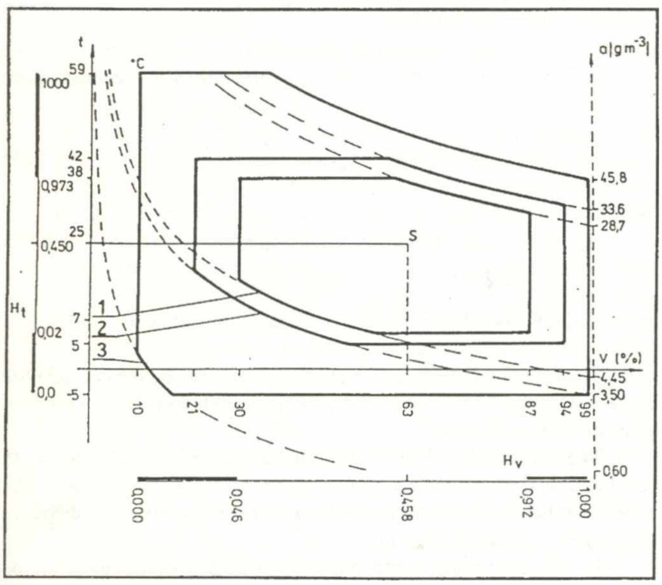

Fig. 1. The a-t-v climatogram for the exposed deck: area 1 - daily mean values, area 2 - mean values of daily extreme values, area 3 - absolute values

The values inside climatograms are the most frequent ones. Area 1 provides a range of the long-lasting values which are important for electric equipment with long time-constant. Occurence probability of these values is very high: about 0.93.

Cumulative distribution functions of temperature and relative humidity can also be given on the climatograms. Occurence frequency of a given temperature (H_t) or relative humidity (H_w) is defined as the ratio of the occurence time of the parameters to the total measurement time. Point S represents the mean arithmetic value calculated from multi-year measurement values recorded on various ships in the same type of compartments. From data elaborated in this way various information on climatic exposures can be obtained.

Information collected from pilot books and maritime geographical atlases [6] to [9] has been primarily used to estimate conditions on exposed decks. A way of using the data is given for the Atlantic Ocean as an example.

The Atlantic Ocean maps were prepared with geographic coordinates mesh $5^0 \times 5^0$ (dimensions: 100^0 W, 20^0 E, 50^0 N, 50^0 S).

Calculation results of such parameters as: mean, maximum and minimum temperatures, relative humidity and sea-salt concentration were put in the mesh.

On the basis of the collected data several histograms of occurence frequency for monthly mean temperatures (Fig. 2.), monthly mean relative humidity (Fig. 3.) as well as sea-salt concentration cumulative occurence probability functions(Fig. 4.) were prepared. The histograms were elaborated for 4 quarters of a year. Corrosion intensity on exposed decks depends on sea region, ship route, year season and weather conditions.

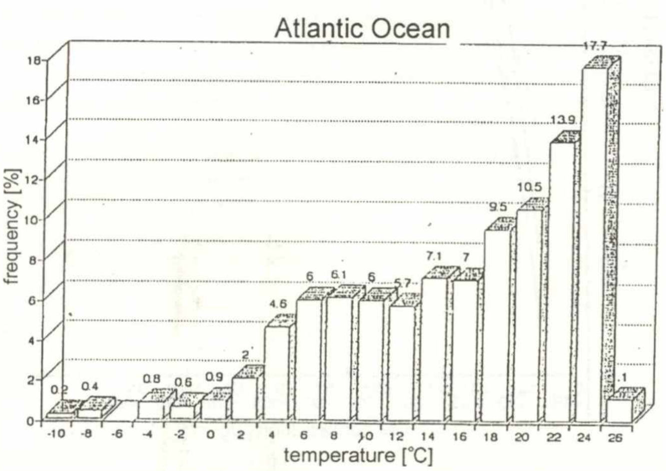

Fig. 2. Occurence frequency histograms of monthly mean temperatures

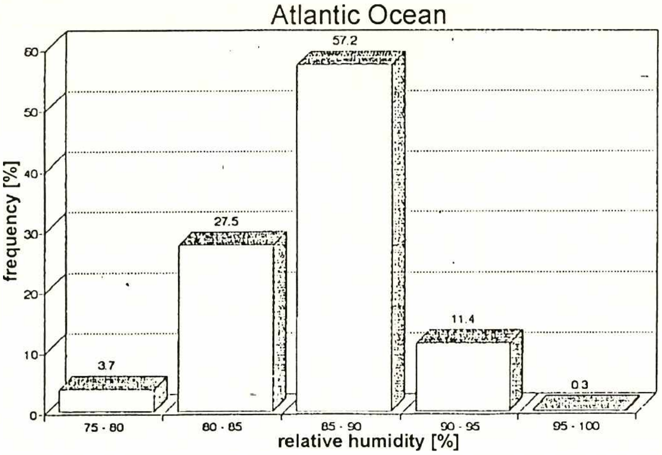

Fig. 3. Occurence frequency histograms of monthly mean relative humidity

It is difficult to build a universal model, however it is possible to estimate ranges of climatic or aggressive parameters within which degradation occurence would be the most possible.

From Fig. 2. it can be observed that positive temperatures occur on exposed decks of ships sailing on the Atlantic Ocean for 98% of year time and the temperatures exceed 18^{0}C, as a rule.

From the relative humidity(RH) histogram given in Fig. 4 it is seen that the humidity greater than 80% occurs for 96% of time. The RH value equal 80% is usually considered as the critical for triggering corrosion processes.

From the histograms of salt concetration occurence probability given in Fig. 4 it is seen that the most frequent value of salt concentration occurring on the Atlantic Ocean is 15 to 45 $\mu g \cdot m^{-3}$. The values up to 90 $\mu g \cdot m^{-3}$ may occur with 0,1 probability.

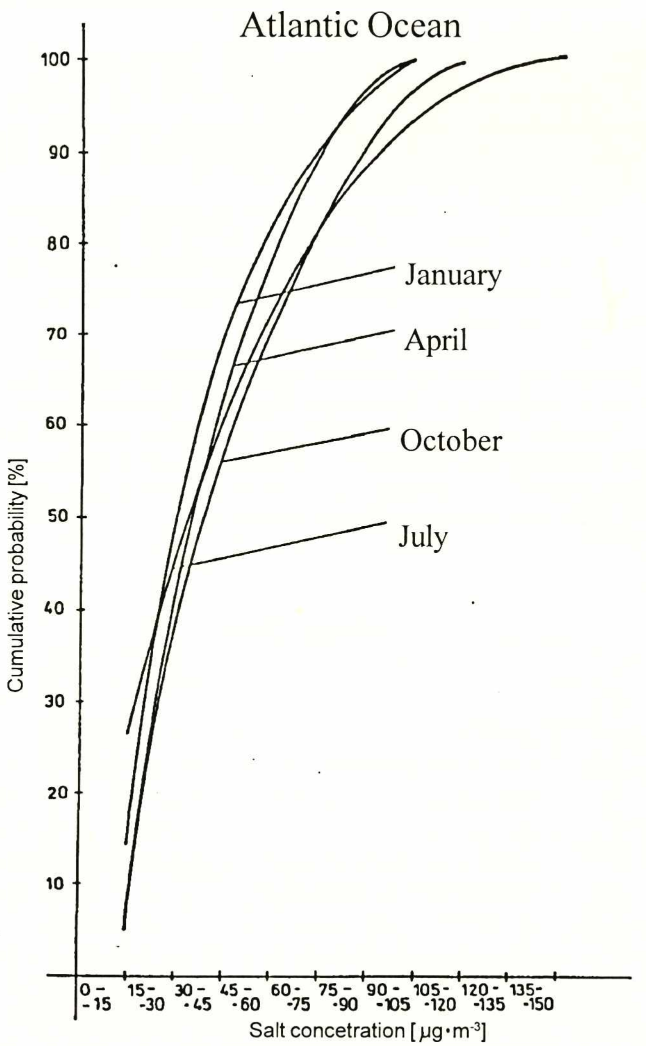

Fig. 4. Sea-salt concetration cumulative probability functions for four selected months

Corrosion aggressiveness of microclimate in service compartments is generally a dozen or so times lower than on exposed decks. It is confirmed by the observed corrosion wastage level of selected metal specimens exposed in some such compartments during ship voyages.

The Data Bank is aimed at implementation of the collected information to quality assessment of the applied equipment, choice of proper preventive means against enviromental stress, estimation of correlation between conditions occuring in various ship compartments and those used in laboratory tests. Data on mechanical factors (vibration) appearing in various ship compartments are also saved in the Bank apart from the climatic and aggressive parameters for these compartments. The data are still waiting for further processing.

The Data Bank of ship environment parameters provides for multi-level use of the data, their multi-lateral processing, reviewing and retrieving in a descriptive and graphical form; it is fully compatible with FOX.PRO software system.

CHT METHOD AND ITS MODIFICATION

A concept how to use the collected data files for calculation of degradation indices has been based on a modified transformation method. CHT prediction method [10] to [14] is based on the assumption that a level of degradation in natural conditions would be the same as in model conditions. The method enables to estimate durability of equipment (or its components) in various service stressing conditions and their stress equivalents.

Equipment service time T is composed of conventional time intervals in which a value ,e.g. of temperature or humidity, is constant and known. Due to this it is possible to determine a deterioration curve describing changes of the tested equipment properties with time.

For model(laboratory)testing the service time T^m is usually assumed as a sum of seperate time intervals t^m. Degradation indices in time t^m and t are equal.

Model testing time for two stress factors (e.g. temperature and relative humidity) may be expessed in the following general form [15]:

$$t^m = F\left[\varphi\left(\frac{n_f}{n_f^m}\right), \psi\left(\frac{n_g}{n_g^m}\right)\right] \qquad (1)$$

where:

n_f, n_g - values of service stress factors

n_f^m, n_g^m - values of model stress factors

F, φ, ψ - functions of the above given arguments

The function F expresses a relationship between the degradation in service conditions and that in model conditions and levels of relevant stress factors.

The method has been elaborated for fixed objects (i.e. with localization defined by geographical coordinates). It needed to be somewhat modified before its application to ships sailing on different routes and in changeable conditions.

In this case course and parameters of stress factors must be determined from short diurnal time intervals, as the stresses are changeable in consecutive days of ship's voyage. The problem has been solved for one of the dominant stresses (viz. water vapour sorption - moistening).

Diurnal and annual amplitudes of humidity and temperature changes on the Atlantic Ocean are much smaller than on the mainland (see Tab. 2 and 3).

Tab. 2. Annual air temperature amplitude [^{0}C]

Latitude [°]	0	10	20	30	40	50
Ocean	2,3	2,4	3,6	5,9	7,5	5,6
Mainland	-	3,3	7,2	10,2	14,0	24,4

Tab. 3. Annual course of air temperature [°C] - standard deviation of monthly mean temperature from annual mean temperature

Month	Ocean		Mainland	
	Latitude[°]			
	35	60	40	60
January	-3,4	-3,2	-15,3	-24,4
February	-3,5	-3,4	-13,9	-19,5
March	-3,5	-3,5	-5,6	-10,0
April	-2,2	-1,6	1,7	-0,7
May	-0,5	0,3	8,0	10,7
June	2,0	3,2	12,2	20,6
July	4,2	4,4	14,2	24,2
August	4,8	4,7	12,4	20,0
September	3,9	3,2	6,6	12,5
October	1,6	0,7	-0,8	0,9
November	-0,4	-2,0	-7,1	-13,8
December	-2,8	-2,8	-12,2	-22,3

It reveals from these tables that temperatures measured on land and ocean greatly differ, independently of latitude.

Four calculation matrices are used to compute sorptional degradation indices for the mainland; these are:

* multi-year monthly mean values of the relative humidity measured at 7 a.m. and 2 p.m.(given for the consecutive months of a year) and

* multi-year monthly mean values of maximum and minimum temperatures (given for the consecutive months of a year).

Two of the matrices are set separately for day and night with relative humidity values given in 2% and 5% intervals and air temperature in 5°C intervals as matrix elements.

Elaboration of a two-dimensional matrix accounting for relative humidity changes at 1% intervals and temperature at 1°C intervals was however necessary to calculate degradation indices for the Atlantic Ocean.

Moreover it was decided, taking into account low temperature and humidity amplitudes occuring on the Altantic, to make use of quarterly data for two stress factors: multi-year mean values of daily temperature calculated for each of four quarters, and multi-year mean values of daily relative humidity calculated also for the quarters.

The elaborated matrix for materials of group A (see Tab. 4.) is of two-dimensions: air temperature and relative humidity, with 1% relative humidity intervals and 1°C temperature intervals. It contains 5000 elements.

The matrix elements are the values, given in hours of laboratory testing time, of sorption stress equivalent to one day of voyage or staying in a port on the Atlantic Ocean area (for standard test in Warm Damp conditions). A part of such matrix is presented in Tab. 4. The matrix is set for A-class materials to which belong in general organic, electro-insulating and non-organic materials.

t °C \ %	100	99	98	97	96	95	94	93	92	91
24	8,97	8,68	8,40	8,12	7,88	7,60	7,31	7,03	6,75	6,42
23	8,45	8,19	7,92	7,65	7,43	7,16	6,90	6,63	6,36	6,05
22	7,94	7,69	7,44	7,19	6,98	6,73	6,48	6,23	5,98	5,68
21	7,43	7,19	6,96	6,73	6,53	6,30	6,06	5,83	5,59	
20	6,92	6,70	6,48	6,26	6,08	5,86	5,64	5,42	5.21	
19	6,40	6,20	6,0	5,80	5,63	5,43	5,22	5,02		
18	5,89	5,71	5,52	5,33	5,18	4,99	4,81			
17	5,64	5,46	5,28	5,10	4,95	4,78	4,60			
16	5,38	5,21	5,04	4,87	4,73	4,56				
15	5,12	4,96	4,80	4,64	4,50	4,34				
14	4,87	4,71	4,56	4,41	4,28					
13	4,61	4,47	4,32	4,17	4,05					
12	4,36	4,22	4,08	3,94						
11	4,10	3,97	3,84	3,71						
10	3,84	3,72	3,60							
9	3,59	3,47	3,36							
8	3,33	3,23								
7	3,07	2,98								

Tab. 4. Daily sorption stress matrix for A-class materials

CALCULATION OF INDICES (EQUIVALENTS) FOR DEGRADATION DUE TO SORPTION STRESS

On the basis of the above described data four maps of Atlantic zone containing sorption stress equivalents were elaborated; one for each year quarter:

- winter: December-January-February
- spring: March-April-May
- summer: June-July-August
- autumn: September-October-November.

Numbers inserted into the map meshes are the values equivalent to sorption stress during one day in a given year quarter. The indices were calculated on the basis of the mean quarterly values of relative humidity and air temperatures.

For ports located on the Atlantic coast the equivalents were calculated from multi-year mean monthly maximum and minimum temperatures, and the mean monthly air humidity measured at 7 a.m. and 2 p.m. The basis for the calculation of the equivalents for Atlantic zone and ports was a modified matrix given in Tab. 4.

Each cell area of the map mesh is described with one index number. Fragments of the maps are shown in Fig. 5 to 8.

Indices calculated for ports are in most cases lower than those for neighbouring open sea mesh cell. It probably results from that the indices for ports were calculated on the basis of pilot books [6], which are based on meteorolgical measurements (weather stations are mostly land-based in some distance from sea side).

It seems therefore that the mean value for a port and neighbouring mesh area should be taken when calculating index value for ships lying in the port.

Moreover, having in mind that the modified matrix differs from the matrix used in CHT method, the mean daily stress in ports N may be calculated from the following formula:

$$N = \frac{2N_{night}}{3} + \frac{N_{day}}{3}$$

where:

N_{night} - stress determined from multi-year meteorological data (the mean monthly relative humidity measured at 7 a.m. and the mean monthly temperature calculated from minimum diurnal temperatures)

N_{day} - stress determined from multi-year meteorological data (the mean monthly relative humidity measured at 2 p.m. and the mean monthly temperature measured at 2 p.m. calculated from maximum diurnal temperatures)

Stress indices given for ports are equivalent to one-day sorption stress in a given year quarter.

The monthly stress indices for ports are more changeable than those for the Atlantic zone, therefore standard deviations of stress values for the most unfavourable month of a given quarter in relation to the mean stress value in that quarter was also calculated. In the most unfavourable month of a quarter the stress is greater than the mean value and are for the mean value :

equal	2 h	- +20%
from	2 to 4 h	- +15%
greater than 4 h		- +10%

Calculation of the mean diurnal sorption stress for a port is examplified in Tab. 5.

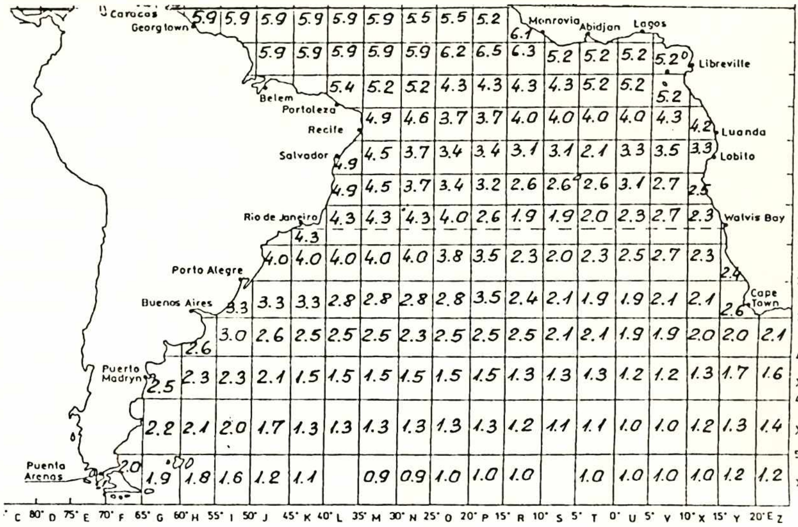

Fig. 5. Sorption stress indices (equivalents) for South Atlantic in winter time: (December-January-February).
Time interval: 1 day of navigation or stay in a port
Index unit: 1 hour of model test in 40±2°C temperature and 97±2% relative humidity
Applicable to: synthetic, electro-insulating and A-class materials, located on exposed decks or in non-heated compartments

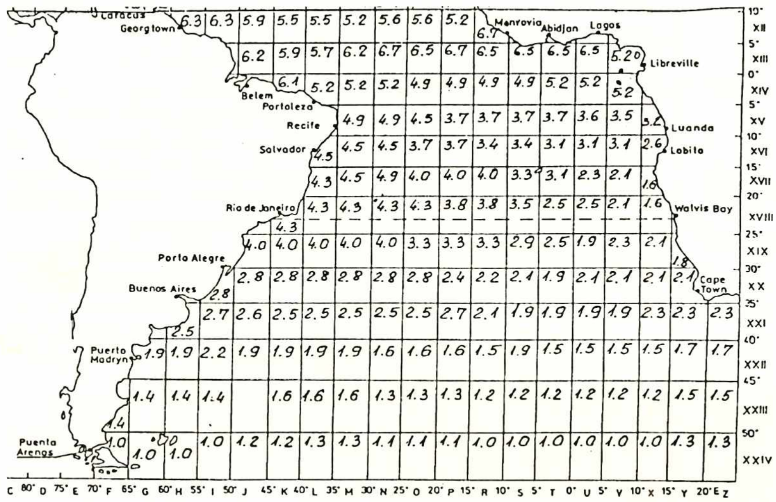

Fig. 6. Sorption stress indices (equivalents) for South Atlantic in spring time: (March-April-May)
Time interval: 1 day of navigation or stay in a port
Index unit: 1 hour of model test in 40±2°C temperature and 97±2% relative humidity
Applicable to: synthetic, electro-insulating and A-class materials, located on exposed decks or in non-heated compartments

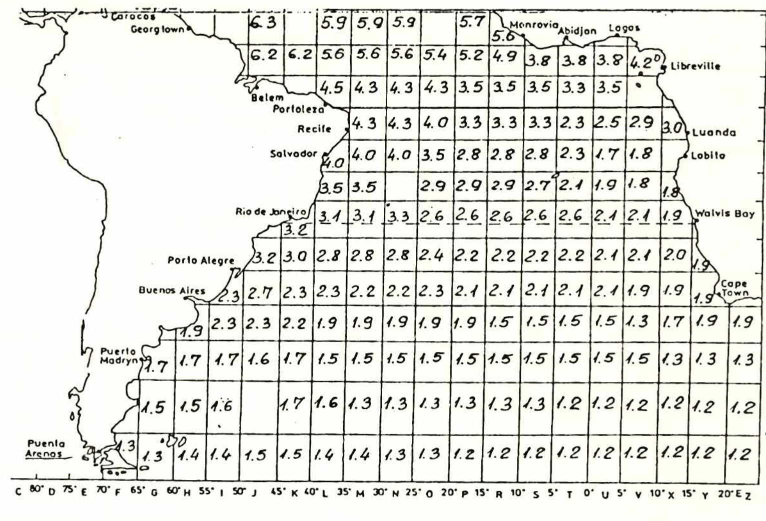

Fig. 7. Sorption stress indices (equivalents) for South Atlantic in summer time: (Juny-July-August)
Time interval: 1 day of navigation or stay in a port
Index unit: 1 hour of model test in 40±2°C temperature and 97±2% relative humidity
Applicable to: synthetic, electroinsulating and A-class materials, located on exposed decks or in non-heated compartments

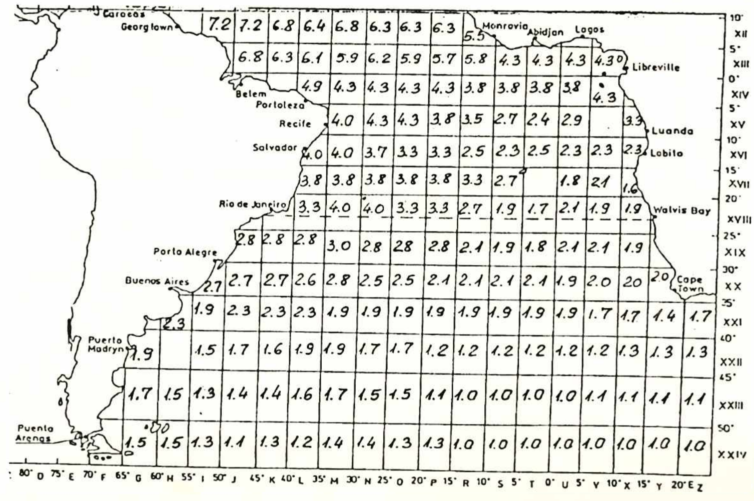

Fig. 8. Sorption stress indices (equivalents) for South Atlantic in autumn time: (September-October-November)
Time interval: 1 day of navigation or stay in a port
Index unit: 1 hour of model test in 40±2°C temperature and 97±2% relative humidity
Applicable to: synthetic, electro-insulating and A-class materials, located on exposed decks or in non-heated compartments

Tab. 5. Example of sorption stress calculations for a ship staying in Hamburg

month	night	day	sum	quarter
1	0,9	0,5	1,4	1,4
2	0,9	0,4	1,3	
3	0,8	0,1	0,9	
4	0,8	-0,1	0,7	0,7
5	0,6	-0,2	0,4	
6	0,8	-0,2	0,6	
7	1,2	-0,1	1,1	1,1
8	1,7	0,0	1,7	
9	1,7	0,1	1,8	
10	1,4	0,3	1,7	1,7
11	1,2	0,5	1,7	
12	0,9	0,5	1,4	
year			14,7	1,2

Numbers given in the table are laboratory test days with test parameters: t=40±2°C, 97±2% relative humidity) in which material stress would be the same as during one-day ship's stay in Hamburg.

Stress indices for most ports of the Atlantic coast were this way calculated. (see Tab. 2 and 3).

SORPTION STRESS PREDICTION FOR SHIP'S ATLANTIC VOYAGE

A prediction method for material degradation in ship's Atlantic voyage was elaborated to check if the applied approach to prediction problem was correct and its implementation possible.

The following procedure has been assumed for that:

* a standard time interval of one voyage-day
* a model test time equal 1 h, equivalent to 1 day
* a map was chosen out of four quarterly maps in accordance with ship's voyage date and her route was traced on it

- then stress indices were step by step read for each day. If a day route crossed two map meshes, the mean of two values given on these mesh cells was taken for calculation;
- for ship's stay in ports stress indices were calculated as the mean value of a port index and neighbouring mesh cell index.

The read or calculated values of diurnal stress indices were chronologically summed up and the sum was taken as equivalent for the entire voyage.

Calculation example was prepared for elements of equipment installed on the deck or in non-heated compartments.

EXAMPLE OF CALCULATIONS

Calculation of equivalent sorption stress in ship's voyage was performed applying data from two sources: the elaborated maps and measurement records of temperature and relative humidity.

Ship's route is shown in Fig. 9. where stress indices for ports visited by the ship, open sea mesh cells crossed by the route, and consecutive days of the voyage are also given.

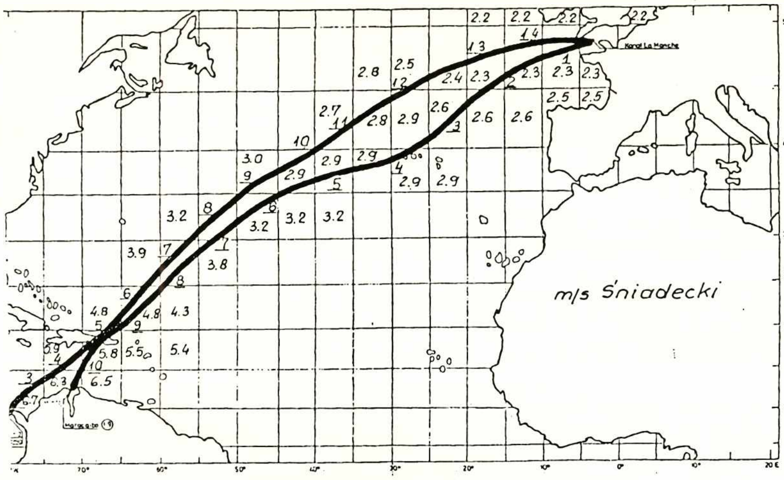

Fig. 9. Ship's route for m/s ŚNIADECKI depicted on the stress index map.

The sorption stress indices, calculated from the two source data for the voyage, are compared in Tab. 6.

Tab. 6. Calculation example of sorption stress indices for a ship's voyage

Ship's route	voyage days	'1'	'2'	ship's route	'1'	'2'
	'there' voyage leg			'back' voyage leg		
English Channel	1	2,3	1,8	Panama Channel	5,6	4,9
Atlantic	2	2,3	2,4	Panama Channel	5,6	4,9
Atlantic	3	2,6	2,9	Carribean Sea	6,5	5,2
Azores	4	2,9	1,5	Carribean Sea	6,3	4,6
Atlantic	5	2,9	3,1	Atlantic	5,3	5,2
Atlantic	6	3,1	3,9	Atlantic	4,6	3,7
Atlantic	7	3,6	5,0	Atlantic	3,7	0,8
Atlantic	8	3,9	1,6	Atlantic	3,2	3,1
Lesser Antilles	9	5,0	3,7	Atlantic	3,1	1,0
Carribean Sea	10	5,3	6,0	Atlantic	2,8	1,5
Maracaibo	11	4,1	5,7	Azores	2,8	2,7
Maracaibo	12	4,1	6,2	Atlantic	2,7	2,3
Maracaibo	13	4,1	4,2	Atlantic	2,3	1,7
Maracaibo	14	4,1	7,6	Atlantic	2,3	2,2
-	15	-	-	English Channel	2,3	2,1
Sum of hours:		50,3	55,6		59,1	45,9

Notation:

"1" - sorption stress indices determined from the maps [h]

"2" - sorption stress indices determined from measurements recorded during the voyage [h]

The sorption stress indices are given in hours of laboratory test time (standard test in Warm Damp conditions: temperature 40±2°C, relative humidity 97±2%). This time is degradation index for the ship's voyage period.

The presented stress indices, calculated on the basis of data from two different sources, differ by 10 to 20% from each other. The differences would be even less substantial after statistical processing of the data from a large number of ship voyages.

CONCLUSIONS

● The Data Bank containing information on stress factors dominating in ship's enviroment and samples of information collected in the bank were presented.

● Proposals on how to apply the degradation prediction method to materials used in ship equipment were also given.

● The example of calculation of stress indices for a given ship's voyage, based on predicted and measured data, showed discrepancies of 10 to 20% only suggesting correctness of the assumed approach.

● The presented method and the Data Bank could be a basis for special expert systems helpful in enviroment aggressiveness assessment, degradation, failure or damage risk assessment, selection of laboratory test type and time for an equipment guaranteed period or required durability, material durability prediction etc.

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Miscellanea

Ship Handling Training Center

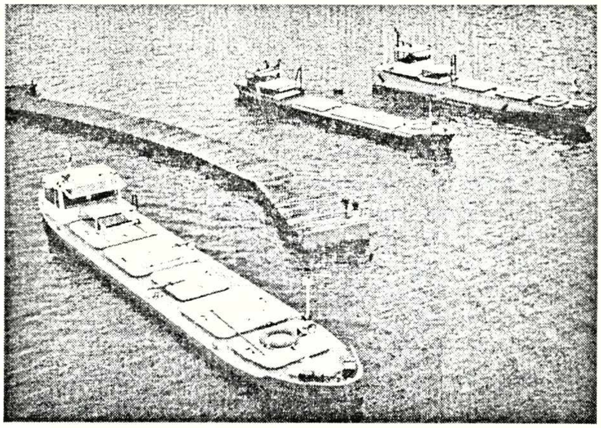
The training and research center in Iława-Kamionka was established 16 years ago, with the aim to provide manoeuvring courses for marine officers and pilots. Over 1000 ship masters, senior officers and pilots received training courses there in manoeuvring vessels of special navigation characteristics. This year the training season has started on May 1 with a series of 6 one-week courses for 42 harbour pilots from Sweden.

Masters and pilots from Norway, Finland, Australia, USA and Equatorial Guinea also expressed their wish to take such courses also.

The growing demand for such courses induced the Foundation of Shipping Safety and Environment Protection, which manages the Center, to invest in its development.

A model of 300 000 tdw supertanker is constructed actually, thus increasing the number of models to 5. The already existing models are: bulk carrier Panamax (scale 1:24), a 146 000 tdw tanker (1:24), a Ro-Ro ship (1:24) and a 25 000 tdw passenger - car ferry (1:16). Another new arrangement is a built-in channel for manoeuvre training and to study some phenomena observed while sailing in channels.

The masters and officers who took training courses in Iława, spread the positive opinion about the Center, thus drawing new clients, said capt. dr B.Łączyński, deputy director of the Foundation. Directors of two similar training centers in Port Reval (France) and Warsash (UK) confirmed that opinion, after they had visited the Center in Iława. They were especially impressed by the system for positioning and monitoring the models and by the models themselves.



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