BOGUSŁAW ZAKRZEWSKI, D.Sc
SERGEY FILIN, Assoc.Prof.,D.Sc.
PIOTR KONIECZNY, M.Sc.
Technical University of Szczecin
Faculty of Maritime Technology

An analysis of energy consumption in refrigerated cargo sea transport

SUMMARY

In the paper a concept is presented of comparing various means of refrigerated cargo sea shipping. Present state of development of this transport branch shows increasing use of the refrigerated containers whose advantages are broadly recognized : standardized cargo lots, very high loading rate, stable storing temperature during the way from producer to receiver. This paper is aimed at assessing also other consequences of increasing use of the containers such as a loss of payload volume relative to that of the refrigerated ship holds, as well as an increase of energy consumption per unit net volume in relation to that of the refrigerated ship.

INTRODUCTION

Application of the refrigerated containers offers many advantages the main of which is stable cargo temperature in the way from producer to receiver (as multiple loading operations are avoided). Recently increasing use of the refrigerated containers in refrigerated cargo shipping is worldwide observed which makes trade of the cargo by the classical refrigerated ships dropping.

The increasing transport of containers by ships results from increasing worldwide turnover of unitized cargoes, including the refrigerated ones, as well as from tight integration of land and sea transport sectors within the so-called refrigerated cargo transport chain. However a new type of containerships adjusted to carrying great number of refrigerated containers has recently appeared [1]. The ship is supposed to show much greater energy consumption per unit volume of shipped cargo, and a decreased payload volume of ship holds in relation to the classical container carrier or refrigerated ship.

The question arises what will be the consequences to energy consumption and volume demand of further development of container shipping. Therefore it is important to compare energy consumption per unit volume of cargo shipped with the use of various transport means.

In the presented analysis the energy consumption rate and volumetric effectiveness of a transport device was assumed the main criterion for assessment of the particular solution. The solution of a greater energy consumption rate or smaller volumetric effectiveness of the shipped cargo as well as that of a greater detrimental impact on marine environment is considered as obsolete and unfavourable one.

REFRIGERATED SHIPS OR REFRIGERATED CONTAINERS ?

Many discussions have recently taken place on the challenge to the fleet of refrigerated ships, caused by the expansion of refrigerated containers into the refrigerated cargo sea shipping. According to many experts it does not mean that traditional refrigerated ships would be completely squeezed out from the market by the container carriers and other ships adjusted to carrying refrigerated containers. From the world sea trade analysis it can be concluded that the refrigerated ships will be further exploited on many shipping routes. The most important premise of the conclusion is that the market of most vegetable products shipped by sea is characterized by huge seasonal fluctuations. It especially concerns the market of fruit shipped from the south hemisphere (bananas, citrus fruit).

In order to provide shipping capacity sufficient for these goods during full season it would be necessary to employ vast number of containers which would be useless outside the season. Moreover the refrigerated containers are seldom carried back loaded on North-South routes.

Therefore their shipping is profitable only in the case if not very large containership's capacity is provided for refrigerated containers.

The above given remarks do not concern the traditional refrigerated ships whose holds are adjusted to carrying different goods, not only vegetables.

However, further increase of employment of the refrigerated containers is expected on East-West routes (USA – Europe, USA – the Far East). Shipping on those routes does not show such very large seasonal fluctuations because of a larger, typical of them, variety of vegetable goods harvested in different seasons of the year.

From the above presented considerations it would result that really there is no competition between full-ship refrigerated cargo shipping by refrigerated ships and that realized with the use of containers carried on other sea-going ships. However, a recently imple-

Tab. 1. Technical data of the analyzed sea-going ships

Technical data	Name or type of ship and its building year					
	B68	JUSTINIAN	PACIFIC	BARRINGTON ISLAND	DOLE CHILE	B170
	1976	1991	1996	1993	1999	1999
Main engine output N_{ME} [kW]	14132	11400	6750	13320	23920	13320
Output of electric energy generating sets N_G [kW]	1920	3100	1200	6440	17280	4621
Number of holds	4	4	4	4	6	4
Net hold volume V_n [m^3]	11277	14573	11283	17631	33914	21048.8
Gross hold volume V_g [m^3]	16669	18806.1	14560.4	22752.4	58243.3	30335.7
Total gross volume (main deck + holds) V_{tg} [m^3]	16669	18806.1	14560.4*	31850.9	105995.7	72279.6
Total net volume V_{tn} [m^3]	11277	14573	11283*	25726.6	54700	57436
Number of containers on main deck [pieces/type]	–	–	27/40'	322/20' (212/40') (148/40') refrigerated	380/40'	1096/20'
Number of containers in holds [pieces/type]	–	–	40/20'	112/20' (56/40')	620/40'	634/20'
N_G/V_{tg} [kW/m^3]	0.115	0.165	0.082	0.202	0.163	0.064
N_G/V_{tn} [kW/m^3]	0.17	0.213	0.106	0.25	0.316	0.08
N_G/V_n [kW/m^3]	0.17	0.213	0.106	0.22**	0.316**	0.08***
V_{tn}/V_{tg} [-]	0.677	0.775	0.775	0.808	0.516	0.795
V_n/V_g [-]	0.677	0.775	0.775	0.775	0.582	0.694
N_G / N_{ME} [-]	0.136	0.272	0.178	0.483	0.722	0.347
Relative energy-consumption of refrigerated cargo shipping means (DOLE CHILE data taken as 100%) $(\overline{N}_{Gr})_t$ [-]	53.8	67.4	33.5	79.1	100	25.3
Relative energy-consumption of refrigerated cargo shipping with only ship holds accounted for $\overline{N}_{Gr}$ [-]	53.8	67.4	33.5	69.7	100	25.3

* *values obtained without accounting for on-deck containers*

** *values determined at the assumption that the power demand of 40' container is the same as that in the case of the DOLE CHILE, hence the power N_G was reduced by the product of the number of the refrigerated containers and their average power demand (17.28 kW)*

*** *value determined with accounting for technical conditions of refrigeration of the holds* mented solution such as the refrigerated containerships probably indicates a quite new trend.

The question arises if the two above mentioned cargo shipping methods complement one another. What does decide of the choice of a new ship design ? Which of the parameters such as : amount of cargo shippment, freight rate, total shipping cost, cargo delivery time etc, are taken into account ? It should be rather concluded that both shipping methods are in the phase of mutual competition, and in the future each of them will go its own way of development and find its own area of application, which challenges opinions expressed in [8] and [20].

ENERGY AND VOLUMETRIC ASSESSMENT INDICES OF TRANSPORT MEANS

Refrigerated ships and refrigerated containerships

In Fig.1 some technical data are presented of the following sea-going ships to be compared :

B68	– the refrigerated fishing transport ship [6]
JUSTINIAN	– the refrigerated ship [5]
PACIFIC	– the refrigerated ship [10]
BARRINGTON ISLAND	– the refrigerated ship carrying refrigerated containers [1]
DOLE CHILE	– the refrigerated containership [4]
B170	– the containership [23] (taken as a basis for comparison).

From the data presented in Tab.1. and Fig.1. it can be observed that the power output of electric energy sources installed on the particular ships is very different.

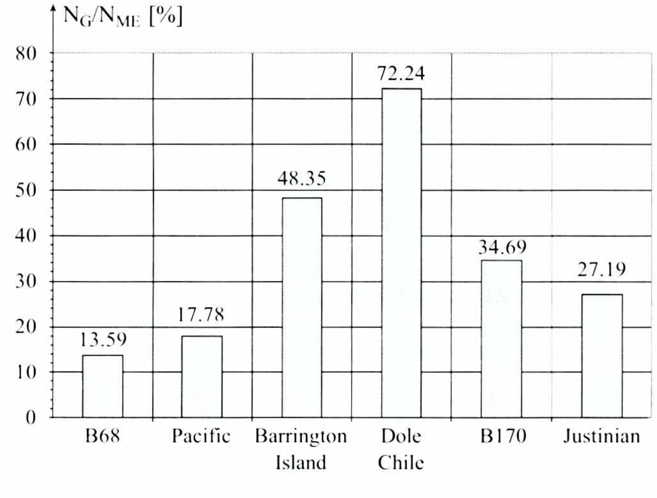


Fig.1. Ratio of power output of electric energy generating sets to that of the main engine

The power output of the generating sets installed in the refrigerated containership DOLE CHILE is the largest, somewhat smaller – in the refrigerated ship adjusted for carrying refrigerated containers, BARRINGTON ISLAND, and even smaller – in other refrigerated ships.

Another index of importance seems to be the power output of electric generating sets related to the total net volume :

$N_{Gr} = N_G/V_{tn}$, presented in Fig.2.

The largest value of the index, out of those for the considered ships, belongs to the refrigerated containership DOLE CHILE, amounting to N_{Gr} = 0.316 kW/m³, somewhat smaller for the BARRINGTON ISLAND, N_{Gr} = 0.250 kW/m³, smaller for the JUSTINIAN, N_{Gr} = 0.213 kW/m³, and even smaller for the remaining refrigerated ships, down to 0.106 kW/m³. Of course, the smallest value (0.08 kW/m³) is for B170, the typical container carrier.

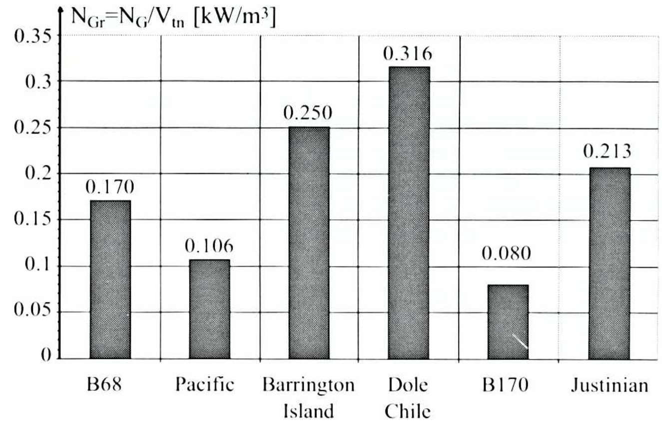


Fig.2. Power output of electric generating sets per unit total net volume, for the considered ships

Relative values of N_{Gr} index (related to the N_{Gr} value for the DOLE CHILE) are shown in Fig.3.

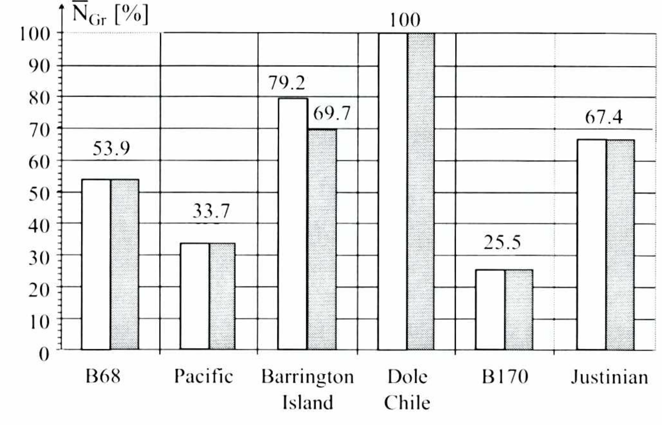


Fig.3. Relative $\overline{N}_{Gr}$ values of power output of electric generating sets per unit net volume of the considered ships („Dole Chile" data taken as 100%)

□ *Refrigerated cargo shipping energy consumption index for the entire ship*
□ *Refrigerated cargo shipping energy consumption index for ship's holds only*

For JUSTINIAN refrigerated ship the value amounts to 67.4 %, and for B68 refrigerated ship and the PACIFIC : 53.8 % and 33.5 %, respectively. For the BARRINGTON ISLAND two different values are obtained : 79.2 % for the entire ship together with containers, and 69.7 % for the case of taking into account only the energy necessary to freeze cargo in the holds (without containers). For the typical container carrier the index value amounts to 25.3 % only. However linking the output of the genenerating sets with operation of either only a refrigerating plant or refrigerated containers is obviously doubtful, as also other devices, not connected with the refrigerating plant, could be simultaneously supplied. Nonetheless in the case of high thermal load of the refrigerating plant during carrying refrigerated cargo the electric generating sets should ensure appropriate operation of the plant, otherwise it could be harmful for the precious cargo in holds.

It is rather hard to precisely assess which part of the generating sets' output is used for supplying the refrigerating plant only as the other electrical equipment of the considered ships is very different. However the proposed index well illustrates output levels of the electric energy sources installed in various sea transport means.

In Fig.4 results are presented of power demand calculations of a ship refrigerating plant at different working modes (temperatures) [9]. The calculations concern the JUSTINIAN only as data for other ships were not available. It results that the maximum load can occur during loading operations in the port. Therefore the electric generating sets have to ensure the energy supply of that level to the refrigerating plant at the main engine stand-by. On the basis of the calculations the power demand per unit net volume of the holds, N_{cr}, was determined, as shown in Fig.4.

From the analysis of those data it results that the power demand per unit net volume N_{cr} is contained within the range from 0.03 to 0.075 kW/m³. The index values are much lower than those of the N_{Gr} index for the generating sets installed in the ships under comparison. However, the results do not much differ from the values $N_{Gr} = 0.106$ kW/m³ obtained for the refrigerated ship PACIFIC. For the remaining ships N_{Gr} index values are much higher, especially those for the refrigerated containership. Hence it is necessary to analyze power demand of refrigerating plants serving the containers.

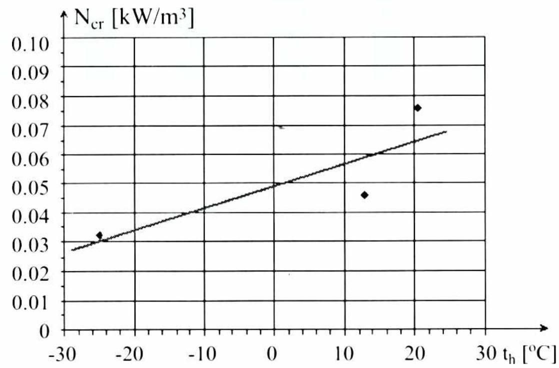


Fig.4. *The calculated power demand per unit net volume of the holds, N_{cr}, versus the working temperature t_h, for the JUSTINIAN*

If it is assumed that the typical containership and the refrigerated containership have a similar power demand for other purposes than refrigeration, then the power demanded for refrigeration only could be assessed as the difference of the N_{cr} index values for the two ships :

$$0.316 - 0.08 = 0.236 \text{ kW/m}^3.$$

Therefore the approximate value for the refrigerated containership seems to be many times higher than that for the refrigerated ship.

VOLUMETRIC CHARACTERISTICS OF THE REFRIGERATED COMPARTMENTS

Thermal insulation of the refrigerated compartments takes up some part of hold volume, which results from a compromise between tending to limit heat inflow and loss of load-carrying capacity. A value of the heat-transfer coefficient k is selected in dependence on a kind of use of the compartment in question and its working temperature range. From the selected k value results a calculated heat loss value, and on this basis after assuming a kind of insulation material (its λ), the insulation wall thickness can be determined. Moreover, in the modern refrigerated compartments air circulation is forced by means of fans. Capacity of the fans depends on the kind of cargo (for instance : meat – – 40 changes of air per hour, fruit – 120 changes of air per hour).

Therefore a greater or smaller part of the hold volume is occupied by air coolers, fans, air ducts and other elements of ventilating system, depending on its design. In order to assess the total volume loss it is necessary to determine the following :

V_g – gross hold volume [m³]
V_{is} – insulation volume [m³]
V_{CO} – volume occupied by air coolers and ducts fitted in the holds [m³]
V_n – net hold volume [m³].

Approximate ratios of these parameters are as follows :

$$V_{is} / V_g = 0.1 \text{ to } 0.3$$

$$V_{CO} / V_g = 0.1 \text{ to } 0.2$$

$$V_n / V_g = 0.6 \text{ to } 0.7$$

Values of the V_n / V_g ratio calculated for some of the considered ships are given in Tab.1 and Fig.6.

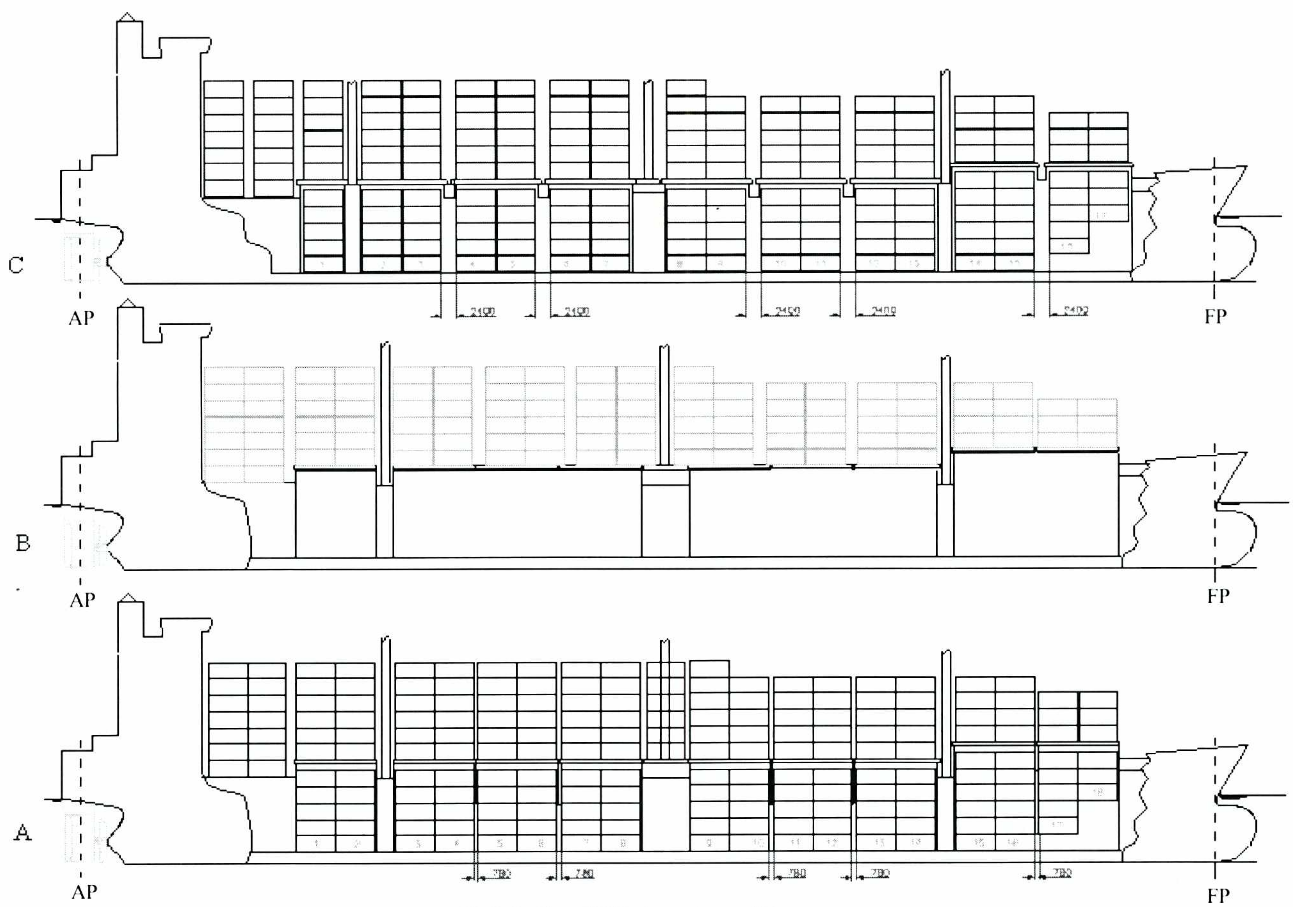


Fig.5. *Profiles of B170 ship and its modifications :*
A *- basic version (typical containership),* ***B*** *- refrigerated ship,* ***C*** *- refrigerated containership*

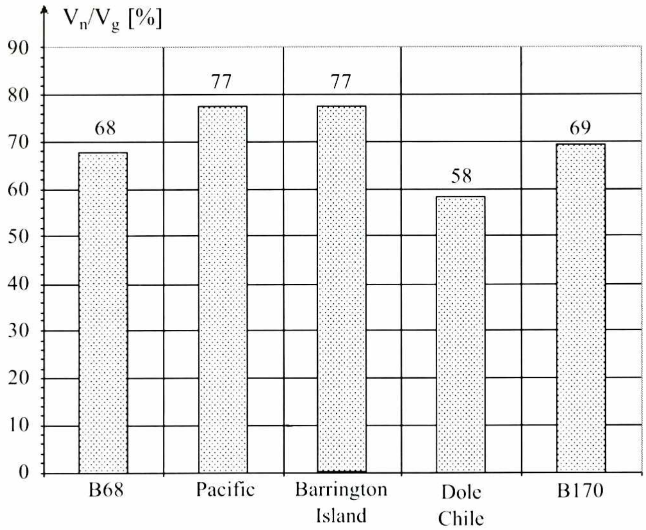


Fig.6. *V_n / V_g percentage values for some of the considered ships*

The values of V_n/V_g ratio, presented in Fig.6. indicate that the ship's space is much better utilized in the refrigerated ships : 68% at B68 ship, 77% at the PACIFIC and the BARRINGTON ISLAND, and only 58% at the refrigerated containership DOLE CHILE. For a typical containership, B170, the ratio value is somewhat higher and amounts to 69% as the typical, non-insulated containers and smaller inter-container spaces were taken into account.

The obtained difference of almost 20% between the refrigerated ship and refrigerated containership seems to support the necessity of very careful consideration of possible resigning from the use of refrigerated ships.

In order to compare consequences of different design solutions respective to their volumetric characteristics typical containership B170 was selected as the reference version (A) and its modifications as comparative versions to be analyzed : the refrigerated ship as version (B), and the refrigerated containership – as version (C) (see Fig.5).

For the refrigerated containership (C) the net volume was calculated as the product of net container volume V_n and number of containers, n, according to catalogue data, and its gross volume V_g – – on the basis of the following formula :

$$V_g = nV_g + \Delta V_1 + \Delta V_2 + \Delta V_3$$

where :

V_g - gross container volume (calculated from its gabarites)
ΔV_1 - space between containers and hold structure
ΔV_2 - space occupied by ventilating system in the holds (assumed as total between-hold volumes)
ΔV_3 - space between containers.

V_g value for the refrigerated ship (version B) was assumed identical to that of the basic containership (version A).

On the refrigerated containership free spaces between the containers were so enlarged as to make heat transfer by means of the ventilation system possible (as the refrigerating systems of the containers were assumed to be used). The number of containers in holds was assumed smaller by one row to obtain a sufficient space for the ventilation system and access for maintenance of the refrigerated containers. V_g volume was practically calculated from the first to the last row of the containers together with the inter-hold spaces. Result of the calculations is presented in Fig.7.

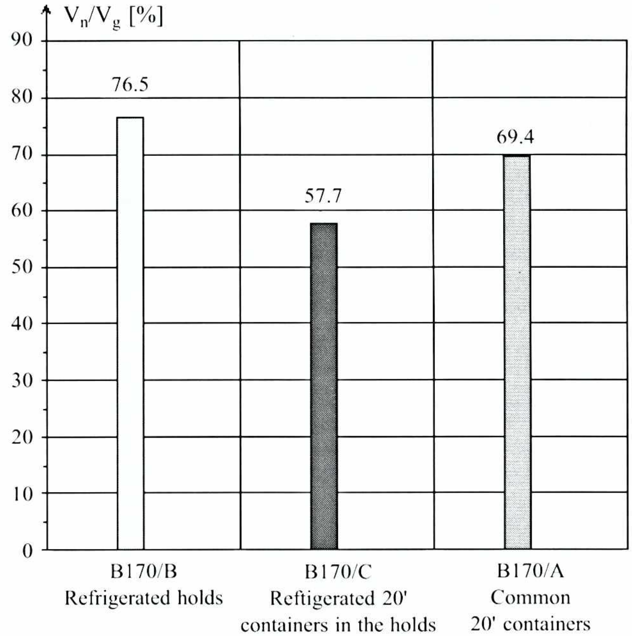


Fig.7. *Volumetric effectiveness of three analyzed versions of B170 containership Vn/Vg values in B and C versions were determined with accounting for technical conditions of refrigeration of the holds (B version) or carriage of refrigerated containers (C version)*

In result three different values of the volumetric effectiveness index V_n/V_g were obtained : the greatest – 76.5% for version B, the smallest – 57.7% for version C and 69.4% for version A. The differences should be carefully considered during choice of a design solution.

REFRIGERATED CONTAINERS

New technical solutions of the refrigerated containers respective to, among others, effective and reliable insulation, efficient refrigeration units, air circulation, temperature keeping and application of controlled air mixtures, resulted in more durable, safer, lighter and possibly less expensive transport units. broadly applied in shipping cargo from producer to consumer, irrespective of distance and variety of the engaged transport means.

Tab.2. *Characteristic parameters of some 20'refrigerated containers*

Type / Producer	Seacold 1 [19]	Refcon-Indo [17]	ISO 1CC [18]	Refrigerate D20'RE/Graaff elze F.R.G., Klinge, Denmark [13]	Daikin 1 [14]	Polar Box [12]	Mean value
Net volume v_n [m^3]	28.18	26.9	27.76	27.2	28	28.19	27.71
Gross volume v_g [m^3]	38.27	38.27	38.27	38.27	38.27	38.27	38.27
Heat transfer coefficient k [W/m^{2}K]	0.4	–	0.39	0.37	–	0.39	0.39
v_n/v_g [-]	0.736	0.703	0.725	0.711	0.732	0.737	0.724

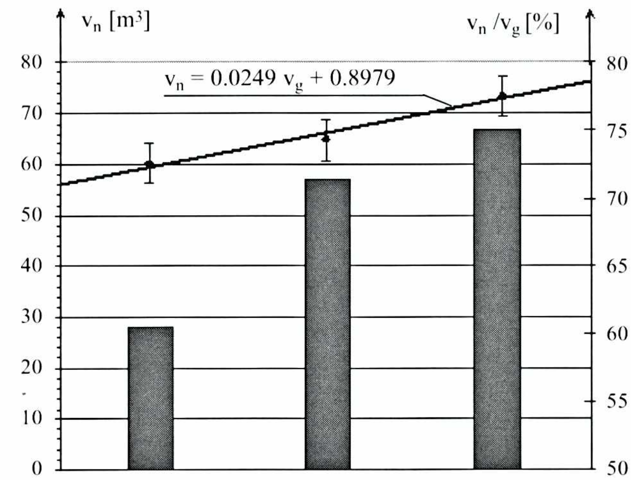
Tab.3. Characteristic parameters of some 40' refrigerated containers

Type/Producer	Net volume v_n [m³]	Gross volume v_g [m³]	Heat transfer coeff. k [W/m²K]	v_n/v_g [-]
Seacold 2 [19]	58.76	77.02	0.34	0.763
ISO 1AA [18]	58.7	77.02	0.37	0.762
Refrigerated 40'RE/Trailor France-Lefroid Ind.York [13]	54.7	77.02	0.29	0.71
Refrigerated 40'RE/Fruehauf France-Lefroid Ind.York [13]	54.25	77.02	0.28	0.704
Refrigerated 40'RE/ Graaff elze F.R.G. 1 – Carrier [13]	57.5	77.02	0.37	0.747
Refrigerated 40'RE/ Graaff elze F.R.G. 2 – Carrier [13]	57.5	77.02	0.33	0.747
Daikin 2 [14]	59	77.02	–	0.766
Finsam [16]	66.2	86.08	0.33	0.769
ISO 1AAA [18]	68	86.08	0.37	0.79
Daikin 3 [14]	66	86.08	–	0.767
Mean values for 40'cont. (ISO 1AA)	57.2	77.02	0.33	0.743
Mean values for 40' cont. + (ISO 1AAA)	66.73	86.08	0.35	0.775

Characteristic technical parameters are presented of the refrigerated containers offered by several producers : for 20' containers in Tab.2.and for 40' containers in Tab.3.

The mean value of the net volume of the 20' refrigerated containers of six producers amounts to v_n = 27.71 m³, and its ratio v_n/v_g = 0.724. For 40' refrigerated containers of seven firms the ratio amounts to 0.743, and for the containers together with those of another three firms – 0.775. The increasing volumetric effectiveness along with increasing size of the containers can be observed. From this point of view the largest containers are the most favourable. In Fig.8 the v_n mean value is linearly approximated in function of v_g.

In Tab.4 power demand of refrigeration units of some containers are presented as well as the power per unit net volume relevant to the mean net volume of 20' containers equal to 27.71 m³ and that of 40' containers equal to 57.2 m³.



v_g [m³]	1CC(38.27)	1AA(77.02)	1AAA(86.08)
v_n [m³]	27.76	57.2	66.73
v_n/v_g [%]	72.54	74.27	77.52

Fig.8. Mean value of the net volume of different refrigerated containers

Tab. 4. Power demand of refrigeration units of 20' and 40' Daikin containers [2],[3]

Type of device	Internal/external temperature of the container : 0/38°C	Internal/external temperature of the container : -18/38°C
Power demand of 20' LXE5C refrigeration unit [kW]	7.36	5
Power demand of 40' LXE10CA refrigeration unit [kW]	10.3	7.95
Power demand per unit net volume of 20'container, N_{cr} [kW/m³]	0.264	0.18
Power demand per unit net volume of 40'container, N_{cr} [kW/m³]	0.18	0.139

In Fig.9 the unit power demand N_{cr} is presented in function of the gross volume of the containers at the temperatures 0/38°C, -18/38°C of the 20' and 40' containers.

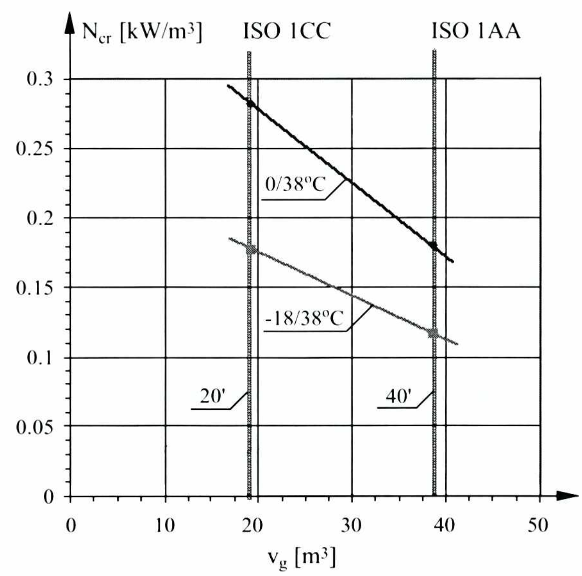


Fig.9. Power demand of refrigeration units, per unit net volume, N_{cr}, of 20' and 40' containers in function of their gross volume v_g, at the internal/external temperatures : 0/38°C, -18/38°C respectively.

The unit power demand ratio $N_{cr}(20') / N_{cr}(40')$ is shown in Fig.10.

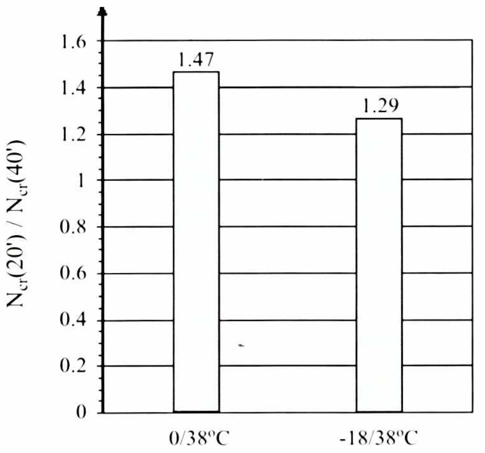


Fig.10. *The unit power demand ratio $N_{cr}(20') / N_{cr}(40')$ at the internal/external temperatures : 0/38°C and -18/38°C respectively.*

It results from Fig.10 that the ratio is much greater than one in both analyzed temperature conditions : at 0/38°C the unit power demand of 20' containers is about 1.5 times greater than that of 40' containers, and at -18/38°C about 1.3 times greater.

In Fig.11. the unit power demand of the containers, N_{cr}, is presented in function of the refrigerated hold temperature t_h, and in Fig.12. values of the unit power demand of the 20' and 40' containers are compared to that of the holds of JUSTINIAN refrigerated ship in function of the temperature t_{CO} .

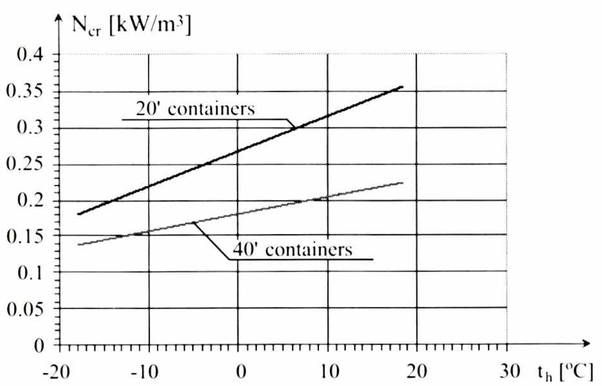


Fig.11. *The unit power demand N_{cr} in function of the refrigerated hold temperature*

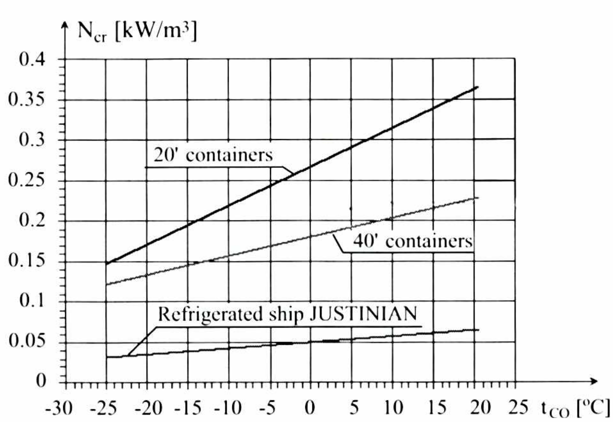


Fig.12. *The unit power demand of the 20' and 40' containers, compared to that of the holds of JUSTINIAN refrigerated ship, in function of the temperature t_{CO}*

It results from the comparison that the amount of energy (per unit net volume) to be supplied to the refrigerated containers is several times greater than that required by the refrigerated ship holds. This clearly demonstrates that the cargo transport by means of the refrigerated containers is of some serious disadvantages to which belongs first of all its low energy effectiveness decreasing along with decreasing amount of the refrigerated cargo. Even 40' containers consume more energy per unit net volume than the refrigerated ship hold.

The design solutions with an additional refrigerating plant installed in the containership make it possible to spare some energy demanded for refrigerating the cargo, but such systems are also less efficient than that of the refrigerated ship. Moreover a complex air channel system for ventilating the containers generates many troubles. Simultaneously, investment cost of such containership is higher as the ship must have the refrigerating plant capable of serving a considerable number of containers. Hence the development trend of shipping the refrigerated cargo in containers contributes to increasing energy consumption and thereby CO_2 emission to atmosphere. Therefore the refrigerated containers are also more detrimental to environment. From that point of view shipping the refrigerated cargo by means of refrigerated ships is more favourable.

CONCLUSIONS

On the basis of the performed comparison of unit energy amount and net volume demanded for shipping the refrigerated cargo by various transport means the following conclusions can be offered :

- The electric power plants installed in different ships intended for shipping the refrigerated cargo are of very diversified output which demonstrates that a new approach to the energy consumption problem is necessary, especially in the light of wider and wider use of the refrigerated containers.
- The power output of electric generating sets per unit net volume of holds, N_{Gr}, is about two times greater for the refrigerated containership than that for the refrigerated ship.
- Similarly, the energy demand per unit net volume N_{cr} of refrigerated containers is very different depending on the size of containers and their thermal conditions: for 20' containers from 1.29 to 1.47 greater than for the 40' ones.
- The unit power demand N_{cr} of the refrigerated containers is from about three to four times greater than that for the holds of refrigerated ships.
- The volumetric effectiveness of refrigerated containerships is by about 20% smaller than that of the usual refrigerated ships.
- It seems necessary to search for ways for improving the energy consumption and volumetric effectiveness indices of the refrigerated containers as well as of the entire shipping system which uses them.

Appraised by Eduard Partskhaladze, Assoc.Prof.,D.Sc.

NOMENCLATURE

N	- power
N_{cr}	- refrigeration unit power demand related to net volume of a refrigerated compartment (hold or container)
N_G	- power output of electric generating sets
N_{Gr}	- power output of electric generating sets, related to the hold - or total volume
N_{ME}	- main engine power output
t_{CO}	- refrigerated compartment internal temperature
t_h	- temperature in the hold
v	- container volume
V	- hold volume
V_t	- total volume (of main-deck containers + holds)

Indices

g	- gross
n	- net
r	- related
t	- total

BIBLIOGRAPHY

1. *Barrington Island : a „green" reefer ship*. Significant Ships of 1993
2. *Daikin Container Refrigeration & Heating Unit Using New Refrigerant (HFC 134a)*, FR 94 04
3. *Daikin Marine Type Container Refrigeration Unit. Service Manual*. Daikin industries Ltd, TR94-02B
4. Hunsalzer G., Mechsner A.: *Dole-Kuehlkontainerschiff –Jumbos*. Hansa-Schiffbau-Hafen, No 12, 1999
5. Iwański E. : *Statki polskie : B369/1 „Justinian"*. Budownictwo Okrętowe i Gospodarka Morska, nr 10, 1991
6. *Karta o stanie technicznym m/s Wineta*. 17-06-1994
7. Nowakowski L. : „Konkurencja kontenerów chłodzonych z chłodniowcami". Biul. CTO „Stocznie, porty i żegluga", nr 2, 1995
8. Oględcki R., Zakrzewski B.: *Nowoczesny chłodniowiec*. Chłodnictwo, nr 7, 1999
9. Oględcki R. : *Projekt wstępny urządzenia chłodniczego nowoczesnego chłodniowca*. Praca dyplomowa (niepublikowana). Politechnika Szczecińska, Wydział Techniki Morskiej. Szczecin, 1998
10. *Pacific – fitted with improved refrigeration systems*. Significant Ships of 1996
11. Klinge P. : *Specification of refrigeration unit – model TNE 556-02 for 20' refrigeration containers*
12. *Reefer container repair manual & spare part list. Model/type : 2212* . Polar Box, Gothenburg, 29-09-1992
13. *Polcontainer : Technical specification 1997 (revised & updated)*. Container service. Gdynia
14. *Marine container refrigeration unit applying the new refrigerant (HFC 134a)*. Products guide, Daikin Industries Ltd. June 1994
15. *Reefers : An industry cooling to economic demands*. International Shipping Review. 1994
16. *Reefer container 40'*. A/S Finsam international Inc.
17. *Refrigerated containers 20'. Aluminium with Corten Frame*. Refconindo.
18. Germanischer Lloyd : *Regulations for the Construction, Repair and Testing of Freight Containers*. GL 1988. Utech Asia '97
19. Seacold Reefers Types RS2 & RS4. Models 012A (20') & 011 (40')
20. Szymański T., Wasiluk W. : *Chłodniowce czy kontenery chłodzone to przyszłość przewozu ładunków chłodzonych*. Technika chłodnicza i klimatyzacyjna, nr 8, 1996
21. Urban J. : *Chłodniowce przyszłości*. Biul. CTO „Stocznie, porty i żegluga", nr 4, Gdańsk, 1995
22. Zakrzewski B., Haberek J. : *Badanie termiczne kontenerów chłodniczych*. Chłodnictwo nr 3, 1994
23. *50 lat –Stocznia Szczecińska*. Wyd. Studio 69. Szczecin 1998.

Conference

SCIENTIFIC--ORGANIZATIONAL MEETING OF ZTM

On 9 November the last-of-the-year meeting of Marine Technology Unit (ZTM), Polish Academy of Sciences, was held in Szczecin, hosted by Faculty of Marine Technology, Technical University of Szczecin.

During the scientific part of the meeting two papers prepared by the Faculty's workers, were presented :

- *Evaluation of possible application of FSA method to safety assessment of shipboard equipment* - by W.Rosochacki
- *Ultimate strength of ship hull structure under bending and compression loads* - by M.Taczała

After interesting discussion on both topics ZTM activity in the passing year as well as its plans for the next year were discussed.

Conference

NEW MARITIME IMPULSES IN THE PRESENCE OF A NEW CENTURY

Under this heading 2nd International Congress on Maritime Technological Innovations and Research was held on 8÷11 November 2000 in Cadiz.

A group of Polish scientific workers also contributed with 12 papers to the Conference's program which contained about 200 papers prepared by the maritime economy circles from 20 countries and all continents. The papers were presented within three topic groups, namely :

Theme A
Maritime way for sustainable mobility

- *The system of safety in Polish waters* by T. Stupak, Gdynia Maritime Academy
- *The concept of application of fuzzy sets theory to calculate stability characteristics of ro-ro passenger ferries* by Z.Szozda, Maritime University of Szczecin
- *Application of the Japanese liquefaction potential tests* by M. Popek, M. Rutkowska and Z. Michałowski, Gdynia Maritime Academy
- *Decision support for loading of vessels – selected numerical problems* by W. Filipowicz, Gdynia Maritime Academy
- *Fatigue properties of girder intersection* by J. Kozak, Technical University of Gdańsk
- *DGP system improves accuracy of bathymetric and dredging work in West Pomerania* by A. Dołgopołow, Maritime Office, and A. Wolski, Maritime University of Szczecin

Theme B
Efficiency and quality

- *New criteria of separation of oxidizes and ammonium salts in marine transport* by Z. Michałowski, K. Kwiatkowska--Sienkiewicz, M. Rutkowska and K. Barcewicz, Gdynia Maritime Academy
- *Terrestial and satellite radionavigation systems at the turn of XX century* by J. Januszewski, Gdynia Maritime Academy
- *Ship nonlinear autopilot* by L. Morawski, J. Pomirski, Gdynia Maritime Academy and H. Siguerdidjane, SUPELEC (France)

Theme C
Human factors

- *Deck officers' training by means of simulators* by R. Wawruch, Gdynia Maritime Academy
- *Implementation of the provisions of the 78/95 STCW convention into activity of Polish Maritime Universities* by A. Walczak, Maritime University of Szczecin
- *Evaluation of the injury potential by evacuation with the use of free-fall systems: focus on the causalities in marine accidents* by Z. Wiśniewski, Gdynia Maritime Academy