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Management of assignment of operational tasks realized in ship power plant

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ABSTRACT

The frequent cause of ships' detentions by port authorities are abnormalities of ship power plant functioning. Each extended ship lay time in port results in waste of ship operating time thus costs rise to shipowners. This is connected with improper ship power plant management. In order to avoid this, a ship engineer should have at his disposal computer aided system supporting him in managing of ship power plant. Such a system can be worked out on condition that mathematical formula which represents the decision – making process of an engineer has been built. The present work shows approache to the problem according to the situation in which the engineer is made to take certain decisions. In formulation of the most substantial operating states of a ship like lay time in harbour and sea voyage the ,knapsack algorithm' was applied. For both approaches objective function was formulated.

Keywords: ship power plant, management

INTRODUCTION

According to many experts to reach correct management of ship power plant involves great difficulties to decision-making persons, i.e. ship chief engineers. This is caused a.o. by:
- increasing number of automated ship systems
- multiple number of operational processes executed in parallel
- lack of appropriate information making it possible to quickly master systems and task planning
- frequent changes of staff members
- increasing number of requirements for safety of persons, ship and environment.

Moreover changing international maritime law imposes many additional tasks dealing not only with new procedures connected with safety at sea but also with their detail documentation.

Such state leads to a situation in which decision-making is more and more difficult and knowledge and experience of ship engineers may appear insufficient. In such conditions making a decision dealing with power plant management may be incorrect or irrational and in consequence causing various losses, e.g. loss of ship service time leading this way to increasing overall cost of ship operation. In order to eliminate such situations ship engineers should have at his disposal a software which could be a „tool" aiding him in organizing ship power plant management process. Such system would collect information concerning realization of all operations in power plant or make use of data bases of already functioning information systems, analyze any limitations associated with their realization and finally advising ship engineer on which tasks and in which sequence they have to be realized.

In ship power plant a team often consisted of several persons performs operations resulting from realization of many tasks of different time horizons, realized in parallel.

This requires, from chief engineer, to make rational decisions concerning a.o. determination of a kind, range, sequence and executors of operations. To make such decisions it is necessary to collect and process suitable information. Among other, the following can serve as their sources:
- technical and operational documentation of machines and installations, requirements associated with safety at sea and marine environment protection (conventions, codes, rules of classification societies, rules of maritime administrations, ship owner's regulations etc)
- data bases of information systems used in ship power plant
- assessment of technical state of ship power plant machines and systems
- assessment of state of provisions (fuels, lubricants, spare parts etc)
- occurrence of a destructive event, e. g. machine failure
- assessment of feasibility of appropriate actions, e.g. expected time of port staying, deadline of subsequent shipyard's repair etc
- assessment of accessibility of an external service in a given shipping region
- assessment of capability of crew to realize planned operations
- assessment of crew experience associated with carrying out given kinds of operations [4].

All the information may appear or be used during decision making process in various service states of ship. Generally ship's service process can be represented by a sequence of three main states:

- staying in port (loading – reloading)
- manoeuvres (in ports, channels etc)
- sea voyage.

In the above presented states disturbances may appear as a result of e.g. changes of ship motion parameters (or ship stopping) or a longer time of ship staying in port.

The main problem to be solved by ship chief engineer within the scope of ship power plant management can be formulated as follows:

„Knowing a set of tasks to be realized as well as taking into account available means (technical, personnel and time resources),operational requirements concerning ship, as well as limitations of different kind, one should make choice of appropriate operations and integrate them into one ordered set of actions".

In other words the thing is that a decision should be taken as to such above mentioned operations whose realization would be most effective from the point of view of ship service.

FORMULATION OF DECISION-MAKING PROBLEM OF SHIP ENGINEER

From the operational point of view the best (optimum) plan of the tasks which are necessary to be realized in a given operational situation constitutes the solution of the decision problem faced by ship engineer.

Analyzing situations in which ship engineer may be forced to solve the presented decision problem one can distinguish several, different to each other ways of its formulation. For instance, the first situation of the kind is that in which a ship continues a long sea voyage. In such situation there are no strict time limitations as to realization of ship power plant operation process as well as to particular operational tasks. So, the decision problem can be formulated as a planning process without any time limitations. However the tasks should be effectively planned with the use of available personnel and material resources as well as with taking into account the instant of realization of a given task, imposed by external factors such as: requirements resulting from regulations given by producers of ship machines and devices, classification societies, port control (*PSC*) etc.

The other situation is that in which strict time limitations are present such as e.g.: during ship staying in a port where the ship's strict departure time is known and number of the tasks to be realized is usually much greater than that possible for crew of power plant. In such situation the chief engineer must make decision regarding which of the operational tasks should be made during the time being at his disposal and which could be postponed to another time as well as who should be assigned to execute particular tasks. In such moment, making incorrect decisions can cause non-fulfilment of the tasks, that consequently may result e.g.: in stopping the ship by port control (*PSC, FSC*) or subsequently in breaking the normal process of ship power plant operation (e.g. *black-out*). The decision problem in such situation can be formulated as the choice of the crucial tasks from the point of view of ship power plant operation and planning them in such a way as to make use of the available time most effectively.

Another situation is that in which both the strict time limitations are present and one aims at the best making use of the available resources, where the features of the first above described situation and the other one are combined in a sense. Such formulation of the decision problem may concern the situation when a ship undergoes repair in a shipyard.

In ship operation many other situations (ship service states) can also happen such as e.g.: lying at anchor, manoeuvres, canal passing etc, in which the chief engineer may be forced to take decisions dealing with planning the operational tasks. However such states constitute a very small part of overall operational time of ship as they appear very rarely during its service process, or a situation requires to promptly make decision regarding a way of action to be undertaken (e.g. manoeuvres in port) where possible making use of a computer system is not rational.

In this connection for further considerations only two - out of the presented service states - namely: sea voyage and staying in port, are taken into account.

In the general theory of decision making the decision problem is such situation in which decision maker faces necessity of choosing one – out at least two possible – variants of acting. In ship power plant the chief engineer must take decision on which of the acting variants (sets of sequenced operations) would be the best from the point of view of ship service. According to the definition of the problem faced by ship engineer, he must, out of all operations to be executed, select and sequence as well as assign (to respective members of machinery crew) the most important ones in a given operational situation taking into account all relevant conditions and limitations.

On the basis of the general, formal theory of decision making the overall form of the management problem of operations in ship power plant, can be presented as follows:

$$PD_{ZSO} = (Z_Z, Z_O, r) \tag{1}$$

where:

PD_{ZSO} – Decision making problem of ship power plant management

Z_Z – set of operational tasks

Z_O – set of operators

r – relations appearing between elements, operators, tasks etc.

The decision problem of technical management of ship power plant, (PD_{ZSO}), is defined as the following triple: the set of decision variables, Z_Z, (i.e. the set of all operations to be executed), the set of operators to which appropriate operations should be assigned, Z_O, as well as that of the relations r understood as the relationships between elements of the sets Z_Z and Z_O and also containing some features of the elements.

In the process of decision making by ship engineer dealing with assigning the operational tasks to power plant crew members the following three main phases should be distinguished:

- collecting and processing all available and necessary data (those earlier mentioned and those presented in [4])
- selecting the tasks whose realization is constrained by all possible operational limitations as well as ambient conditions in which a given decision is made [3]
- assigning the earlier selected tasks to power plant crew members, in compliance with their competences so as to obtain the best schedule from the operational point of view [1, 2].

In this work only the latter presented stage is considered, i.e. the assigning of the operational tasks to ship power plant operators with imposing the additional time limitation T_S in which the tasks have to be realized (e.g. short stay in port, short sea voyage etc). In the situation, strategy of task assigning can be based on two aims: maximization of sum of values of the tasks included into the schedule or the most effective use of the available time T_S.

The problem of planning the operational tasks in ship power plant in the case of both the aims, can be presented, like many problems, as the problem of packing (in other words: knapsack problem or loading problem) being a special cause of zero-one problems of linear programming [6, 7]. The zero-one character consists in that one of the task parameters takes value of one if the task is included to the schedule or value of zero if the task is omitted during elaboration of the schedule.

FORMULATION OF THE CONSIDERED PROBLEM AS A KNAPSACK PROBLEM

General problem of packing

In the literature on task scheduling there are many papers describing different methods and algorithms for planning various particular kinds of problems, e.g. [5, 8]. However the models are as a rule excessively general as compared with real problems and they do not take into account different practical conditions.

The standard knapsack problem consists in filling the "knapsack" of a given limited volume by using elements (blocks) of various dimensions and values in such a way as to fill the knapsack so as to make its value the greatest.

In the same way can be formulated the problem faced by ship chief engineer in some specific situations (e.g. short stay in port or short sea voyage), who must assign operational tasks to power plant crew members so as to make the best use of available time and simultaneously to realize the most important tasks out of the set of the tasks whose realization cannot be performed during the available time interval.

Scheduling the operational tasks, considered as a packing problem

Problem of planning the operational tasks, i.e. assigning them to particular members of power plant crew, can be considered as a multi-knapsack problem (shortly: 0-1 MKP) [7]. The operators o_j, i.e. power plant crew members are considered to be "knapsacks" of equal height which represents the time available for realization of tasks, T_S (e.g. time of staying in port, sea voyage time). They have the suitable competences k_j graphically represented by knapsack's breadth. To the operators are assigned the operational tasks z_i considered as the things packed to the knapsacks (Fig. 1). Every task, like the things placed in the knapsacks, has some parameters:

- the competences necessary for execution of a given task are represented by block's breadth (k_i=o_i)
- the time t_i necessary for realization of a given task – by block's height
- the importance of task, w_{gi}, i.e. that of a given operational task from the operational point of view – by block's value.

Such schedule of operational tasks which should be realized within a given time and in a given service situation, elaborated for each of the operators available in power plant, constitutes the solution of the presented problem. Such schedule has the form of a list of appropriately sequenced tasks which satisfy all limitations present in the problem.

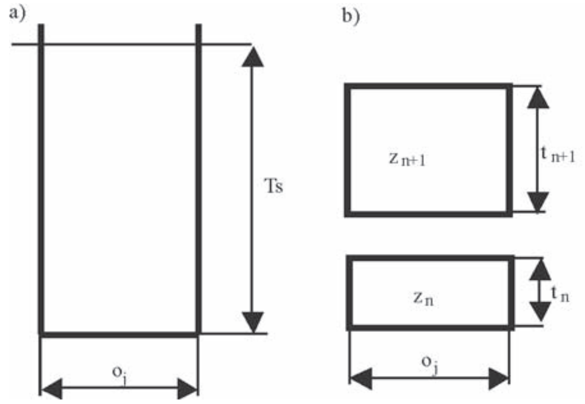

***Fig. 1.** Graphical representation of elements of knapsack problem*

Mathematical model

The main elements of the decision problem of chief engineer, considered as a packing problem are as follows:

- tasks of given parameters (the importance index wg_i, realization time t_i etc)
- operators of determined capability of realizing the tasks [having the suitable competences $k_i(o_i)$]
- time being at disposal, t_s.

The operational task constitutes a sequence of actions performed by an operator or a team of operators in power plant in compliance with a procedure valid in a given situation, to ensure continuous operation of all systems, machines and devices as well as installations. An example operational task - fuel bunkering covers a.o. the following actions (operations): opening or closing appropriate valves of fuel installation, connecting the fuel installation with a fuel source from which it will be delivered, starting the fuel transport pump, and also appropriate reverse operations after ending the fuel bunkering.

All operational tasks realized in power plant are characterized by certain important parameters, i.e.: the realization time of each of them, t_i, as well as the assignment of each of the tasks to concrete operators, resulting from proffesional obligations assigned to them. The tasks out of which the schedule is directly prepared, are those selected, fulfilling operational limitations, as well as being hierarchized regarding their realization importance, that is described in [1, 2].

The operators constitute all persons working in ship power plant and realizing necessary operational tasks, i.e. those to whom the scheduled tasks will be assigned. Number of persons working day after day in power plant is usually constant, however it may be sometimes changed depending on a given operational situation. For instance, a member of permanent power plant crew may be disable to work (that will make number of operators lower) or other persons not being members of the permanent crew, e.g. external service, shipyard pesonnel, may work in the power plant (that can increase number of operators). Consequently, it is not possible to unambigously and in advance determine the number of available operators, j; it will be changeable and individually determined for each considered situation:

$$Z_O = \{o : (o_1, \ldots, o_j)\} \tag{2}$$

where:
Z – set of operators
o – available operators.

Every day each member of power plant crew realizes his tasks in compliance with his obligations assigned to him depending on a held post. In some situations, with a view of necessity to maintain continuous work of power plant systems and devices, certain operational tasks can be performed by other members of power plant crew than those to whom the obligations were assigned. The tasks should be however assigned with satisfying all requirements (according to knowledge, experience and capabilities of operators), hence a given task can be performed by the operator o_p (to whom it was assigned in the frame of his obligations) or by an operator who has the higher competences $k(o_j)$, i.e. that being higher ranked within professional hierarchy of power plant crew members (3):

$$k(o_p) \leq k(o_j) \;\; ; \;\; \forall x_{ij} \in H \qquad (3)$$

where:
- $k(o_p)$ – competences of the operator to whom i-th task was assigned in the frame of his obligations
- $k(o_j)$ – competences of the operator to whom the task x_{ij} was assigned in the schedule **H**
- x_{ij} – a factor which determines the assignement of i-th task to j-th operator.

During ship power plant operation one has to do with the situations in which the time allocated for realization of necessary tasks is limited, e.g.: staying in port, staying in shipyard. Therefore, the taking into account of the available time allocated for realization of tasks is necessary (4):

$$\sum_{i=1}^{n} t_i x_{ij} \leq T_S \;\; ; \;\; \forall i, \forall j : i \in Z_Z, \; j \in Z_O \qquad (4)$$

where:
- t_i – realization time of i-th task
- x_{ij} – a factor which determines the assignement of i-th task to j-th operator
- Z_Z – set of operational tasks
- Z_O – set of available operators
- T_S – termination time of i-th task realization, imposed from outside (e.g. by PSC, etc).

It should be stressed that in the presented approach to scheduling the operational tasks in ship power plant, certain general assumptions and simplifications were made. It was namely assumed that:
- ✶ every operator is able to realize only one task within a given time interval
- ✶ every task is realized only by one operator
- ✶ number of tasks to be realized in ship power plant greatly exceeds that possible to be realized by the operators
- ✶ every task is characterized by a few parameters saved in a data base or determined in advance during preceding stages (elimination of tasks impossible to be realized in given conditions, hierarchization of tasks) [1, 2]
- ✶ assignement of tasks to particular operators will be performed in accordance with the above described proffesional relationships (3).

The searched schedule expressed in a graphical form, will be hence a set of knapsacks (boxes) of an equal height corresponding to the available time Ts within which the tasks must be fulfilled (Fig. 1a). The operators o_j are graphically represented by knapsacks whose number corresponds to a number of operators available in power plant in a given time instant. To them are packed the operational tasks represented by blocks whose height corresponds to the realization time t_i of each of them, and whose breadth of base – to competences of the operator to whom the task is assigned in the frame of his obligations (Fig. 1b).

According to the presented definition of the problem in question one aims at filling the "knapsacks" to a maximum degree by using the blocks of maximum validity (i.e. importance from operational point of view in a given situation) or to a maximum degree of packing.

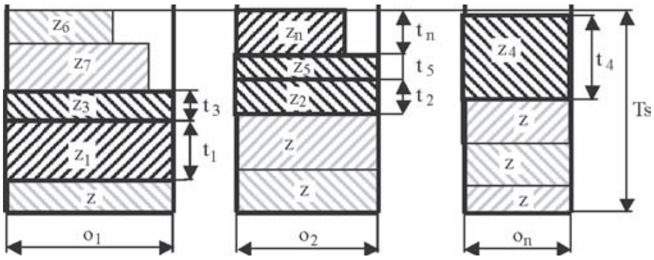

Fig. 2. The example showing the assignement of operational tasks to three operators, i.e. packing three different knapsacks

In Fig. 2 the example of possible solution of the problem in question is graphically presented.

Objective function

Large number of operational tasks of which their schedule is prepared, makes that the problem has many allowable solutions satisfying all appearing requirements and limitations. To find the best solution (optimum schedule) from the operational point of view, it is necessary to determine quality of each of the obtained solutions - i.e. the objective function Fj of optimization problem.

In the problem in question two following assessment criteria have to be applied:
- ❖ the most important tasks fj_1 (5) should be realized, i.e. the schedule should consist of the lists of the tasks assigned to every operator, and having the importance index wg_i of the possible largest value
- ❖ the time of realization of the tasks should be close to the available time for their realization, fj_2, (6), in other words to obtain the best use of the available time.

$$fj_1 = wg_1 x_{1j} + wg_2 x_{2j} + \ldots + wg_n x_{nj} = \sum_{i=1} wg_i x_{ij} \qquad (5)$$

$$fj_2 = x_{1j}\frac{t_1}{T_S} + x_{2j}\frac{t_2}{T_S} + x_{3j}\frac{t_3}{T_S} + \ldots + x_{nj}\frac{t_n}{T_S} = \frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S} \qquad (6)$$

In accordance with the way of formulation of optimization function, described in [9], in the presented problem such function can be assumed to be a combination of assessment criteria of scalar form, generally defined as a weighed sum of: task importance indices and time intervals for their realization.

In the case of the so formulated objective function one has to do with two-criterion optimization. By introducing to it the coefficients ρ_1, ρ_2 called the criterion weighing factors, a choice on which criterion would be more important, becomes possible. Such choice is made by the decision maker, i.e. chief engineer, depending on needs appearing in a given instant. The coefficients ρ_1, ρ_2 can take values from the interval <0, 1>, and their sum should be always equal to 1. Hence it is usually assumed that: $\rho_2 = (1 - \rho_1)$.

Therefore the best schedule, out of all allowable solutions, is that for which the sum of the weighed sums of two presented criteria, fj_1 and fj_2, for all considered operators, reaches a maximum (7).

$$Fj = \max \sum_{j=1}^{o}\sum_{i=1}^{2} sk\cdot\rho_i\cdot fj_i(o_j) = \sum_{j=1}^{o}\left(sk\cdot\rho_1\cdot\sum_{i=1}^{n} wg_i x_{ij} + (1-\rho_1)\frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S}\right) \quad (7)$$

where:

- $i = 1,2,3,....,n$ – number of tasks
- $j = 1,2,3,....,o$ – number of operators
- ρ_1 – weighing factor of the criterion fj_1
- x_{ij} – factor which determines the assignement of i-th task to j-th operator
- sk – scale (a coefficient so selected as to obtain balanced values of sum components)
- wg_i – task importance index.

However such form of objective function suffers a deffect consisting in that the schedule consisted of many tasks of a low importance index (i.e. rather non-important) and short realization time, can show a greater value of such function than that consisted of the tasks of a high importance index and a longer time of realization of particular tasks.

In this connection a modified form of it is here proposed. The change consists in supplementing the first criterion with the relative task importance factor kw_i (8) which is the product of the relative realization time of a given task and the relative competences necessary to its realization. In compliance with the notation used in the knapsack problem the product in question represents a relative size of the rectangle (height x breadth) with regard to the knapsack in which a given object is placed.

$$kw_i = t_{wzgl}\cdot k_{wzgl} = \frac{t_i}{T_S}\cdot\frac{k_i}{k_o} \quad (8)$$

where:

- kw_i – relative importance factor of i-th task
- k_i – competences necessary for realization of a given task
- k_o – competences of operator to whom a given task is assigned in the schedule.

In such situation the objective function will be of the following form:

$$Fj = \max\sum_{j=1}^{o}\left(sk\cdot\rho_1\cdot\sum_{i=1}^{n} wg_i kw_i x_{ij} + (1-\rho_1)\frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S}\right) \quad (9)$$

Such form of the objective function eliminates the above mention deffect consisting in possible elaboration of an optimum schedule which contains many tasks of a low importance.

Decision variables

In the so formulated problem the decision variables are as follows: the event whether a given task will be included into the considered schedule or not, determined by value of the parameter x_{ij} which can take one of the two values: 1 or 0, (10), as well as by the time instants of beginning the realization of particular operational tasks, tr_i. The decision maker decides which of the tasks will be included into the schedule under elaboration, as well as in which sequence they should be realized.

$$x_{ij} = \begin{cases} 1 & \text{If the task is in the schedule} \\ 0 & \text{If the task is beyond the schedule} \end{cases} \quad (10)$$

The time instant of task beginning, tr_i, will depend on the position a given task takes in the schedule. Hence for each of the tasks the variable will be directly dependent on the sum of values of the realization time, t_i, of the tasks preceding in the schedule. Values of tr_i (time instant of beginning the realization of i-th task) are not direct decision variables because they are not taken into account directly in the process of scheduling (such value does not appear in the objective function equation).

The quantity tr_i can take only certain limited values. They cannot be smaller than zero (as it is not possible to determine time of realization of a given task in the past – its minimum is the beginning of the considered schedule). And, its maximum cannot be greater than the time interval covered by the schedule in question, T_S (11).

Moreover, with a view of that realization time of particular tasks is given by ship engineers as well as producers of machines only in an approximate way, the decision variables can be given values with the accuracy of 5 min. Such accuracy of the decision values seems to be rationally justified; it will be discrete values, that will definitely make number of allowable solutions of the optimization problem of scheduling the operational tasks in ship power plant, lower. For the decision variables tr_i the following range of their variability can be provisionally determined:

$$0 \le tr_i < T_S \;,\; tr_i = 0, 5, 10, \ldots \;;\; i = 1,\ldots,n \quad (11)$$

where:

- tr_i – time instant of the begining of i-th task realization
- T_S – time interval covered by the schedule in question.

Constraints

In such approach to the considered problem two main constraints (limitations) appear:

- the total realization time of the tasks assigned to each of the operators cannot be greater than the available time interval t_s provided for their realization (3)
- a given task can be assigned only once in the schedule, (12):

$$\sum_{i=1}^{m} x_{ij} \in H \le 1 \quad \forall i \in Z_Z \quad (12)$$

where:

$x_{ij} \in H$ – tasks placed in the schedule H,

The remaining constraints of the problem are the following:

- the way of assigning the tasks to particular operators, determined by (2)
- every task is realized by one of the operators only:

$$\sum_{i=1}^{m} o_n(x_{ij}) \le 1 \quad \forall n \in Z_O \quad (13)$$

SELECTION OF CALCULATION METHOD FOR SOLVING THE PROBLEM

Method of searching the space of general problem solutions

From the point of view of calculations the knapsack problems are deemed difficult. Like in the case of other optimization problems, many different calculation methods for solving the problems of the kind have been elaborated. In the subject-matter literature can be found both approximate methods (reduction and approximation ones) and exact ones such as: network approach, dynamic programming or searching methods. For solving the problem of optimization of the schedule of operational tasks in ship power plant the last of the presented method, i.e. the method of indirect searching, called also the searching with reversals. The method was selected due to its simplicity, as it contains basic steps of almost all searching methods and simultaneously is one of the quickest among them [7].

Algorithm of the method of searching with reversals finds a solution of a given problem by applying the systematic searching its whole space of solutions. It makes use of the space represenation in the form of the tree in which problem variables correspond to successive levels of the tree and each of the tree nodes has at last two branches corresponding to 0-1values (Fig.3). The method of searching the space of solutions consists in forming first the left branch, and as soon as the searching process on the left side is terminated the right branch (of the tree) is formed and the searching is moved to this side. Such method of forming the tree nodes is very economical, and despite this, no three which could lead to a better solution, is ommited.

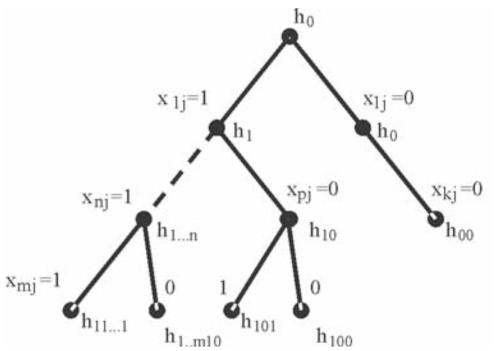

Fig. 3. *Way of elaborating the solution tree for the knapsack problem by means of searching method with reversals. Numbers given at nodes correspond to values of the coefficient which determines the assignment of i-th task to j-th operator in the considered schedule harmonogramie $h_{n...n}$.*

Method of searching the solution space of the problem of assigning the tasks to several operators in ship power plant

The above presented algorithm of searching the space of allowable solutions of optimization problem deals with the one-knapsack problem. However in ship power plant the situation occurs in which the tasks must be assigned to a greater number of operators; hence the presented algorithm requires some modifications to be introduced. For further considerations is selected the following situation usually met in merchant fleet, i.e.: four operators to whom operational tasks are assigned. They are: chief engineer – I, second (first assistant) engineer – II, third engineer – III, fourth engineer – IV.

The use of the greater number of operators (four) makes that every task, provided the imposed constraints do not hold off, can be assigned to any of the four operators. Therefore in the state in which to a given task the value of the parameter x_{ij} equal to 1 is attributed (Fig.3), four additional solution variants appear (Fig.4a). However the principle of searching the space of solutions remains the same as in the case of the one-knapsack problem, hence the solutions on the left-hand side of the solution tree are searched (Fig.4b). The checking of possibility of assigning a given task is started from the operator whose proffessional competences are the lowest. If any of the constraints does not allow to assign it to this operator the task is tried to be assigned to that whose competences are the lowest among the remaining operators available in a given moment.

The assignement of the task to one of the operators creates the new allowable solution in which value of the objective function is checked („sum of weighing factors" of each of the operators) and compared with the best solution has been obtained so far. If the calculated value of the objective function is greater than that has been obtained so far, its new value and the new entire solution are saved.

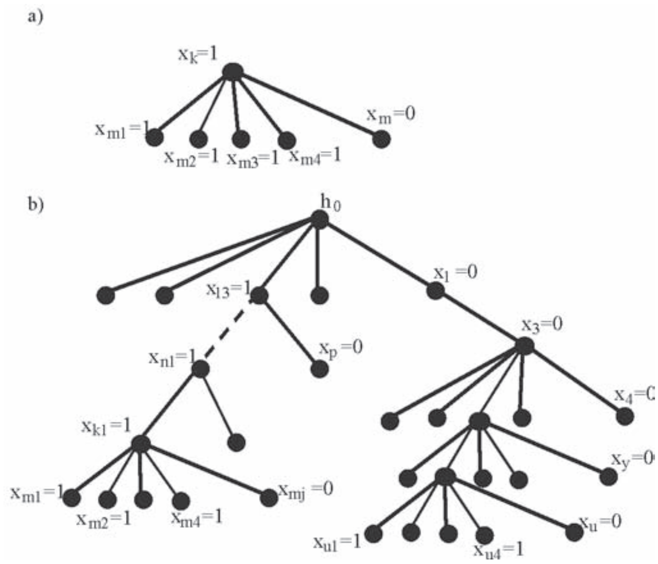

Fig. 4. *Modified way of forming three solutions for the multi-knapsack problem by means of the method of searching with reversals*

In the case of scheduling the operational tasks in ship power plant, the successive solutions h_n would be created by adding or omitting (the factor x_i in Fig. 4) one by one successive tasks taken from the hierarchized list of tasks, to each of the operators, with simultaneous checking all constraints and value of the objective function for each solution in each case. The process will be continued up to the moment when adding a successive task makes the available time Ts exceeded by the sum of realization time values of the tasks included in the schedule for a given operator or no task which would improve the schedule by increasing the value of the solution objective function, is found.

The graphical representation of the algorithm for searching the solution space for the problem of assigning the operational tasks, considered as a knapsack problem, is shown in Fig. 5.

COMPUTER SYSTEM FOR PLANNING THE OPERATIONAL TASKS, BASED ON THE PRESENTED MULTI-KNAPSACK PROBLEM

In order to check the above presented mathematical model as well as the method of solving of the decision problem usually faced by ship chief engineers, a prototype computer software for aiding the chief engineer in planning the operational tasks in ship power plant in some definite conditions, was elaborated.

The presented graphical interface of the software consists of two main parts. The first of them, shown on the right-hand side of Fig. 6, is characteristic for computer systems applied in ship power plants and it represents structure of ship power plant design solution.

The second part of the interface (on the right-hand side of the screen), i.e. working one, consists of two bookmarks:

- ⇨ TASKS (Fig.6) in which the operational task parameters are defined for particular elements of ship power plant structure
- ⇨ SCHEDULE (Fig.7) in which the functions triggering the searching process of allowable solution space for the

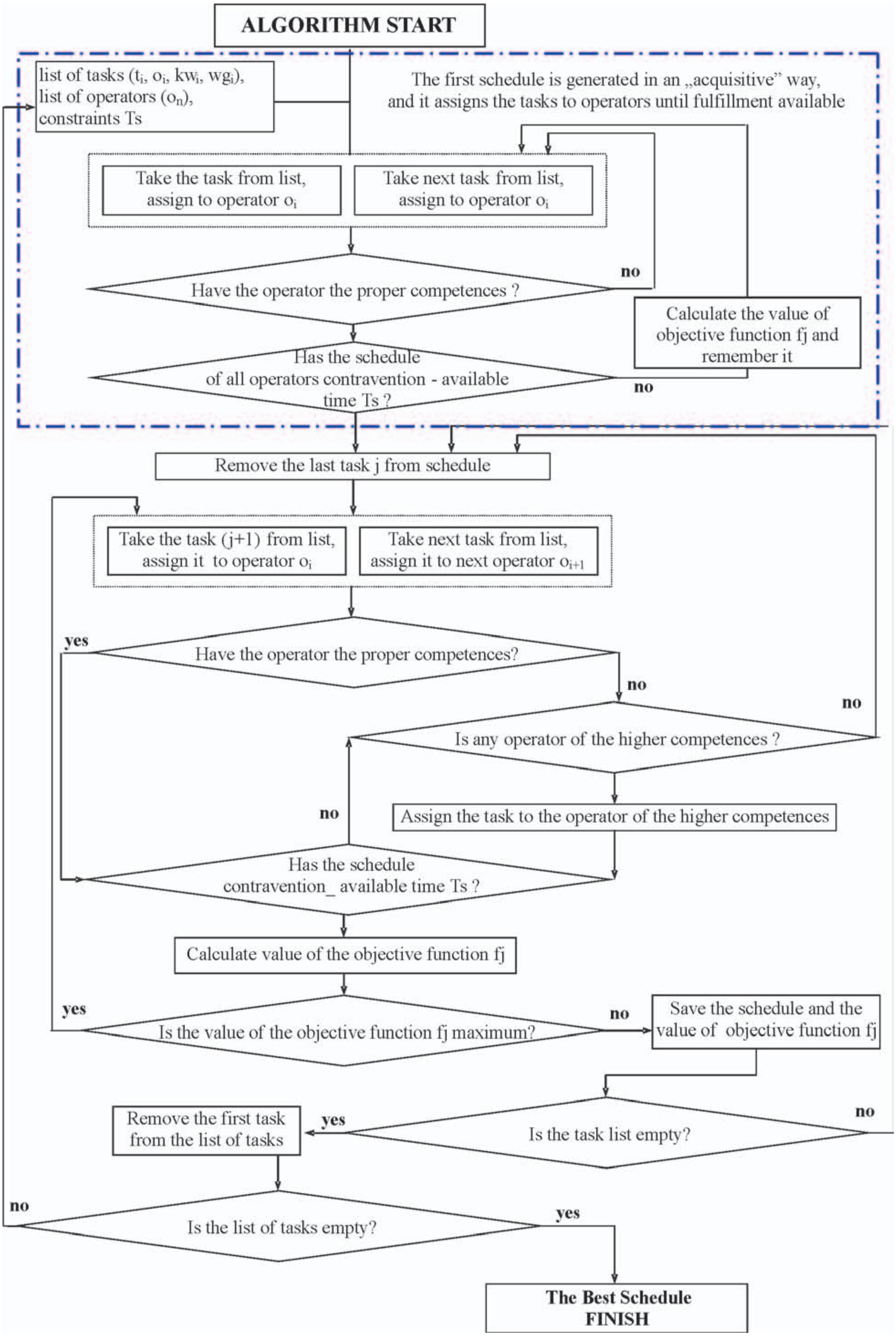

Fig. 5. *Algorithm of searching the solution space for multi-knapsack problem*

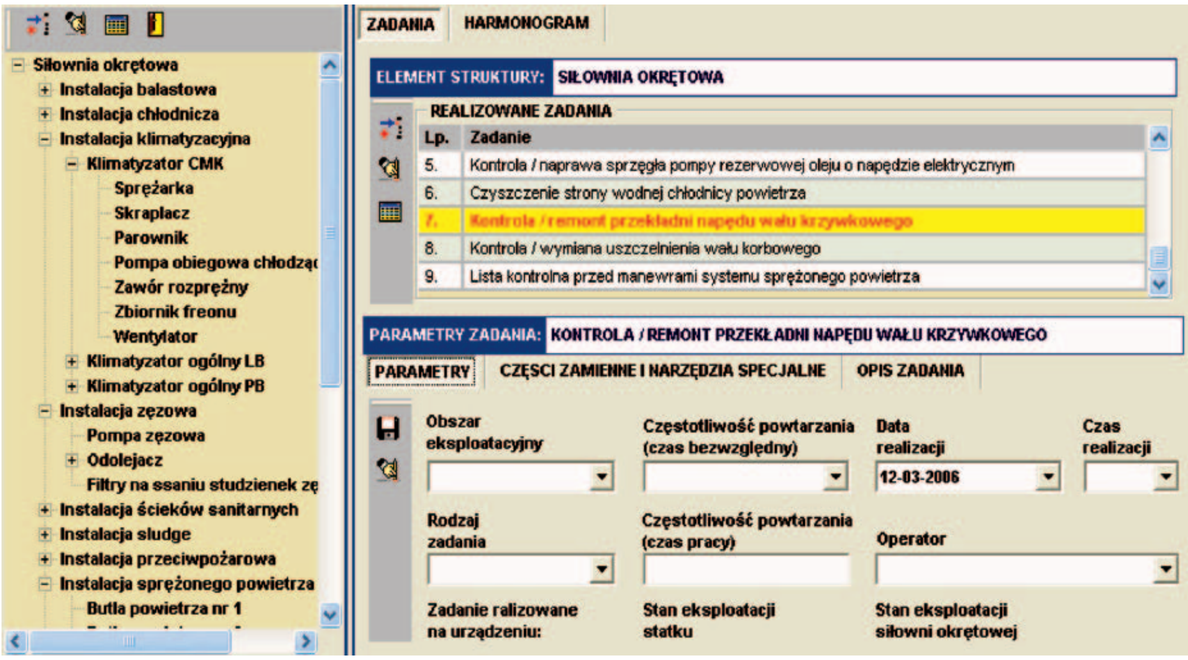

Fig. 6. *An example screen of the graphical interface of the computer software for assigning the operational tasks in ship power plant. Ship power plant structure (on left hand side), task operational parameters (on rightrighthand sideright hand side)*

Notation displayed on:
Left hand side area : Siłownia okrętowa – Ship power plant, Instalacja balastowa – Ballast system, Instalacja chłodnicza – Cooling system, Instalacja klimatyzacyjna – Air conditioning system, Sprężarka – Compressor, Skraplacz – Condenser, Parownik – Evaporator, Pompa obiegowa chłodząca – Cooling circulation pump, Zawór rozprężny – Expansion valve, Zbiornik freonu – Freon tank, Wentylator – Fan, Klimatyzator ogólny LB – General air conditioner – Portside, Klimatyzator ogólny PB – General air conditioner – Starboard side, Instalacja zęzowa – Bilge system, Pompa zęzowa – Bilge pump, Odolejacz – Oil separator, Filtry na ssaniu studzienek zęzowych – Filters at bilge well suction, Instalacja ścieków sanitarnych – Sanitary sewage system, Instalacja sludge – Sludge system, Instalacja przeciwpożarowa – Fire extinguishing system, Instalacja sprężonego powietrza – Compressed air system, Butla sprężonego powietrza nr.1 – Starting air receiver no.1, ….
Right hand side area: Zadania – Tasks, Harmonogram – Schedule, Element struktury: Siłownia okrętowa – Structure element: Ship power plant, Realizowane zadania – Realized tasks, Lp. .. Zadanie – No...Task, 5. Kontrola/naprawa sprzęgła pompy rezerwowej oleju o napedzie elektrycznym – Control/ repair of coupling of electrically driven stand–by pump, 6. Czyszczenie strony wodnej chłodnicy powietrza – Cleansing of air cooler water side, 7. Kontrola/remont przekładni napędu wału krzywkowego – Control/repair of reduction gear of camshaft drive, 8. Kontrola/wymiana uszczelnienia wały korbowego – Control/ replacement of crankshaft packing, 9. Lista kontrolna przed manewrami systemu sprężonego powietrza – Check list before manoeuvers of air compression system, Parametry zadania: Kontrola/remont przekładni napędu wału krzywkowego – Task's parameters : Control/repair of reduction gear of camshaft drive, Parametry..Części zamienne i narzędzia specjalne..Opis zadania – Parameters..Spare parts and special tools.. Task's description, Obszar exploatacyjny.. Częstotliwość powtarzania (czas bezwzględny)..Data realizacji..Czas realizacji… – Operational area.. Repeating frequency (absolute time).. Realization date… Realization time.., Rodzaj zadania…Częstotliwość powtarzania (czas pracy)..Operator..– Type of task..Reapeating frequency (time of operation).. Operator.., Zadanie realizowane na urządzeniu:…Stan eksploatacji statku..Stan eksploatacji siłowni okrętowej.. – Task realized on the device : …Ship's operation stage.. Ship power plant's operation stage...

operational task assigning problem are contained. Its user unaided defines two main parameters of the optimization process:

- „Maximum time", i.e. the time interval for which the schedule is considered (e.g. port staying time, sea voyage time etc)
- „Criterion weighing factor" (the parameter ρ in Eqs. 7 and 9), i.e. that determining which choice is of a greater importance: that of the most important tasks or that of the most effective use of the available time.

The main area of the interface screen is divided into two parts in the first of which the obtained results on " Schedule variants" are displayed, and in the other, i.e. „Gantt's Diagrams", graphical presentation of the obtained results for each of the operators is shown in the form of Gantt's diagrams. Each of the operators is assigned by an area in which the "rectangulars" representing the assigned operational tasks are drawn. The area is shown as a white rectangular whose dimensions stand for:

- the time interval available for task realization (length of the rectangular)
- the competences attributed to a given operator (height of the rectangular).

In the area „Schedule variants " the following data are displayed:

- the tasks assigned to each of the considered operators; only identification numbers of assigned tasks are displayed to make control of the software's operation correctness, possible
- sum of values of the task realization time intervals
- sum of values of the task weighing factors
- sum of values of the weighing factors for the whole schedule, which simultaneously stands for the quality index of a given solution.

In the other part of the interface screen are placed also two keys whose switching-on leads to display and visualization of all solutions determined in the course of optimization process.

In the status bar placed at the lower edge of the interface screen (Fig. 7) are displayed three aditional information data important in analyzing the obtained results:

- number of the analyzed solutions
- number of the tasks taken into account
- calculation time consumed for finding the best solution.

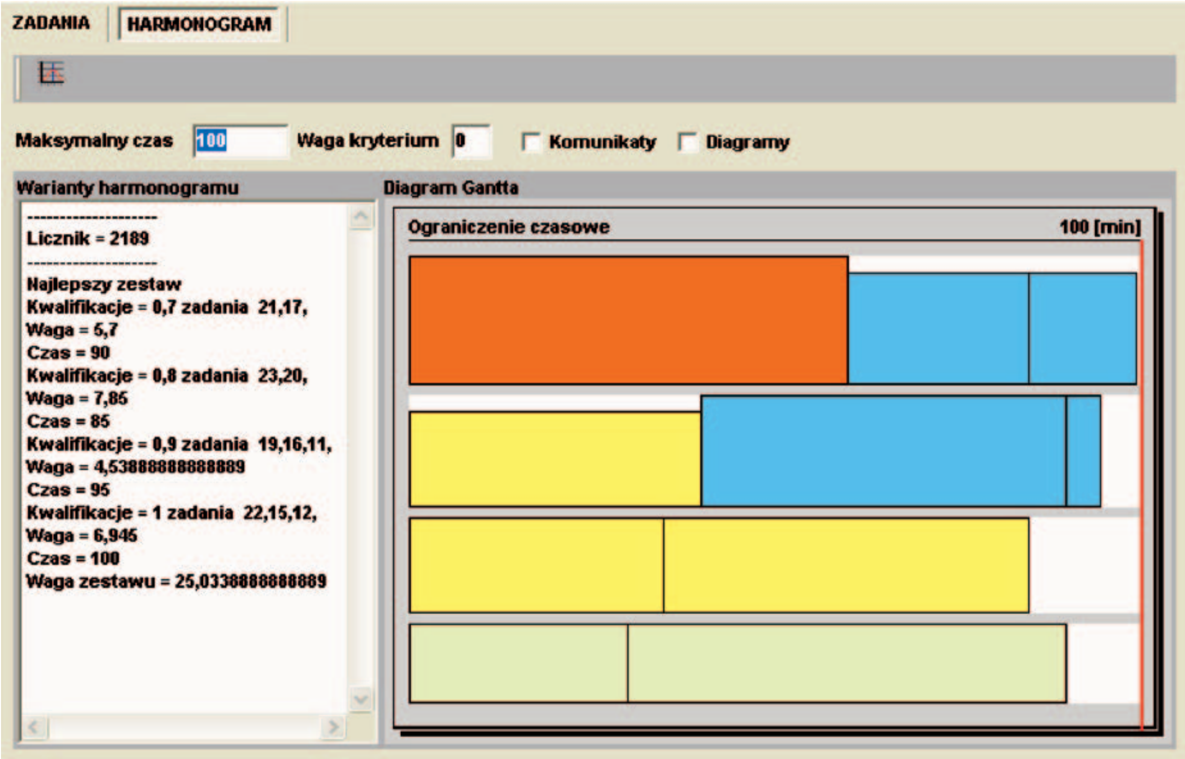

Fig. 7. An example fragment of the graphical interface of the computer software, which displays results of optimization process of assigning the operational tasks in ship power plant

Notation displayed on:
Upper horizontal bar : Zadania -Tasks, Harmonogram – Schedule
Upper area : Maksymalny czas – Maximum time, Waga kryterium-Criterion weighing factor, Komunikaty – Messages, Diagramy – Diagrams
Left hand side area : Warianty harmonogramu – Schedule variants, Licznik – Counter, Najlepszy zestaw – The best set, Kwalifikacje... zadania.. – Competences... tasks no., Waga – Weighing factor, Czas – Time, Kwalifikacje ...zadania – Competences...tasks no., Waga – Weighing factor, Time – Czas, Kwalifikacje… zadania – Competences... tasks no., Kwalifikacje… zadania – Competences... tasks no. , Waga – Weighing factor, Czas – Time, Set's weighing factor..
Right hand side area : Wykresy Gantta – Gantt's diagrams, Ograniczenie czasowe – Time limitation,
Lower horizontal bar : Akademia – Gdynia Maritime University, Liczba rozwiązań – Number of solutions, Liczba zadań – Number of tasks, Czas obliczeń – Calculation time.

RECAPITULATION AND CONCLUSIONS

In this paper has been presented an approach to solving the decision problem associated with attribution of operational tasks realized by relevant operators in ship power plant, with taking into account different conditions. The problem has been presented as a packing (knapsack) problem often used for scheduling the tasks in industry.

The paper covers only one, the last stage of the considered decision problem, out of its several stages such as the collecting and analyzing of information concerning operational tasks, their selection, generating the schedules being single allowable solutions of the problem in question.

A mathematical model of two-criterion optimization process of scheduling the operational tasks in ship power plant, i.e. finding the best solution out of the set of allowable ones, has been presented, and within its frame the following has been done in particular:

- The objective function which takes into account the crucial elements considered by chief engineer in scheduling the operational tasks in ship power plant: i.e. importance of a given task, competences of each of the operators, time available for realization of necessary tasks, has been elaborated.
- The most important limitations (constraints) occurring in scheduling the tasks in ship power plant have been defined.
- The method of searching the solution space, i.e. the searching algorithm with reversals, has been selected and modified for its application in the problem in which four operators are considered.
- The prototype computer software for assigning the operational tasks in ship power plant, based on the presented mathematical model, has been elaborated.

Several assumptions and limitations have been made, among which the following are the most important:

- Every task can be realized by one of the operators only.
- Every operator is able to realize only one task in a given time.

Further investigations are aimed at checking whether the assumed objective function as well as the constraints are sufficient for solving the problem in question, as well as whether the assumed method of thorough searching would be fast enough for application to ship power plant problems.

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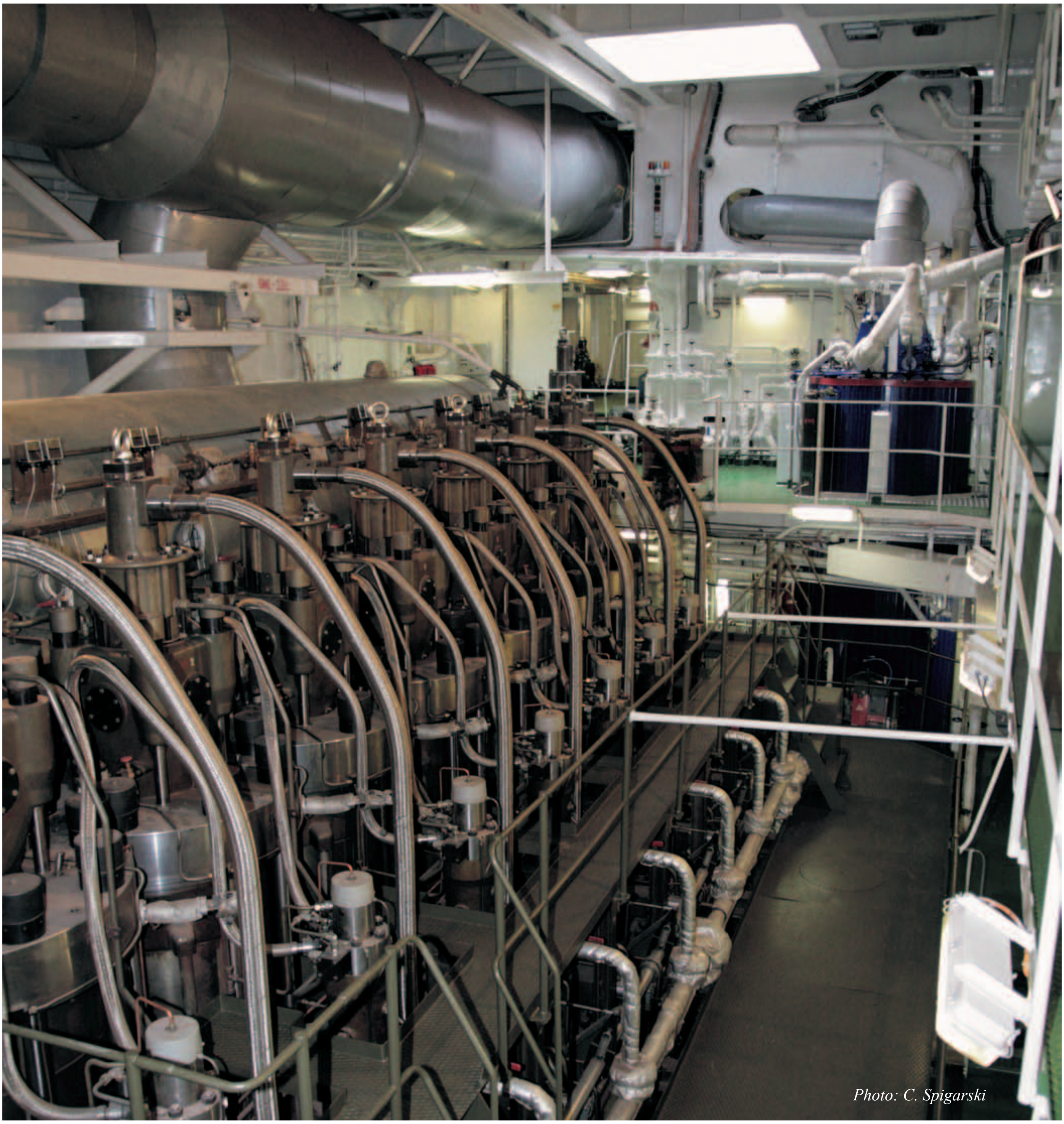

Photo: C. Spigarski