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Cause and effect factors of refrigeration system faults in fishing vessels

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Abstract

Growing environmental protection requirements also include problems of ozone depletion by coolants. This article presents a possibility of using a cause-and-effect diagram, known as Ishikawa diagram, for an analysis of faults occurring in marine refrigeration systems. The analysis, focused on refrigeration systems installed in Polish fishing vessels, makes use of extensive faults data collected during research.

Introduction

In 1990 Poland ratified the Vienna Convention on the protection of the ozone layer, under which production, import and use of materials with high ozone depletion potential is not allowed. In the first place prohibition was posed on halon, used as a fire extinguishing agent. Further restrictions included chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) and methyl bromide. For years, the refrigerating industry has been under pressure of decisions resulting from the restrictions put on factors affecting ozone depletion layer. CFC coolants were officially withdrawn, and the next step to be taken is phasing out HCFC coolants [1, 2]. At present, the withdrawal of these compounds remains in a transitory phase. A number of research projects were carried out to develop new coolants, and solve problems connected with their use and necessary modernization of the existing refrigeration installations [3, 4]. In terms of operation, problems addressed were the changed efficiency and effectiveness of the installation, a change in working temperature range, compatibility of oils and lubricating problems. Despite research already done [5, 6], some operational and economical problems remain to be solved.

The authors use an Ishikawa diagram determining cause and effect factors of refrigeration system faults occurring in fishing vessels. It is the first concept, not found in the available literature, of fault analysis covering refrigeration systems operated in sea conditions.

The problem description

Ishikawa [7] developed a cause-and-effect diagram, in which analysis begins from ascertaining that a fault occurred (failure or another undesired state, e.g. damage) and follows towards an identification of all possible causes of that fault. The resultant ca*use and effect diagram*, is also known as *fishbone diagram*, or fault tree diagram [8]. Used for illustrating cause and effect relations, the diagram assists in separating the causes and effects of a given situation and perceiving the complexity of a problem. Ishikawa distinguished five groups of causes, the so-called five Ms: manpower, methods, machines, materials and management. Each of the groups is divided into subgroups (causes), that should be individually considered as problems to be solved [9]. An example of an Ishikawa diagram is shown in figure 1.

The cause and effect diagram is a graphical analysis of the influence of various factors and their interrelations causing a specific qualitative problem, as well as an analysis of the results (effects) caused by those interrelations. The diagram logically and chronologically orders the causes or actions due to a defined problem (Fig. 1).

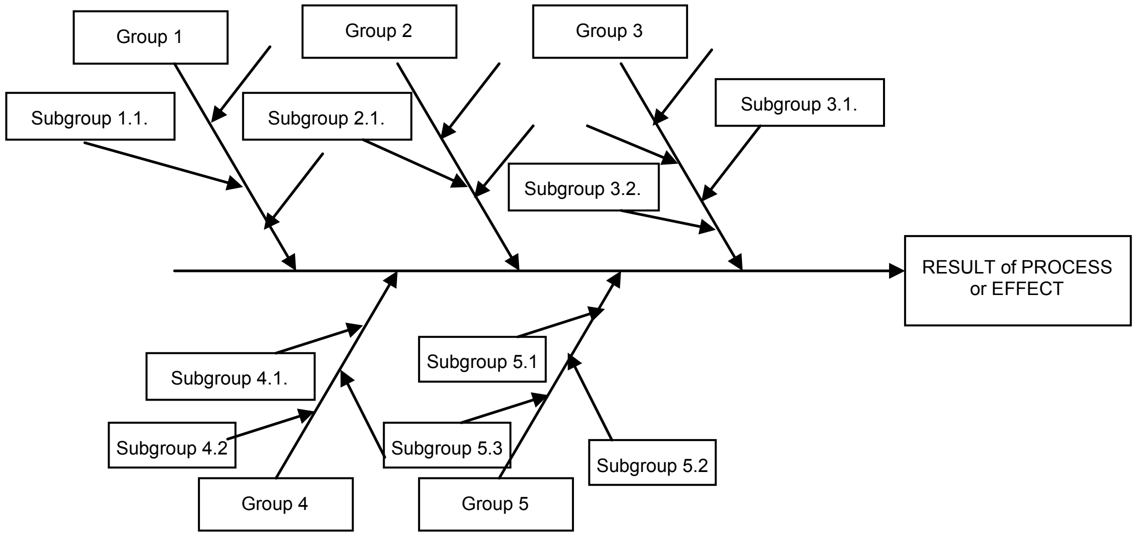

Fig. 1. A schematic Ishikawa diagram [7]

An analysis of matrix and Ishikawa diagrams for refrigeration system faults in fishing vessels

One point to note is that a classical Ishikawa diagram does not include quantitative information. In [10] the author proposes to add weights of each cause to the diagram, which allows to find the percentage of significance of each fault identified in the refrigeration system of a fishing vessel. Such diagram, therefore, may be used for the evaluation of the causes that lead to a given fault. Data used in this analysis were collected during the operation of selected craft (25 fishing vessels of Polish fleet operating in the Baltic Sea). The data were obtained through questionnaires filled in the years 2007–2011 by ship owners, crew members and ship repair companies, and during interviews held in fishing harbors and repair yards. A lot of data were gathered in the project implemented under the Sector Operating Program "Fisheries and Fish Processing" [11].

The data were used to make matrix diagrams of refrigeration system faults identified on fishing vessels. Once the main causes (Tab. 1) and a set of subcauses were determined (Tab. 2), each main cause and subcause was assigned its weight. Then absolute values of subcause weights were defined, so that the Ishikawa diagram was extended to include specific weights [8].

The weights of particular causes were determined using a matrix of comparisons by pairs based on the principle [7]: if one of the comparable factors is regarded as more important, it is assigned grade 1; the other gets 0. If both factors are equally important, they get 0.5 each. To make the valuation scale more precise, it can be extended [10] by assuming numbers 0; 0.25; 0.5; 0.75; 1 as it was done below. The standardized weights of major factors were included in the Ishikawa diagram (Fig. 2) in circles (under the headings: manpower, management, material, method, machine – refrigeration system). The upper number in the circle represents a relative weight referred to a given factor, while the lower number is the absolute weight referred to the whole group. For major factors, both weights are equal. Using a comparison matrix (Tab. 1–2) we determined subcauses of the secondary order (both weights, relative and absolute, are put in circles) and placed them in the Ishikawa diagram, too (Fig. 2). Table 3 contains contribution percentages of groups and subgroups affecting the faults relating to leakages in refrigeration installations of the fishing vessels.

Table 1. A matrix table for refrigeration system faults – impact of major groups (manpower, management, material, method, refrigeration system)

Factor	1	Σn
Manpower	0.5	0.133
Management	0.5	0.133
Material	1	0.266
Method	1	0.266
Refrigeration System	0.75	0.2
Sum	3.75	1

n – relative weight

In table 1, causes identified as major ones are: management (influence of wrong management decisions etc.), manpower (human factor, i.e. qualifications, bad habits, etc.), material (a factor affecting the quality of a process etc.), method (procedures, rules of behaviour) and refrigeration system (where such factors as durability, reliability etc. are taken into account).

Table 2. Matrix diagram of groups affecting the category 1 – faults of refrigerating systems

Group	Subgroup	Category 1	Σ*n*
Management	insufficient communication between employees	0.5	0.2
	lack of control of repairs, overhauls, surveys, maintenance, etc.	1	0.4
	improper diagnostic documentation	1	0.4
	Sum	**2.5**	**1**
Manpower	no proper qualifications	0.5	0.25
	insufficient work discipline	1.0	0.5
	reduced physical and mental fitness	0.5	0.25
	Sum	**2.0**	**1**
Method	improperly developed operating process	1	0.5
	inappropriate methods of operating process control	1	0.5
	Sum	**2**	**1**
Material	poor quality of manufacturer's or replacement material and protecting materials	1	0.5
	improperly selected production, replacement or protecting material	1	0.5
	Sum	**2**	**1**
Refrigerating system	incorrect calibration	0.5	0.166
	improper, too high or too low, temperature and pressure in the refrigeration system	1	0.333
	leaks in the system	1	0.333
	improper selection of operating parameters	0.5	0.166
	Sum	**3**	**≈ 1**

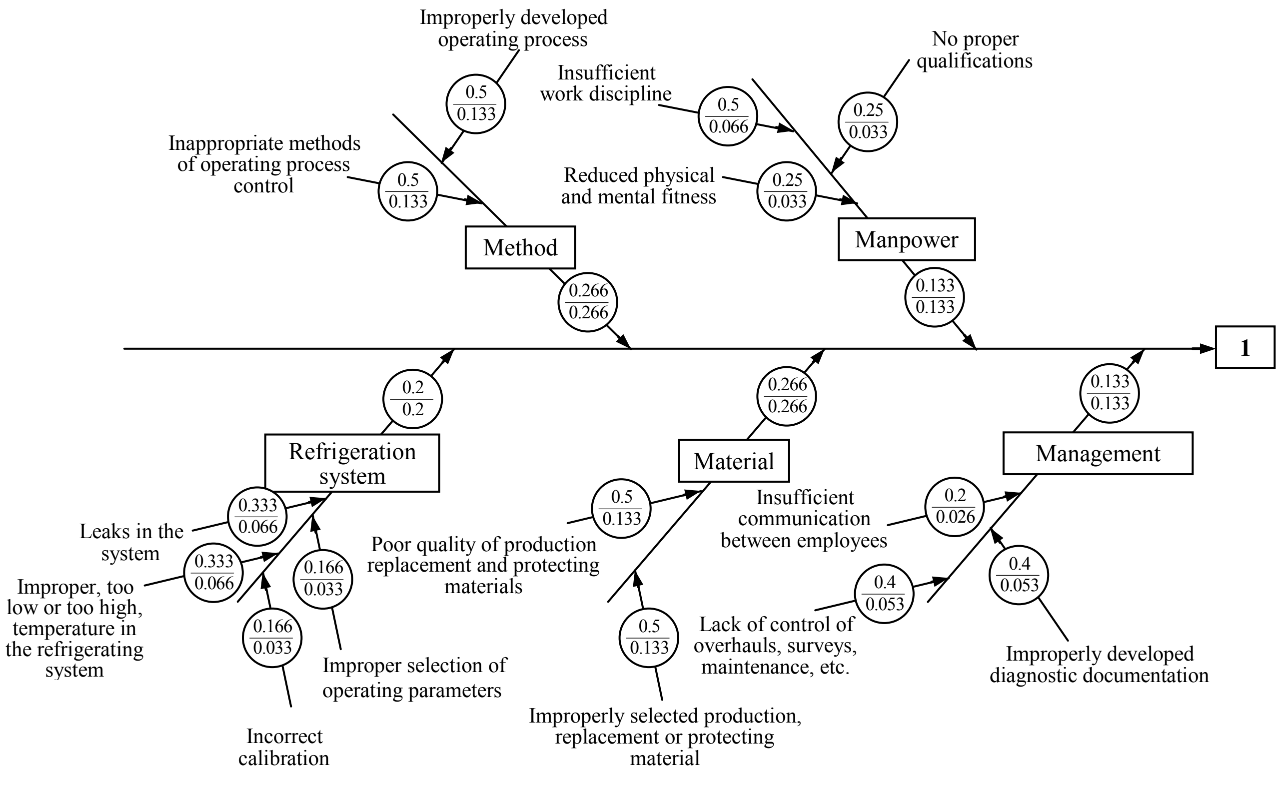

Fig. 2. Weighted Ishikawa diagram for refrigeration system faults in fishing vessels (1 – means a fault, a problem under consideration)

Once the matrix diagram was made (Tab. 2), we defined and valued subcauses for each major cause. The subcause is understood as a more detailed determination of categories of factors affecting a given main group. For example, the main group: refrigeration system, subgroup: incorrect calibration, was attributed a weight-significance 0.5, according to the above rules.

Using the data from the above tables, we made an Ishikawa diagram, drawing a horizontal line that represents the main axis of the diagram, with the arrow indicating the problem. The diagram branches represent groups of causes and subcauses (plus their weights) responsible for the problem. Table 3 presents the fraction (percentage) of the groups and subgroups (read from the diagram) contributing to fault occurrence in fishing vessel refrigeration systems.

Table 3. Percentage contribution of groups and subgroups to faults of refrigeration systems installed in Polish fishing vessels

Group	Subgroup	Subgroup percentage [%] in a given group	Subgroup percentage [%] in a given fault category
Management	insufficient communication between employees	20	2.6
	lack of control of repairs, overhauls, surveys, maintenance, etc.	40	5.3
	improper diagnostic documentation	40	5.3
	Sum	**100**	–
Manpower	no proper qualifications	25	3.3
	insufficient work discipline	50	6.6
	reduced physical and mental fitness	25	3.3
	Sum	**100**	–
Method	improperly developed operating process	50	13.3
	inappropriate methods of operating process control	50	13.3
	Sum	**100**	–
Material	poor quality of manufacturer's or replacement material and protecting materials	50	13.3
	improperly selected production, replacement or protecting material	50	13.3
	Sum	**100**	–
Refrigeration system	incorrect calibration	16.6	3.3
	improper, too high or too low, temperature and pressure in the refrigeration system	33.3	6.6
	system untightness	33.3	6.6
	improper selection of operating parameters	16.6	3.3
	Sum	**100**	**≈ 100**

Conclusions

Important changes in ecological requirements also refer to fishing vessels, since the operation of the latter affects the atmosphere [11]. The issue of ship's installations that cause the increase in surface water temperature, fauna destruction, and changes in surface water composition due to flushing exhaust gases with outboard water is a fundamental problem to be solved. Therefore, it is of utmost importance to determine cause-and-effect factors of faults in shipboard systems. The presented analysis is a simple method facilitating the solution of the problem. The weighted Ishikawa diagram can be analyzed in detail to obtain quantitative data on factors causing faults in refrigeration systems in fishing vessels. For instance, in the group "refrigeration system" (cause: incorrect calibration) (Fig. 2) the upper weight is a relative weight of 0.166 and means that this subcause accounts for 16.6% of effects caused by the group 'management'. If, however, we consider that 16.6% and compare it to the weight of the entire group (0.2), then we get the absolute weight of that subcause amounting to 0.033 or 3.3%.

The conclusions from such analysis may provide a basis for developing guidelines for both, designers and operators of marine refrigeration systems.

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