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QUALITY AND COMPETITIVENESS IN THE PORTS INTEGRATION OF PORT AND MARITIME SERVICES

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ABTRACT

A project for defining "Quality of Service Systems" has been developed in the Spanish Ports, in accordance to the norms ISO 9000:2000. This project focuses more in the management of the institution itself rather than in results or commitments of services oriented towards port operations. The present paper specifies the stages developed for the proposal and validation of a quality of port and maritime service system.

Key words: quality of services, Ports, Operational Guide

INTRODUCTION

As a result of the work carried out, service manuals have been approved to serve as the base for adopting the system in the different ports, and the approval and possible certification of the different operating firms.

The system designed and conveyed in the mentioned manuals, contemplates as well the creation of a permanent observatory of the service level, which may also be the germ/embryo of a larger observatory incorporating more port services and the area of costs and prices of the services.

The work has been developed in collaboration with Port Authorities and their operators, and the manuals have been revised by the Spanish Federation of Tow-

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boats, ANARE (National Association of Tugboats) and the Spanish Association of Vessel Runners. They have also been revised by ATEIA (Freight Forwarders Association) and by ANAVE (Spanish Ship owners Association).

INTEGRATION OF PORT AND MARITIME SERVICES

The project

The Quality of Service Project, applied to the integration of Port and Maritime Services, and driven forth by the Public Entity State Ports, has as aims:

- To design and validate a System of Maritime and Port Quality.
- To study the conditions for rendering port services to the vessels and their requirements/needs as client.
- To study the service conditions offered by the vessel and the requirements of the merchandise.
- To define the quality standards with the consensus of all the operators.
- To design and elaborate the documentary support which will gather all the commitments.
- To define the follow-up mechanism of the system (management processes and continued improvement).
- To be able to ensure the quality of the rendered services, through an optional Certification of Services.

For this purpose, it was decided to fulfil a diagnosis of the situation in a first phase, and in a second one to define a Quality of Service System, developed in four Normative Documents: three of them specific for port operators and another one specific for maritime transport.

The parts involved in the Project have been:

- State Ports and Port Authorities (Barcelona, Baleares and Las Palmas de G. Canaria and S/C de Tenerife).
- Ship owner companies (Barcelona - Palma de Mallorca and Barcelona - Las Palmas and Tenerife).
- Supplier of vessel services (pilotage, towing and anchorage).
- End clients: Shippers/receptors.

The Port Authorities, as those ultimately accountable for the port services will be also involved in the process.

The Project consists of four fundamental Phases, three of which have already been carried out:

- Diagnosis of the state of departure and analysis of all the documentation related to the scope of the Project.

- Design of the Normative Documents of standardization of the port and maritime services, fulfilling the field work in 3 Port Authorities: Barcelona, Palma de Mallorca, and Las Palmas de Gran Canaria and S/C Tenerife
- Validation of the previous documents by all the parties involved (specifically by the part of the users of the services, their suppliers, the Public Entity itself, and experts in inspection)
- Certification of the quality of service of those operators who voluntarily petition it to show to an independent third party the conformity of their services with the requisites developed in the normative documents

THE DIAGNOSTIC PHASE

The aims of this phase were, apart from defining and planning the Project, identifying the state of departure in the involved port Organizations and the existing standards of quality, as well as determining the characteristics of the service which are relevant for satisfying the expectation of the clients and users, in each one of the port activities that make up the chain of service, as is shown in Fig. 1. These characteristics will be the base of the future certification in those Organizations who voluntarily petition it.

An initial mapping of the processes was developed with the previous analysis, as well as fieldwork in four ports (Barcelona, Palma de Mallorca, Las Palmas and Tenerife), consisting of interviews with operator representatives, observation of the work systems and processes of the operators and gathering of new information (operation procedures, control methods, records, client data, claims, quality indicators …).

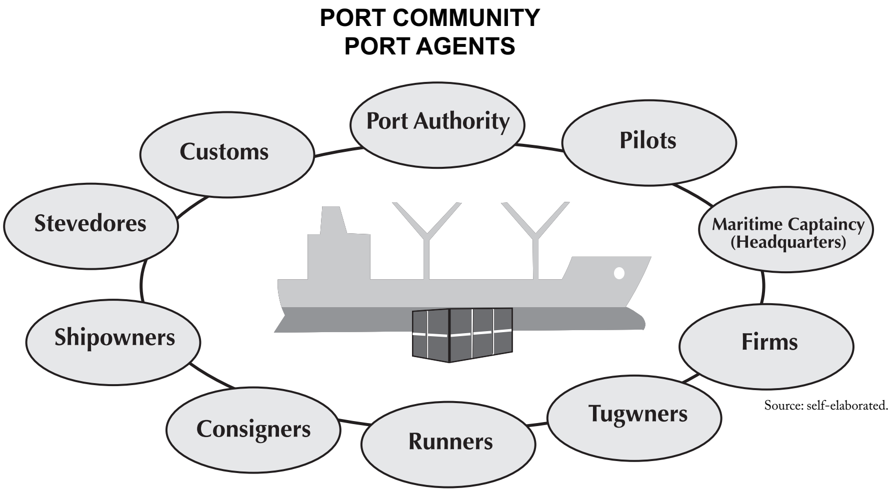


Figure 1. Components intervening in port activity.

Following the analysis of the interviews held and the documentation consulted and always considering the frame of reference established by the State Ports as web as the regulation applicable to each case, it is concluded that the characteristics of service expected by the end client of the merchandise, and that in turn the maritime operator (vessel) requires of its port operators, had to be based on the following parameters: prices, security, reliability, information, availability and personalization.

With the base, were the characteristics defined of services common to the agents or logistic operators considered (Ship owner companies and as port services Pilotage, Anchorage and Cast off and Towing) or specific ones in some cases, in the form of general commitments.

DESIGN OF THE NORMATIVE DOCUMENTS

The characteristics and details of the document, were the object of development and consensus in work teams created to this effect, with the aim of establishing objective parameters of compliance. As a result of the conclusions reached in the work teams, a specific document was developed for each one of the agents provider of services, detailing their service commitments (Manuals for the Quality of Service of Anchorage, Towing and Pilotage), as well as a specific one for Maritime Transport.

As a premise for departure, each agent and in all cases was obliged to comply with the applicable regulations, understanding as such the obligations enforced in the normative and in the specific documents (general and particular) which regulate the services of pilotage, anchorage/cast off and towing.

The commitments or characteristics for service established are the following:

For port operators

a) **Management of material and human resources:** Personnel Training and Qualification; Continued Training Improvement; Human Resources; Material and Equipment.

b) **Transparency in Invoicing**: Clarity and Transparency of Bills; Breakdown of Bills; Fare Policy.

c) **Quality measurement and continued improvement of services:** Measurement of the Level of Quality of Service; Permanent Analysis of the Levels of Quality of Service and Improvement of the Service; Continuous Follow-up of the Client's Satisfaction/Opinion.

d) **Security in the operations, control of environmental aspects and prevention of work risks:** Security of Port Operations (Anchorage/Cast off, Pilotage and Towing), Plan for Emergency and Work Risks; Environmental Aspects.

e) **Client Information Service:** Quality of Information provided for the Client; Quick Answering.

f) **Control of processes and operations:** Responsibility and Direction of Operations; Response Capacity; Availability, Communication the Interested parties.

For maritime transport

a) **Management of material and human resources:** Personnel Training and Qualification; Continued Training Improvement; Human Resources.

b) **Transparency in Invoicing**: Clarity and Transparency of Bills; Breakdown of Bills, Fare Policy.

c) **Measurement of quality and continued improvement of services:** Measurement of the Level of Quality of Service; Permanent Analysis of the Levels of Quality of Service and Plan for Improvement, Continued follow-up of Client Satisfaction, Quality of the Port Service.

d) **Security in the operations, control of environmental aspects and Prevention and Occupational Health:** Security of the Vessels and the Maritime Traffic; Collaboration in the Security of Port Operations; Prevention Risk; Environmental Aspects.

e) **Client Information Service**: Quality of Information provided to the Client; Response Efficiency; Contracts.

f) **Control of processes and operations:** documentation of Operation Processes, Control and Follow-up of Operational Processes; Regularity; Continuity; Frequency; Capacity of Service Supplies; Port Processes; Communication with Interested Parties.

g) **Handling and treatment of merchandise:** Processes; Means; Information of Incidences; Collaboration with other Agents.

h) **Passenger services**: Commercial Process; Information; Port Installations; Embarkation and Disembarkation Processes; Schedules, Service during Navigation; Safety on board; Satisfaction Perceived. Only applicable to lines of mixed transport.

VALIDATION OF THE NORMATIVE DOCUMENTS

With the object of guaranteeing the participation of the different interests to which the Standardization of the sector is directed, and with the object of complying with the requisites of the Certification of Services, regulated through the European norm, EN 45.011, a Technical Committee was summoned formed by: experts in inspection, representatives of service suppliers, representatives of the institutions related to its users, and members of the certification body (SGS ICS Ibérica). Its role consisted in examining and validating the four normative documents designed, ensuring that:

- the requisites specified and the regulations established are objective, measurable, and controllable,
- the characteristics to certify bear an added value for the users, and a better image for the sector,
- the criteria established comply with the laws and norms applicable to each service in question,
- when opting for a consequent certification, the information of the characteristics of the service does not confuse users.

With this philosophy, the 4 standardization documents of the port and maritime sectors were validated by the Committee formed by:

ANARE: Spanish National Tugowners Association
ANAVE: Spanish Shipowner's Association
ATEIA: Freight Forwarders Association
EPPE: Public Service of Weather Forecast Euro Metéo

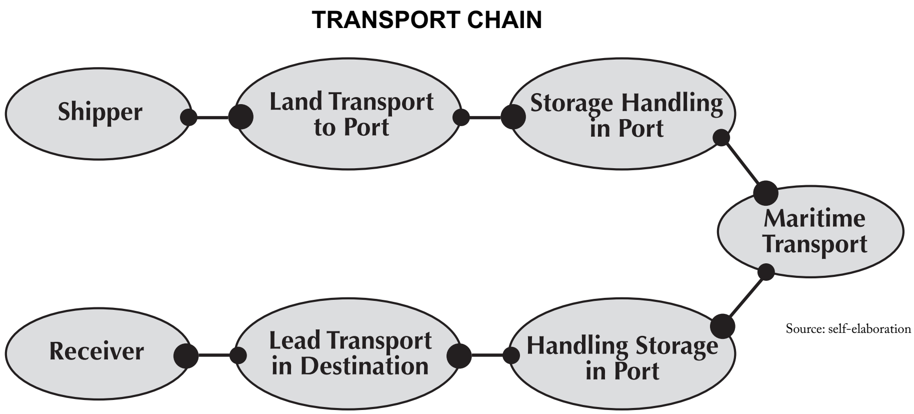


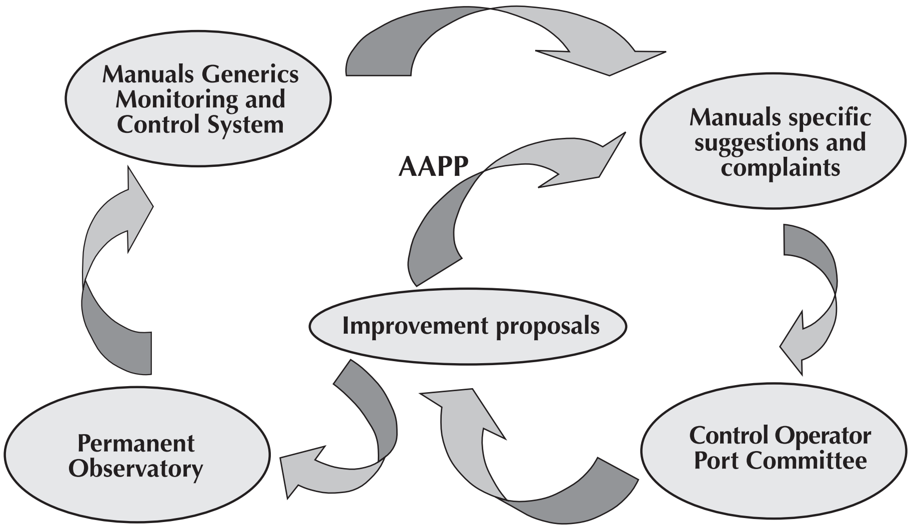
Figure 2. Functioning scheme of the logistics of Maritime transport.

CONCLUSIONS

The joint quality plans with which it is intended to fulfil harbour clientele expectations and requirements with respects to service quality. In this sense, it was established as an objective, to build support in the logistics chain which connects Tenerife's port with Barcelona's port, focussing attention mainly in the traffic of goods.

Between the achievements attained with the establishment of this type of quality plans we find: the simplification of the customs bureaucratic paper works, developments in computing and information systems, reduction of accidents and, consequently, the reduction of insurance premiums.

With respects to the action line, these will be designed according to the requirements of operators and clients of both harbour communities, being found between the critical factors: reliability in delivery dates, supply of returnable equipments for container fillings and agility intensification.



Source: self-elaborated.

Figure: 3. Continouos Improvement application Scheme.

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PROPOSAL OF AN ENVIRONMENTAL CODE OF PRACTICE: IMPROVEMENT OF ENVIRONMENTAL SENSITIVITY IN SHIPBUILDING AND SHIP REPAIR INDUSTRY

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Abstract

One of the mostly discussed topics in the 21st century regarding all industries without exception is the environmental sensitivity which focuses basically on environmental protection and environmental impacts of organizations. Environmental standardization contains the major elements for the realization of environmental sensitivity, including environment side, affection for the general process and product and services those are performed in the organization. For the shipbuilding industry, as being an international market, the importance of quality is beyond doubt. Although quality concept has already proven its necessity in the market, for the 21st century's multi-directional points of view, it is not enough for a successful manufacturing organization. Consequently, the need for the improvement of environmental sensitivity has arisen as a result of the decisive studies of environmentalist organizations, which leaded to toughened national and international legislations. This paper, starting with a environmental policy proposal for the shipbuilding industry, gives an overview of the industry for both the European and the World markets. On the practice part, environmental management system, a useful tool for the improvement of environmental sensitivity is analyzed.

Key words: Shipbuilding, Shipyard, Environmental Sensitivity, Environmental Aspect

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INTRODUCTION

Shipbuilding industry has strategic importance in many respects. It develops advanced technologies that offer considerable spin-offs to other sectors; it provides essential means of transport for international trade; and it supplies modern navies with advanced vessels.

In high-tech industry sectors such as shipbuilding, success is first of all based on knowledge. Only in Europe exists such a dense network of shipyards, equipment suppliers, research centers and other providers of advanced technologies and engineering services.

European Shipbuilding is a strong and dynamic industry. As a result of an impressive streamlining, coupled with pro-active outsourcing strategies and continuous innovation in production methods, a network of highly specialized companies has developed to become one of the competitive advantages of the European shipbuilding industry. Typically 60 to 75% of the values of a new ship are goods and services provided by marine equipment and service industries.

Shipbuilding is an important and strategic industry in a number of EU Member States. Shipyards often play a significant role for the regional industrial infrastructure and with regard to military shipbuilding, for national security interests.

There are more than 150 shipyards in the EU, with about 40 of them active in the global market for large sea-going commercial vessels; 350.000 people are directly employed by yards and the marine equipment industry (which has around 9.000 companies). More than half of the industry's turnover of about 34 billion Euro is achieved through exports.

The European shipbuilding industry is the global leader in the construction of complex vessels such as cruise ships, ferries, mega-yachts and dredgers. It also has a strong position in the building of submarines and other naval vessels. Equally, the European marine equipment industry is world leader for a wide range of products, from large diesel engines to electronics.

- The European shipbuilding industry holds approximately 20% of the world shipbuilding capacity.
- Member Shipyards provide more than 100,000 high qualification jobs through direct employment and generate at least three times as many in the marine equipment and service industries in Europe.
- The annual turnover of shipyards represented by Community of European Shipyards' Association (CESA) in 2006 was 14.4 billion Euro in merchant shipbuilding and 2.1 billion Euro in ship repairing. Exports accounts for roughly 70% of the total turnover.
- As key drivers of maritime excellence, European shipyards invest on average approximately 10% of their turnover on research, development and innovation (CESA,2007).

Commercial shipbuilding and ship repair have always operated in a truly global market, with yards competing for contracts within and outside their own countries. This early and comprehensive exposure to the forces of globalization makes shipbuilding substantially different from most other manufacturing industries. However, market mechanisms are not allowed to function properly due to government interventions in several countries. While a strong state aid discipline exists in the EU, no specific discipline applies at international level.

While most industries are effectively covered by existing multilateral trade rules, shipbuilding, due to its own characteristics, is not easily amenable to the application of those rules. Today, shipbuilding is not subject to an anti-dumping discipline or to custom duties. Consequently, the shipbuilding sector is practically the only industry without effective protection against unfair trading practices.

ENVIRONMENTAL POLICY CODE

In order to establish an environmental policy code, it is better to foresee the main environmental objectives which the shipbuilding sector should aim to achieve. These are listed below:

1. To develop a sustainable shipbuilding infrastructure, for both new building and repair segments with the idea of continual improvement by generating new knowledge and technology and developing sustainable techniques which combine environmental effectiveness and cost efficiency. The aim is to achieve self-regulation and develop a bottom-up approach. Even if the governments decide to issue environmental regulations, the existing self-regulatory instruments, developed by the shipyards themselves and which address day-to-day practice, will provide a background to be used as a basis for governmental environmental policy. This will enable legislation to be more easily supported and implemented.
2. To encourage cooperation between shipyard managements and the relevant stakeholders (ship owners, shipyard workers, public, NGOs) to facilitate the reconciliation, at an early stage, of differing interests and the acceptance of shipyard projects by the local community.
3. To enhance cooperation between shipyard managements in the field of environment and facilitate the exchange of experiences and implementation of best practices on environmental issues to avoid unnecessary duplication and enable shipyard managements to share the costs of environmental solutions. This can be notably achieved through the participation of shipyards in a network. The aim is to create a level playing field by limiting poor environmental practice as a competitive factor between shipyard managements.
4. To encourage shipyard managements to conduct appropriate environmental impact assessments for shipyard projects and appropriate strategic environ-

mental impact assessments for shipyard development plans to assess, at an early stage, how their effects on the environment can be minimized.

ENVIRONMENTAL FRAMEWORK FOR SHIPYARD MANAGEMENTS

The role of shipyard managements in coping with the environmental issues can be analyzed in two different perspectives:

— Shipyard area (land and sea)

— Ship / Shipyard interface

The following sections will demonstrate that the shipbuilding and repair industry is committed to developing voluntary schemes in order to move towards self-regulation.

Development of the Shipyard Area

The activities of industries located in the shipyard area affect the shipyard area as a whole. As a result, the interests of the shipyard management are also related to the environmental effects of the actions undertaken by industries in the shipyard.

Global competition puts pressure on European shipyard managements to offer quality and economy which accommodate the wishes of their customers. On the other hand, shipyard development in Europe is more and more constrained by scarcity of land, urban development and ecological considerations. Shipyard development can be affected by the requirements of a series of Directives: Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), Conservation of Wild Birds and Conservation of Natural Habitats and of Wild Flora and Fauna. Moreover, shipyard development should be seen in the context of Integrated Coastal Zone Management (ICZM). This approach requires a comprehensive assessment, setting of objectives and planning of coastal systems and resources (EU Directive, 2001).

The environmental principles set in the above-mentioned Directives can conflict with the interests of shipyards, as the fulfillment of these requirements may hamper the development of shipyard projects, therefore lead to great delays in their completion and increase costs. The implications are heavily influenced by the way legislation is transposed into national legislation, as well as by the national and regional-specific rules.

Bearing in mind the legal framework and the system of planning consents as operated in each member state, it is recommended that:

— Shipyard managements conduct appropriate environmental impact studies where possible, even if not strictly required under the terms of the Environmental Impact Assessment Directive;

— All shipyard management's plans make sure they collect the public opinion in the planning period, according to the Strategic Environmental Assessment

Directive; a carefully designed public outreach program can ensure the involvement of all stakeholders;

— Shipyard managements get involved in the early processes of designation of protected areas.

Environmental Aspects of Shipyard Phenomena and Shipbuilding Industry

An environmental aspect is defined as an element of a facility's activities, products or services that can or does interact with the environment. These interactions and their effects may be continuous in nature, periodic, or associated only with events, such as emergencies. Traditional environmental impacts related to building processes are considered to be emissions of noise and dust during sandblasting and painting. In addition, the efficiency of the usage of steel plates has been of some concern. Important processes are cutting, forming, joining, grinding, sandblasting, painting and outfitting. The most important environmental aspects concerning those processes are mainly local aspects with relation to air and water (Hayman et al., 2000).

An environmental impact is defined as any change to the environment, whether adverse or beneficial, resulting from a facility's activities, products, or services. A significant environmental aspect is one that may produce a significant environmental impact (EPA,2003). In short, the aspect is the cause and the impact is the effect. Some major environmental aspects and their impacts in the shipyard phenomena is illustrated in Table 1.

Environmental Aspect	→	Environmental Impact(s)
Emissions of volatile organic Compounds (VOC's)	→	Air pollution, smog
Discharges to stream	→	Degradation of aquatic habitat and drinking water supply
Spills and leaks	→	Soil and groundwater contamination
Electricity use	→	Air pollution, global warming
Use of recycled paper	→	Conservation of natural resources

Table 1. Environmental impact and aspect samples for shipyard organizations.

There are numerous techniques and data sources to assist in identifying and evaluating environmental aspects and impacts at the facility. Note that much of the data collected to date will be useful as environmental aspects are identified and their significances are determined. In determining environmental aspects, considerable consensus building and professional judgments are required to develop conclusions about risk. This is because how to evaluate all the factors that determine ecological risk is not well defined and is the subject to interpretation. Individual measures must weighted by the quality and reliability of their data and risk must be estimated from the preponderance, magnitude, extent, and strength of causal relationships between the data on exposure and effects. Some major examples of a shipyard's environmental impacts can be counted as dredging (OSPAR, 1992) and disposal of dredged material (Yozzo, et al., 2004), similarly soil contamination, wastes were discussed by Page et al, (2005) and by Song et al, 2005. Similarly air pollution, noise pollution and water pollution prevention for shipyards were discussed in advanced by the following authors and companies: Kwan (2001), Kellems et al. (2001), Stromwater Ltd (2000), Walker et al. (2005).

Techniques and Data Sources	**When Best Used**
Emission Inventories	Used to quantify emissions of pollutants to the air. Some data on emissions or chemicals of concern may already be available.
Environmental Compliance Audits	Used to assess compliance with federal, state, and local environmental regulations. These methodologies are in common use. Their scope and level of detail vary.
Environmental Cost Accounting	Used to assess the full environmental costs associated with activities, products, or services.
Environmental Impact Assessments	Used to satisfy requirements regarding the evaluation of environmental impacts associated with proposed projects.
Environmental Property Assessments	Used to assess potential environmental liabilities associated with facility or business acquisitions or divestitures.
Failure Mode and Effects Analyses	Commonly used in the quality field to identify and prioritize potential equipment and process failures as well as to identify potential corrective actions.
Life Cycle Assessments	Used to assess the cradle-to-grave impacts of products or processes, from raw material procurement through disposal.
Pollution Prevention or Waste Minimization Audits	Used to identify opportunities to reduce or eliminate pollution at the source and to identify recycling options.
Process Flow Diagrams	Used to allow an organization to visualize and understand how work gets accomplished and how its work processes can be improved.
Process Hazard Analyses	Used to identify and assess potential impacts associated with unplanned releases of hazardous materials.
Project Safety/Hazard Reviews	Used to assess and mitigate potential safety hazards associated with new or modified projects.
Risk Assessments	Used to assess potential health and/or environment risks typically associated with chemical exposure.

Table 2: List of techniques and data sources for determining environmental aspects.

Systematically weighing the evidence of risk rendered conclusions about risk in a manner that was clearly defined, objective, consistent, and did not rely solely on professional judgment (Johnston et al., 2002). In table 2, list of techniques and data sources for determining environmental aspects are given with the correct situations to be used.

SHIPYARDS AND THEIR ENVIRONMENTAL MANAGEMENT

The environmental role of shipyard managements depends on national laws. In certain cases, national legislation already foresees environmental requirements for shipyard users. Environmental duties are also given to public authorities or administrations different from shipyard managements.

An environmental management system (EMS) is a management framework for reducing environmental impacts and improving organizational performance over time. EMSs provide organizations of all types with a structured approach for managing environmental and regulatory responsibilities to improve overall environmental performance, including areas not subject to regulation such as unregulated risk, resource conservation, and energy efficiency (Ross Ltd., 2004) . An EMS helps an organization better integrate the full scope of environmental considerations and get better results, by establishing a continuous process of checking to make sure environmental goals are met. The EMS approach is based on the concept of Total Quality Management (TQM), which was initially developed as a tool by the private sector to achieve higher and more consistent product quality. The framework is based on a plan-do-check-act continual improvement approach that leads an organization through a regular cycle of planning, implementation, performance monitoring and review/improvement.

With an EMS, an organization develops and routinely evaluates processes and procedures to identify and manage its environmental footprint. An organization looks at selected operations associated with its significant impacts and makes them visible, measurable, manageable and therefore subject to improvement. An EMS does not impose new technical requirements. Rather, it helps an organization develop its own short and long-term environmental goals and objectives, its own operational controls, and its own improvement requirements. The EMS may lead an organization to adopt new methods, modify existing ones or accept the practices it already has in place. The EMS framework can be adapted to support the needs, priorities and circumstances of the implementing organization. Typically, an EMS is used to support continual improvement of activities relevant to environmental performance by helping an organization identify and act on opportunities for improvements (Sayre, 1996).

An organization's decision about whether to implement an EMS, and potentially seek third-party certification (e.g., ISO 14001, EMAS) for it, is typically based on a comparison of the perceived costs and benefits (ISO 14001, 2004) and (Melnyk et al., 1999). To pursue an EMS, organizations typically must decide that one or more of the following outcomes are important to business success:

— A strong environmental compliance management system that reduces the risk of non-compliance situations;
— An effective management system for driving environmental policy objectives through the organization, including into core operations;
— A system to support continual improvement of environmental management processes and performance; and
— A system that generates documentation for purposes of internal and/or external auditability.

In addition to organizations' desires to achieve one or more of these outcomes, there are other drivers that can shift the EMS decision dynamics, such as peer pressure within an industry sector, supply chain pressures or expectations, and the presence of incentives for pursuing an EMS. When the cost effective analysis of EMS integration for a shipyard organization is taken into account, the cost factors can be classified as internal costs and external costs. The internal cost can be realized as the cost of efforts that shall be spent for the execution, coordination and implementation of system requirements in the shipyard that can be recognized as the labor cost (it represents the bulk of the EMS resources expended by most facilities) and the cost for the enhancement of infrastructure related with environmental pollution prevention in the shipyard. Similarly the external cost could be the possible consulting assistance and external training of shipyard key personnel. The benefit perspective of EMS integration into shipyard organization can be listed as the improved environmental performance, enhanced compliance assurance, prevention of pollution and resource conservation, new customers/markets, increased efficiency/reduced costs, enhanced employee morale, enhanced image with public, regulators, lenders, investors, and employee awareness of environmental issues and responsibilities and reduced risk.

A recent U.S. National Aeronautics & Space Administration (NASA) study established a gold standard for measuring EMS implementation costs. NASA compiled implementation cost information at three centers piloting EMS, including estimates on in-house civil servant and contractor support. Though costs may be slightly different for a shipbuilding facility, the NASA costs range between \$111 and \$138 per capita with a range of hours spent from 1.3 to 2.3 per capita. The returns on such investments tend to have two-year paybacks and can generate savings of about \$3.50 for every dollar invested (ICF, 2001). Another tool for the application of an environmental management system this time, is implementing an integrated management system, by combining quality and environmental issues. As all management systems share a lot of common practices, the integration will make the record-keeping, audit, review and some other processes much easier. In this respect quality management system and environmental management system integration in generic principles were offered by Beechner and Koch (1997), and its total quality management approximation was discussed by Karapetrovic and Willborn (1998). Besides integrated management system implementation philosophy for small enterprises was analyzed in advanced by Douglas and Glen (2000). Then the enhancement of shipyard facilities in developing countries utilizing with the integration of ISO 9001:2000 and ISO 14001:2004 standards were proposed by Nomak and Er (2004).

Compliance with legal requirements is one of the main pillars upon which the environmental management system should be based because the potential costs of non-compliance (possible damage to the environment, revenue loss and impact on public image, for example) can be very high.

An effective EMS will build on what already is and should include processes to:

- identify and communicate applicable legal and other requirements; and
- ensure that these requirements are factored into the facility's management efforts.

New or revised legal requirements might require modification of the environmental objectives or other EMS elements. By anticipating new requirements and making changes to the operations, some future compliance obligations and their associated costs might be avoided.

Furthermore, national legislation can vary for different countries. For instance, Japan appears to have established environmental policies designed to protect human health and the natural environment. Various laws such as the Air Pollution Control Law, the Water Pollution Control Law and the Chemical Substances Control Law provide the basis for establishing standards on waste releases. Under these laws, environmental standards were established for maintaining ambient air and water quality, and preserving the natural environment in Japan. It is important to note that Japan gives highest priority to environmental impact assessments and environmental Based on the regulations reviewed in this paper, it is hard to get a clear picture on the impact of the environmental standards on shipyards, and the level of environmental compliance by the Japanese shipyards. However, because of the complex processes and chemicals employed in shipyards, it is reasonable to expect that Japanese shipyards are strictly regulated under the current environmental laws (Kura et al. 1997).

CONCLUSION

The total cost of processes handled in order to fulfill the requirements of both national and international environmental legislation, results in an increasing amount day by day. Both states and international organizations are in a race of putting sanctions into motion about environmental care and protection.

Mostly affected bodies from the toughening legislations are the industrial enterprises, especially the heavy industries having various environmental aspects. As the shipbuilding and repair industry is one of them, negative influences of new codes and directives show noteworthy effect on the market share of ones which are faced with tighter legislation. As commercial shipbuilding and repair operates in a global market, with yards competing for contracts outside their own countries, comprehensive exposure to different legislative forces makes shipbuilding absolutely different from most other industries. While a strong state-based discipline exists in the EU, no specific discipline applies at international level, especially in far-eastern countries.

In conclusion, the shipbuilding sector is practically the only industry without effective protection against unfair trading practices. Consequentially, the need for optimizing the cost due to environmental legislation has arisen. The best practice for the minimization of costs without facing with penalties is developing and following an environmental policy code, possibly guided by a management system, which is both a guarantee for the continuation of the system and a tool for optimizing the job done.

An environmental management system, once to be seen luxury for most enterprises, is an indispensable tool to cope with the environmental legislation. The system both eases the prosecution, reduces risks, provides continual improvement and obtains noteworthy decrease in the cumulative running costs.

The implementation period of an environmental management system differs from case to case, for different sizes of organizations, various scopes of production and dynamism. But on the implementation process, the most important fact is the managerial commitment. If the management can persuade the working team on the need of the system, the implementation phase will be painless.

As a result of these, in order to cope with the rapidly arising environmental legislation both nation-wise and internationally, implementation of an environmental policy code, guided by a management system is an indispensable tool for shipyard managements, both for the continuation of productivity and competitive position in the world market.

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BEHAVIOUR OF MARINE ELECTRO GENERATORS UNDER ABNORMAL CONDITIONS USING ENGINE CONTROL ROOM SIMULATOR

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Abstract

The aim of the present paper is to analyze the behaviour of diesel engine driven electro generators used in maritime engineering for the electrical power supply system of ship on real time operation and under abnormal conditions. Two generators that are driven by diesel engines, modelled as high speed engines with all vital subsystems such as governor, sea water system, cooling water – lubrication oil, start air, turbo charge, air cooler, fuel oil. Besides, the research attempts to provide solutions for real operating problems and to test the reactions of personnel that are responsible for the normal function of generators. These solutions will give a quantitative description of the work and it will form a basis to reveal the most important risk factors. Simulator exercises have been defined to reflect some of these options.

Key words: Engine Room Simulator, Generators, Faults, Maintenance.

INTRODUCTION

Today, the extended use of innovative educational tools such as marine engine and bridge simulators allows us to test new technology before implementing it on board. Also, the main aim of the simulator (S.T.C.W., 1995; IMO Model Course 2.07, 2002) is to assist manufacturers and maritime training institutes – academies and their teaching staff in organizing and introducing new training courses or in

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enhancing, updating or supplementing existing training and research material where the quality and effectiveness of the knowledge and experience may thereby be improved.

The simulator exercises could be used as far as practically reasonable to quantify:

— work load, fatigue,
— stress levels
— and available time for watch out.

Parameters to be quantified include number of operations carried out and time used on different tasks.

Misunderstandings (in the man-machine interaction as well as in human-human communication), loss of situation awareness and erroneous planning and execution will be identified as occurring will form a basis to reveal the most important risk factors and to identify hazards. Besides, simulator exercises (I.M.O., Model Course 2.07, 2002; Kluj, 1997) allow the trainees to become familiar with the instrumentation and controls used in the engine rooms of modern merchant ships, as well as, develop the ability to become skilled in the scanning of faults that can occur during the operation plant.

It is a well known that one from the most critical systems for the normal operation of ship is the effective operation without malfunctions of electro generators. The careful use of generators, in combination, with the equitable and periodical maintenance, using suitable checklists (Kluj, 1999), can lead to decreased appearance of total blackout. Under unfortunate conditions a blackout can endanger the safety of ship, leading to grounding or collision. A non planned blackout should therefore be regarded as an emergency situation and treated likewise.

For this purpose the influence of vital subsystems (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999) such as governor, sea water system, cooling water – lubrication oil, start air, turbo charge, air cooler, fuel oil on the normal operation of diesel electro generators, have been studied.

An attempt to examine the basic malfunctions of diesel electro generators and especially how they are could be avoided has been made. This paper discusses some of the faults of such systems and provides an insight into the various technical issues associated with the application and maintenance of electrical power systems for marine applications.

LIST OF SYMBOLS

Mxx	Malfunction xx
ALxx	Alarm xx
EBMxx	Event based malfunction xx

DESCRIPTION OF SIMULATOR

The engine room simulator plant at Merchant Marine Academy of Makedonia is designed, implemented and integrated by Kongsberg Nor control Simulation (Kongsberg Nor control, PPT2000-MC90-III, 1999).

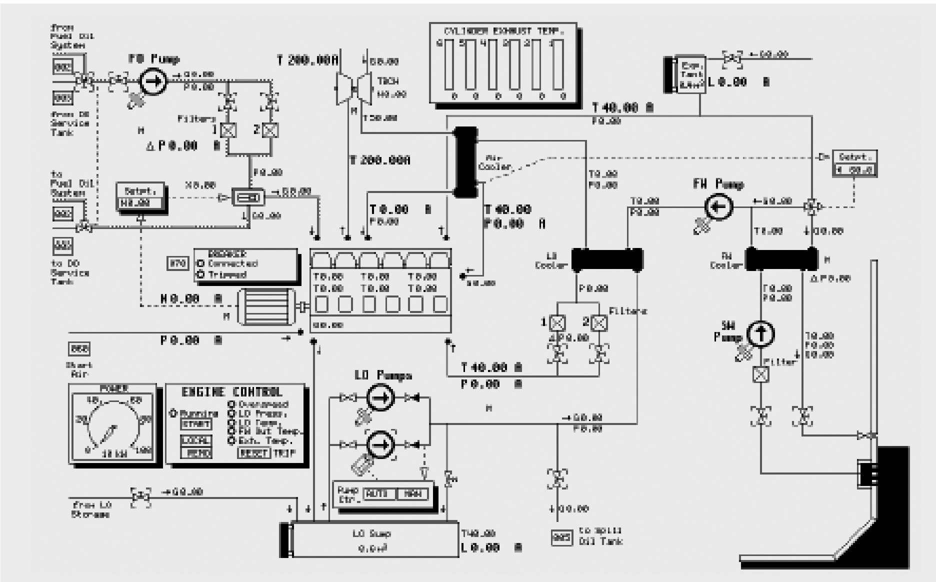
The simulator could be divided into two main parts: The simulated Engine Room and the Instructor system. The simulated engine room is arranged as subsystems identical to those found onboard a real Very Large Crude Oil Carrier Ship (V.L.C.C.). The simulation models have been configured by Operator Training Industrial Simulation System software that it has been developed by Special Analysis and Simulation Technology Ltd, England.

Simulator training or research projects of Merchant Marine Academy of Makedonia are realized by the following phases:

1. Proposal Phase,
2. Data collection and implementation,
3. Simulation and data recording,
4. Analysis
5. Reporting.

The instructor system of engine room simulator comprises the facilities and features needed for the instructor to prepare, control and evaluate the simulator training courses or research studies.

Figure 1: Diesel engine driven generator.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual, The simulated main engine is a B&W 5L90 MC, five cylinder in-line, low speed, two stroke engine with turbo-charging and scavenging air cooling.

Generators are driven by diesel engines [Figure 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)], modelled as high speed engines with all vital subsystems such as rpm governor, cooling water, lubrication oil, start air, turbo charger, air cooler and fuel oil.

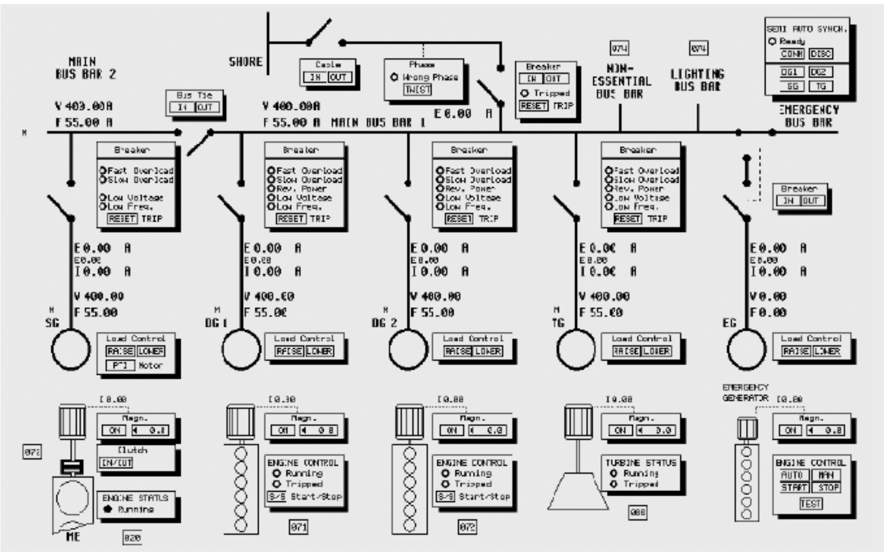
The electrical consumption is monitored and compared to the present possible power production. When deviation from present limits arises, the system will act in order to normalize the situation. The system also performs continuous controls of the frequency and load sharing.

The preferred mode of operation is with Shaft generator as base generator, the turbo generator as an auxiliary generator and with two diesel generators in auto as stand by generators.

The ship's electric distribution [Figure 2, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] is grouped in 2 separate bus bar sections:

— Main Bus Bar 1 is powered by the diesel generators and turbo-generator. The shore supply is also connected to this bus bar. All main consumers are fed from this section.
— Main Bus Bar 2 is powered by the shaft generator. It is normally isolated from the bus bar 1 by a bus tie breaker. The consumers connected to bus bar 2 are all insensitive to frequency/voltage variations and hence are suitable for shaft generator supply.

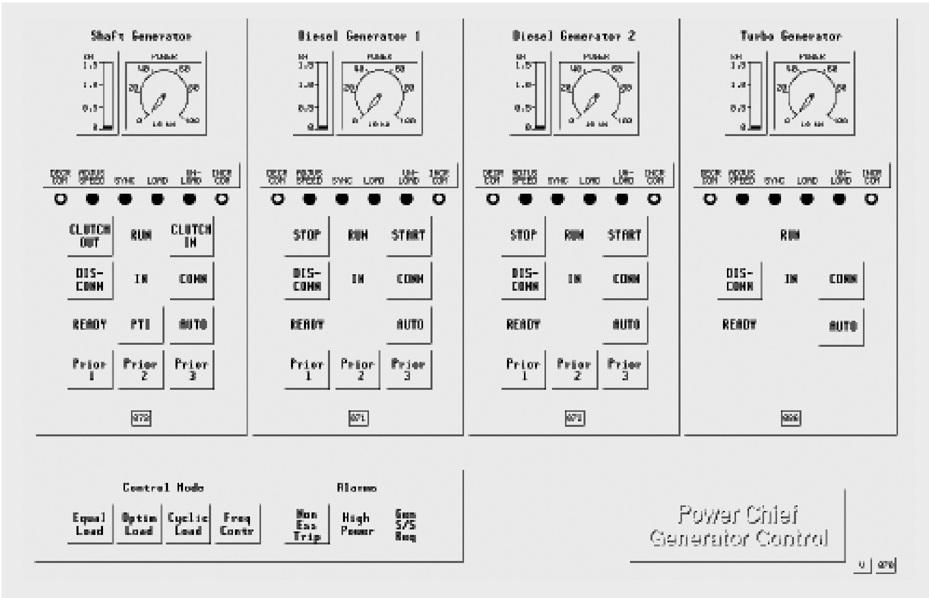
Figure 2. Electric power plant.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual.

The recommended priority setting [Figure 3, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] is priority 1 for the Shaft Generator, priority 2/3 for diesel generator 1/2. Diesel generators, in case of a blackout situation, act as stand by generators. The generator with the highest priority will be the first to be connected. The generator with the highest priority will take the entire load up to 70% of normal rating, while the other generator takes the rest of the load. The load limits for the highest priority generators are 680 to 800 *kW*.

Figure 3. Power chief Generator control.



Source: Kongsberg Nor control, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

Due to the difference in the torque characteristics of the generators, it was not possible to keep the same load sharing over the whole power range except by manual readjustment or by control action from the power chief system.

The system has two load sharing concepts:

— balanced (symmetrical)

— unbalanced (asymmetrical)

For sharing of the load between the generators sets which are connected to the same bus bar. When the balanced mode is selected the system ensures that the load of each generator has the same power ratio (percentage of maximum load). When two diesel electro generators are connected to the bus bar 1 and the unbalanced mode is selected the system ensures that the load of one generator has a specified ration while the other act as a topping up with a minimum load.

The unbalanced load sharing system could serve at least two purposes. One purpose is to optimize the load on one diesel generator with respect to economy while the second diesel generator will handle the remaining load. Another purpose is to protect a newly overhauled auxiliary diesel engine by ensuring a certain maximum load to it.

Table 1. Alarms of Diesel Generators.

	High
AL01	Fuel oil filter drop diesel generator
AL03	Lubrication oil temperature inlet diesel generator
AL05	Fresh water temperature outlet diesel generator
AL06	Exhaust temperature outlet turbo charge
AL07	Exhaust temperature inlet turbo charge
AL08	Bearings temperature diesel generator

	Low
AL02	Lubrication oil pressure inlet diesel generator
AL04	Fresh water pressure inlet diesel generator

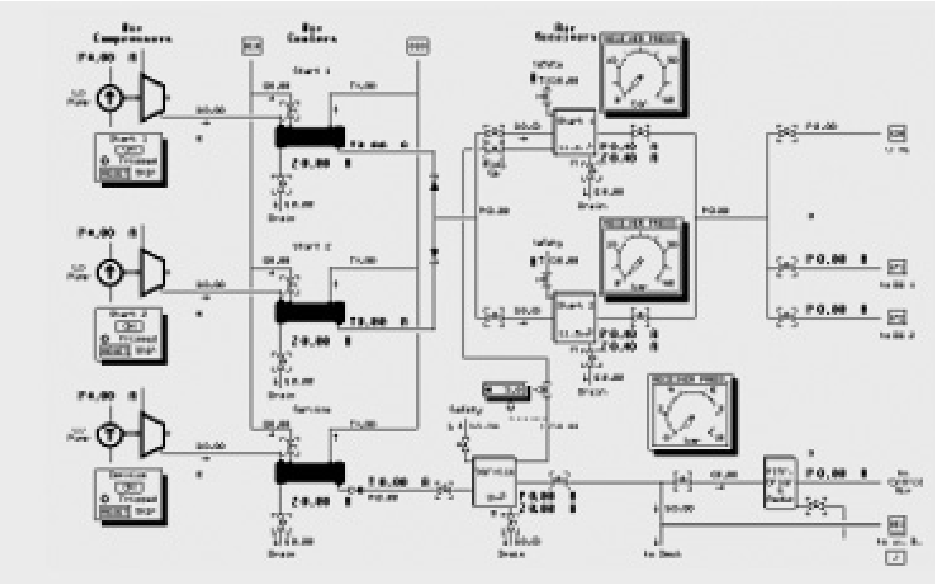
Alarms '*ALxx*' of diesel driven generators are divided into two types: high and low level alarms. Table 1 displays the alarms of diesel generators. Thus, the trouble shooting scenarios were designed to provide experience in identifying malfunctions, faults and applying remedial procedures. All operations have been planned in accordance with the established rules and procedures to ensure safety of operations.

OBSERVATION PLAN

In the examined scenario the ship was running in open sea following the mode 'Slow Ahead – Loaded'. The ambient sea water temperature was 15 ˚C, the ambient air temperature was 20 ˚C and the ambient air humidity was 50%. Sea water depth was 200 m, main engine fuel link position was 43% and the main engine speed command was 49 rpm.

The required seawater and freshwater systems for the cooling of generators have been prepared [Figure 1, (Kongsberg Nor control, PPT2000-MC90-III, 1999)]. Compressors [Figure 4, (Kongsberg Nor control, PPT2000-MC90-III, 1999)] were in operation in order to supply starting and control air. Fuel oil and lubrication oil

Figure 4. Start air and air compressors.



Source: Kongsberg Norcontrol, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

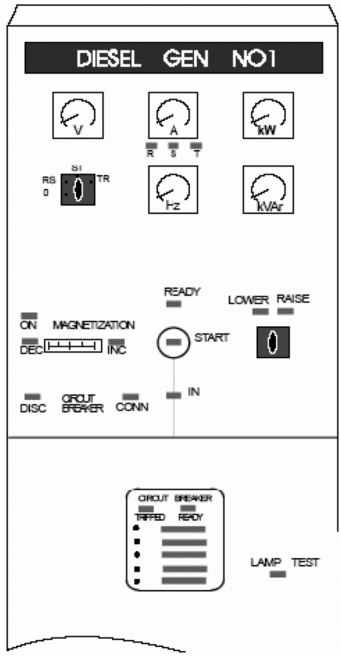
systems for the correct operation of generators also were ready. The procedures of the voltage and frequency adjustment have been followed (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999).

Figure 5 shows the control panel of diesel generators (Kongsberg Norcontrol, PPT2000-MC90-III, 1999). The identification and recording of normal cooling water temperatures exhaust gas temperatures; round per minutes and fuel data consumption data of engines as well as the produced power, voltage, current and frequency for the electrical system have been realized.

Several faults have been introduced in order to demonstrate cascading of abnormal conditions that influence the operation of diesel driven electro generators (I.M.O., Model Course 6.09, 2001; I.M.O., Model Course 2.07, 2002). In the current scenario used nine malfunctions '*Mxx*'. Faults could be edited on line. However, for each inserted malfunction the observation time was specified to be 5 minutes in order to have a stable factor for evaluation. The malfunction might be ramped from the initial value to the specified malfunction set point. Besides in our scenario has been included one event - based malfunction '*EBMxx*' that goes active depending on a specified event that occurs in the process. In general, the event based malfunction will go active if the watched variable is higher or lower than the given limits. If the variable toggles around the limits, it could be set a delay time before the malfunction is triggered.

For the demonstration of the diesel generator driven alarm *AL01* 'High Fuel oil filter drop of diesel generator', the malfunction *M01* 'Dirty diesel oil filter of diesel generator' was activated after the running of scenario. The highest limit of fuel oil filter differential pressure is 1,00 *bar*. Diesel oil filter started to be gradually dirty (0 ÷ 100%) with the use of ramp mode in 5 minutes. Figure 6 shows the appearance time of alarm *AL01* at the different stages of produced fault. From this figure it can be seen that the increase of damage over 20% does not give to personnel the adequate time for the quick re-establishment of damage. For the repair of damage [Figure 1, (Kongsberg Norcontrol, PPT2000-MC90-III, 1999)] was activated the valve for the diesel generator filter 2 and was deactivated the valve for the diesel generator filter 1.

Figure 5. Electrical control panel of diesel generator.



Source: Kongsberg Norcontrol, Propulsion Plant Trainer, PPT2000-MC90-III, User's Manual

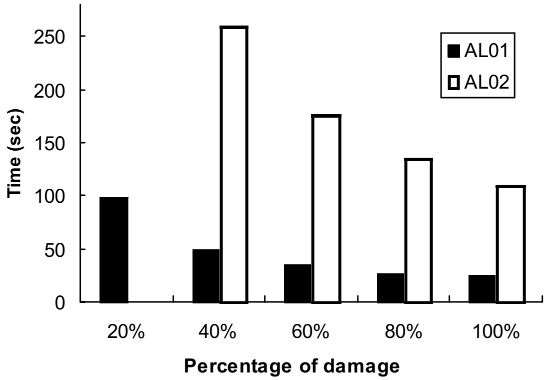
For the demonstration of the diesel generator driven alarm *AL02* 'Low Lubrication oil pressure inlet diesel generator', the malfunction *M02* 'Diesel generator lubricant oil pump 1 wear' was activated 5 minutes of simulated time after the running of scenario. The lowest limit of lubrication oil pressure inlet is 1,40 *bar*. Lubricant oil pump started to be destroyed gradually (0 ÷ 100%) with the use of ramp mode in 5 minutes. Figure 6 shows the appearance time of alarm *AL02* at the different stages of produced fault. From this figure it can be seen that for damages until 40% there is plenty of time for the re-establishment of damage. For the repair of damage [Figure 1, (Kongsberg Norcontrol, PPT2000-MC90-III, 1999)] was activated in auto mode diesel generator lubrication oil priming.

For the demonstration of the diesel generator driven alarm *AL03* 'High Lubrication oil temperature inlet diesel generator' were used one time-based malfunction and one event based malfunction. The highest limit of lubrication oil temperature inlet was 75 ℃. *M03* malfunction 'Diesel generator fresh water cooler dirty' was activated 10 minutes of simulated time after the running of scenario. Fresh water cooler of diesel generator was destroyed suddenly at 70%. The event based malfunction *EBM01* 'Closed diesel generator sea water inlet valve' was specified to be turned active when the lubrication oil temperature inlet of diesel generator exceeds 66 ℃. It can be observed that *AL03* is activated in 39 *sec*. For the avoidance of damage (Figure 1, [7]) the engineer who is doing watch keeping must inspect periodically the cleanness of fresh water coolers and checks the good operation of inlet and outlet valves of sea water for cooling of fresh water system.

For the demonstration of the diesel generator driven alarms, *AL04* 'Low Fresh water pressure inlet diesel generator' and *AL05* 'High fresh water temperature outlet diesel generator', malfunction *M04* 'Wear fresh water pump of diesel generator' was activated 15 minutes of simulated time after the running of scenario.

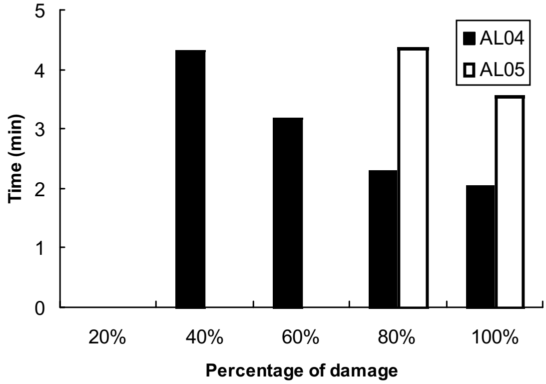
The lowest limit of fresh water inlet pressure is 0,70 *bar* and the highest limit of fresh water outlet temperature is 85 ℃. Attached fresh water pump started to be worn (0 ÷ 100%) with the use of ramp mode, in 5 minutes. Figure 7 shows the appearance time of alarms *AL04* and *AL05* at the different stages of produced wear. From this figure it can be observed that the increase of worn over 60% leads in the simultaneously appearance of two alarms. For the avoidance of blackout the personnel of engine room must check the circuit of fresh water of diesel generator at regular intervals in order to keep the diesel engine cooling and lubricating oil within the correct operational range.

Figure 6. Appearance time of alarm AL01 and AL02



■ *AL01, High Fuel oil filter drop*
□ *AL02, Low Lubrication oil pressure inlet*

Figure 7. Appearance time of alarm AL04 and AL05



■ *AL04, Low Fresh water pressure inlet*
□ *AL05, High fresh water temperature outlet*

For the demonstration of the diesel generator driven alarms, *AL06* 'High diesel generator exhaust temperature outlet turbo charge' and *AL07* 'High diesel generator exhaust temperature inlet turbo charge' were used three malfunctions simultaneously. The produced faults were the next:

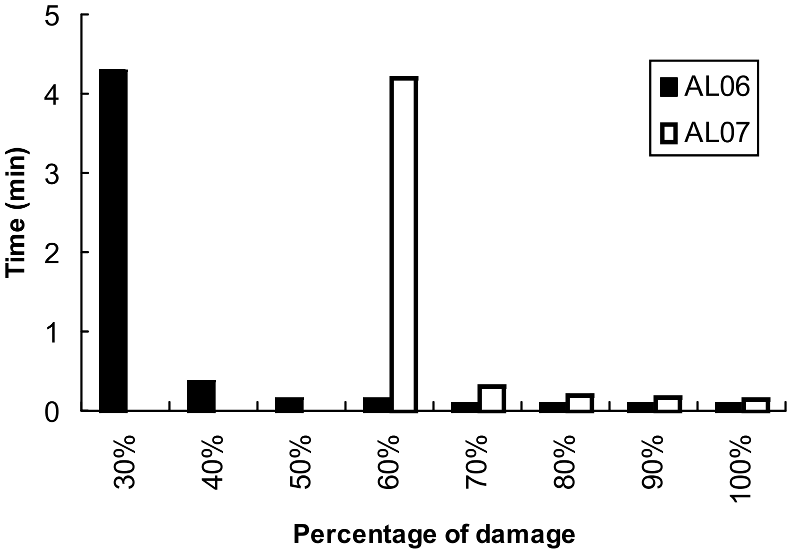
— Malfunction *M05* 'Diesel generator turbocharger dirty',
— Malfunction *M06* 'Diesel generator turbocharger air cooler dirty'
— Malfunction *M07* 'Diesel generator turbocharger air filters dirty'.

These were activated 20 minutes of simulated time after the running of scenario. The highest limits of exhaust temperatures outlet and inlet of turbocharger of diesel generator is 520 ℃ and 610 ℃ respectively. Figure 8 shows the appearance time of alarms *AL06* and *AL07* at the different stages of produced fault.

From this figure it can be observed that the critical percentage of damage for the appearance of *AL06* and *AL07* is the parallel damage of subsystems of turbocharger at 30% and 60% respectively. For bigger percentages of damage than these values it can be deduced that the response time for the re-establishment of damage is very limited.

For the demonstration of the diesel generator driven alarm *AL08* 'High diesel generator Bearings temperature diesel generator' were used two malfunctions at the same time. Malfunction *M08* 'Diesel generator lubrication oil filter 1 dirty' and malfunction *M09* 'Diesel generator lubrication oil cooler dirty'. These were activated 25 minutes of simulated time after the running of scenario. The highest limit of diesel generator bearing temperature is 85 ℃. Increasing gradually the damages, it was observed that for percentages until 40% *AL08* was not activated. The critical percentage of damage was to a value of 50% and alarm *AL08* was activated in 2:45 minutes. For biggest percentages of faults it was deduced that the occurrence of blackout of diesel generator could not be avoided.

Figure 8. Appearance time of alarm AL06 and AL07.



■ *AL06, High exhaust temperature outlet turbo charge*
□ *AL07, High exhaust temperature inlet turbo charge*

CONCLUSIONS

These experiments form part of a larger work (Gourgoulis et al., 2004) concerning the use of engine simulator that simulates a dynamic real time computerized slow speed main propulsion turbocharged diesel engine incorporating a waste heat steam boiler, a turbo generator and one shaft generator.

For the avoidance of malfunctions that influence the normal operation of diesel electro generators during the drip, daily, the operator must check the diesel oil filter of diesel generator, the lubricant oil pump, the sea water temperature control, the fresh water flow resistance, the fresh water pump, the subsystems of turbo charge air cooler and the cooling water flow of start air compressor. Thus, observing all the produced faults it was deduced that the most dangerous fault was malfunction M01 'Dirty diesel oil filter of diesel generator' and the less dangerous fault was malfunction M04 'Wear fresh water pump of diesel generator'.

Familiarisation of students with electrical shipboard systems or equipment combined with possible faults proved that students have the opportunity to develop operational skills, to combine simulations with multimedia techniques such as animation, diagrams, pictures, sound, etc, to develop and improve the English language skills of ships' personnel to make the learning process shorter with the simultaneous increase in quality and to make the assessment process of trainees much more effective.

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COMPORTAMIENTO DE GENERADORES ELÉCTRICOS MARINOS EN CONDICIONES ANORMALES UTILIZANDO UN SIMULADOR DE CONTROL DE LA CÁMARA DE MÁQUINAS

RESUMEN

El objetivo del presente trabajo es analizar el comportamiento del motor diesel, el electro generadores utilizados en ingeniería marítima para el sistema de suministro de energía eléctrica de los buques en tiempo real el funcionamiento y en virtud de condiciones anormales. Dos generadores que están impulsados por motores diesel, como el modelo de alta velocidad con los motores de todos los subsistemas vitales como gobernador, sistema de agua de mar, agua de refrigeración de aceite de lubricación, inicie el aire, la carga de turbo, el aire fresco y fuel. Además, la investigación intenta aportar soluciones para los problemas reales de funcionamiento y poner a prueba las reacciones del personal que se encarga de la función normal de los generadores. Estas soluciones cuantitativos dará una descripción de los trabajos y que servirán de base para revelar los más importantes factores de riesgo. Simulador de ejercicios se han definido para reflejar algunas de estas opciones.

INTRODUCCIÓN

Hoy en día, la extensión del uso de innovadoras herramientas educativas como motor marino y simuladores de puente nos permite probar la nueva tecnología antes de su aplicación a bordo. Además, el objetivo principal del simulador (S.T.C.W., 1995; IMO Model Course 2.07, 2002) es ayudar a los fabricantes e institutos de formación marítima de las academias y de sus profesores en la organización y la introducción de nuevos cursos de capacitación o en la mejora, actualización o suplementar los materiales de formación y de investigación en que la calidad y la Eficacia de los conocimientos y la experiencia puedes ser mejorado.

El simulador de ejercicios podrían utilizarse en la medida de lo razonable para cuantificar:

— carga de trabajo, la fatiga,
— niveles de estrés
— y el tiempo disponible para el cuidado.

Parámetros que deben cuantificarse se incluyen el número de operaciones realizadas y el tiempo utilizado en diferentes tareas.

Malentendidos (en la interacción hombre-máquina, así como en humanos, la comunicación humana), la pérdida de conocimiento de la situación y errónea planificación y ejecución será identificado como ocurren servirán de base para revelar los más importantes factores de riesgo e identificar los peligros. Además de los ejercicios simulador (I.M.O., Model Course 2.07, 2002; Kluj, 1997) permitir a los alumnos a familiarizarse con la instrumentación y los controles utilizados en las salas de máquinas de buques mercantes modernos, así como desarrollar la capacidad de convertirse en experto en la digitalización de las fallas que pueden ocurrir durante la operación de la planta.

Es bien sabido que uno de la mayoría de los sistemas críticos para el funcionamiento normal de los buques es el funcionamiento eficaz sin el mal funcionamiento de electro generadores. El uso cuidadoso de los grupos electrógenos en combinación con la distribución equitativa y el mantenimiento, utilizando listas de control adecuados (Kluj, 1999), puede conducir a la aparición de una disminución total de apagón. En virtud del lamentable condiciones un apagón puede poner en peligro la seguridad del buque, lo que a tierra o colisión. Un apagón no planificado, por lo tanto, debe ser considerada como una situación de emergencia y se trata de igual manera.

Con este fin, la influencia de vital subsistemas (I.M.O., Model Course 7.04, 1999; I.M.O., Model Course 7.02, 1999), como gobernador, sistema de agua de mar, agua de refrigeración de aceite de lubricación, inicie el aire, la carga de turbo, el aire fresco y fuel en el normal funcionamiento de los generadores diesel, el electro, Ha sido estudiada.

Un intento de examinar los casos de mal funcionamiento básico de los generadores diesel, el electro y sobre todo la forma en que se podrían evitarse se ha hecho. En este documento se analizan algunas de las fallas de dichos sistemas y proporciona una visión de las diversas cuestiones técnicas relacionadas con la aplicación y el mantenimiento de los sistemas de energía eléctrica para aplicaciones marinas.

CONCLUSIONES

Estos experimentos forman parte de un concepto más amplio de trabajo (Gourgoulis et al., 2004) respecto de la utilización del simulador de motor que simula una dinámica en tiempo real computarizado de velocidad lenta de propulsión principal motor diesel turbo de la incorporación de una caldera de calor residual de vapor, un turbo generador y un eje generador.

A fin de evitar disfunciones que influyen en el funcionamiento normal de los generadores diesel, el electro durante el goteo, diariamente, el operador deberá comprobar el filtro de aceite diesel generador diesel, la bomba de aceite lubricante, el agua de mar el control de la temperatura, la resistencia al flujo de agua dulce, el Bomba de agua dulce, los subsistemas de la carga de turbo de aire fresco y el flujo de agua de refrigeración de inicio compresor de aire. Por lo tanto, la observación de todas las fallas producidas se deducía que la culpa es más peligroso mal funcionamiento M01 'Sucio filtro de aceite diesel generador diesel y de la culpa era menos peligroso mal funcionamiento M04' desgaste de la bomba de agua dulce generador diesel'.

La familiarización de los estudiantes con los sistemas eléctricos a bordo de los buques o equipos combinados con posibles fallas demostrado que los estudiantes tienen la oportunidad de desarrollar habilidades operacionales, para combinar con simulaciones multimedia de técnicas como animación, gráficos, imágenes, sonido, etc., para desarrollar y mejorar los conocimientos de idiomas Inglés De los buques de personal para hacer más corto el proceso de aprendizaje con el simultáneo aumento de la calidad y para que el proceso de evaluación de los alumnos mucho más eficaz.

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PROCESSING AND ANALYSIS OF SHIP-TO-SHORE GANTRY CRANE OPERATOR PERFORMANCE CURVES IN CONTAINER TERMINALS

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Abstract

To describe the performance of skilled operators in the transport sector, curves are used that relate quality of performance to operator arousal level. Though performance assessment has a long history in the aviation and aerospace industries, the use of performance curves is relatively recent in the transport sector.

The rapid advances in technology accompanied by the demand for highly skilled workers also in port operations have resulted in the need for analytical tools geared to enhancing operator performance, reducing fatigue levels and hence the possibility of accidents involving personal injury occurring.

This paper concerns the analysis of performance curves obtained for a ship-to-shore gantry crane operator in a container transhipment terminal: The curves have been plotted for four work shifts and allow to identify the most critical phases in terms of time on shift, in relation to the task performed. The results of the analysis indicate that curve specification for particular job tasks should be done using a simulator, that is able to represent the entire spectrum of operating conditions, including atypical and the less common ones.

Key words: performance operator curves, fatigue, human factors, ship-to-shore crane simulator.

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INTRODUCTION

Human error is a leading contributor to transportation-related safety problems, especially in the maritime transport sector. In fact human error is the cause, or contributor to a large percentage (80%-90%) of accidents occurring in docks. Despite the high degree of automation achieved in recent years in this sector, the human operator continues to play a central role. As in all transport systems, in maritime transport man becomes the pivot around which the system revolves in terms of safety and the *human factors* discipline is central to the design of the system and to the development of its components (Loi, 2004).

Generally speaking, safety is achieved through a combination of active and passive systems.

Passive safety is concerned with devising measures for reducing the consequences of accidents.

By contrast, active safety is concerned with those factors affecting operator performance and the processes underlying human error in task performance.

The human factors discipline plays an important part in active safety and within this area of activity anthropometry and ergonomics are taking an increasingly prominent role. In general operators are analysed by classes or groups of different individuals based on psychophysical, attitudinal and other characteristics.

Unlike the mechanical properties of the human body, human factors that form the basis of passive safety studies, active safety research embraces :

— biodynamics, analysing how man perceives external stimuli, through the senses (sight, sound, touch);
— information theory, that is founded on the knowledge of the mental processes underlying perception, based on which the most suitable ways of transmitting information to human operator are defined;
— decision theory analysing the human decision making processes that produce the most suitable choice.

The combined study of the above three phases provides an understanding of the reasons underlying human error, that can in general can be attributed to:

— inefficient man-machine interface;
— improper task management and operability;
— operator training and limitations (Fadda, 2002).

Human factors are the primary cause of error-induced accidents in port operations. Accident reports tend not to specify the exact type of error. For example, a report issued by Maritime New Zealand (2004) describes an accident involving a ship-to-shore crane when the spreader collapsed as a result of the support cables snapping. It was not possible to identify the exact cause of the accident though an *"error of judgement"* by the crane operator was perceived as the cause. The report provides the potential causes of accidents divided into environmental, technical and human factors. The latter comprise:

— Failure to comply with regulations (i.e. high speed);
— Failure to obtain ships position or course;
— Improper watchkeeping or lookout;
— Misconduct/Negligence;
— Drugs & Alcohol;
— *Fatigue*;
— Lack of knowledge;
— Error of judgement;
— Overloading;
— Physiological factors.

Fatigue, and impaired performance in general, is regarded as a significant factor in the majority of accidents occurring in transport systems (Fadda, 1984). In the maritime sector an analysis carried out in 1996 by the US Coast Guard (USCG) showed that out of 279 accidents, fatigue accounted for 16% of no-injury accidents and 33% of accidents involving injuries.

Background and fatigue studies. State of the art

It has been ascertained that fatigue, alertness, vigilance, stress and performance all have physiological roots. Two physiological factors, in particular sleep and circadian rhythms, are the primary determinants of arousal state.

Past research conducted on human fatigue prevention has focused on both the physiological mechanism and on methods for measuring fatigue levels (Sherry, 2000 & Czeisler, 1995 & Ji *et al.*, 2002). Current operator fatigue monitoring systems can be divided into two groups (Wylie *et al.*, 1996):

1) measurement of the extent and length of reduced alertness;
2) real time development of drowsiness control and alarm systems (Ji Q. & Yang X., 2002).

From a medical standpoint, research efforts are currently focused on investigating the complex process of fatigue and on the underlying internal and external factors and their interaction.

Lack of sleep leads to a deterioration in the main psychophysical functions which include cognitive processes, alertness, visual and physical coordination, judgement and decision making, communication, etc. Recently a cognitive definition of the factors causing workplace stress has been provided (Seck et al., 2005), distinguishing two macro areas, physical and mental, in turn divided into:

— physical: *environmental* (heat, cold, noise, vibrations, etc.) and *physiological* (lack of sleep, dehydration, muscle fatigue, etc.);

— mental: *cognitive* (too much or too little information, judgement difficulties, etc.) and *emotional* (pressure, frustration, boredom/inactivity etc.).

The same researchers carried out a study on human behaviour simulation using a dynamic stress model to obtain performance curves, adopting the model devised by Yerkes-Dodson (Fadda, 1984).

One of the main deliverables of these investigations are the arousal-performance curves, that provide an estimate of fatigue by measuring performance levels on the basis of task performed.

Numerous laboratory fatigue measurements have shown the process to be complex and no readily usable methods are available. The studies in question (Ji *et al.*, 2006) typically consisted in physiological, behavioural, facial behaviour and performance measurements.

Physiological measurements are used for evaluating fatigue and/or drowsiness, the most common being the electroencephalogram (EEG). Behavioural measurements, that have gained credibility recently, are used to gauge fatigue and are based on the frequency of body movements: the number of movements recorded during task performance over a specific time interval is significantly correlated with the EEG. Fatigue can also be readily detected by observing facial behaviour: changes of facial expression, eye and head movements, gaze are all indicators of fatigue. Others parameters such as eye pupil movement and saccades are indicative of the level of alertness. For example nominal gaze direction for a driver is forward: if gaze shifts in other directions for a prolonged period of time then this is indicative of fatigue and reduced alertness. The data obtained from these measurements, taken using medical instruments designed for diagnosis and not with research in mind, are not readily interpretable. Adopting the analytical methods typically used for dealing with complex data, such as neural networks (NN), Bayesian networks (BN) or fuzzy logic it is possible to treat and properly interpret incomplete, often partial information (Ji *et al.*, 2006).

Though numerous applications of electromedical devices for evaluating task performance in transport systems in general are reported in the international literature, the specific issue of crane operator fatigue has been little studied.

Italian researchers (Colombini, 2006) have conducted applied research in a number of human factor areas including anthropometry and ergonomics. Statistical tests, such as monitoring electromyographic activity using specialized instruments that record, display and amplify nerve response to local electric stimulation and determine muscle anomalies and disorders in specific work postures, have been performed to gauge physical performance of crane operators in non-operating conditions, for use by manufacturers to design innovative control stations for gantry cranes.

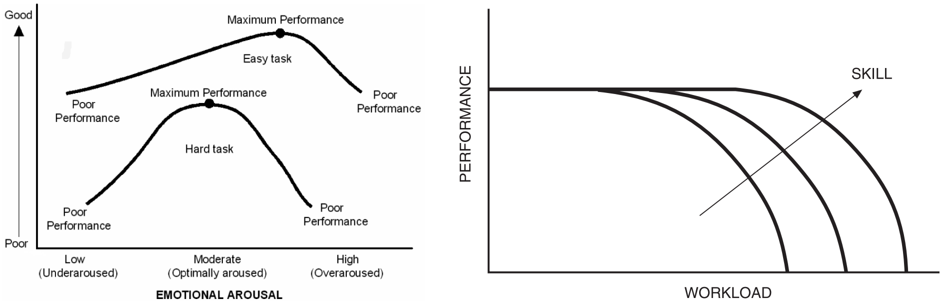
A training manual (Transportation Development Centre of Canada, 2002), provides guidelines for analysing fatigue, drowsiness and the resulting performance deterioration of Canadian navy personnel, combining EEG, EOG (eye movement), ECG (heartbeat) and EMG (muscle tone). It consists of two separate phases: determination of fatigue level and fatigue management programme (FMP). In the first phase drowsiness is determined as a measure of fatigue, associating eye movement and muscle tone with the specific electroencephalographic (EEG) patterns. Eye movements can be slow (SEM) or rapid (REM): during slow eye movements, for example when the examined subject is awake (eyes wide open), the EEG is characterized by closely-spaced irregular spectral fluctuations. Reduced alertness/vigilance is reflected by increased eye rotation and a reduction in EEG wave frequency, with the appearance of the so-called theta waves (the EEG pattern "slows down"). After a number of intermediate steps, the process terminates when the person falls asleep. The sleep stage may be Slow Wave Sleep (SWS), represented by large slow brain waves (delta waves) due to low brain activity or REM sleep during which muscle tone is reduced and EEG waves are sawtooth (apparently with a similar waveform to waking).

One particularly interesting area of human factors is the determination of the visual field using specific devices that identify and record operator gaze points during a work cycle. These applications (Camilli et al., 2007) aim to study the field of vision and the information required by the operator to cope with changing conditions, to determine whether any distractor signals exist that alter perception time and consequently the ability to make the right decision.

METHODS

The aim of this investigation was to construct experimental performance curves for container terminal ship-to-shore gantry crane operators, processed using the Yerkes-Dodson (Y-D) model shown in Fig. 1.

The Yerkes Dodson law states that there exists an inverted-U relationship between arousal and behavioural performance. The performance level is measured or plotted along the y-axis the emotional arousal (taskload) along the x-axis. Optimum



Figs. 1, 2. Yerkes-Dodson curves (complex and simple task) and theoretical relationship between performance, workload and skill.

arousal level and quality of performance will vary with task complexity. Initially, low workloads will result in poor performance, performance level then increasing in a directly proportional manner to arousal level until the optimum level has been attained. Viceversa, as workload increases so performance deteriorates, all the more so the more complex the task.

The upper curve which refers to an **easy task** is generally higher (high performance) and flatter, its peak is higher and lies to the right, while the lower curve for the **difficult task** is steeper and the peak is lower.

The two Y-D curves shown for the simple and complex tasks are both parabolic and can be described by the following 2nd degree equation (Eq. 1):

$$y = a \cdot x^2 + b \cdot x + c \qquad (1)$$

where

— the coefficient *a* determines the convexity (or shape of the parabola). As the Y-D curves are concave parabolas, **then we must have: "*a<0*";**

— the coefficient *b* determines the position of the curve in the Cartesian plane chosen: varying the coefficient will shift the peak performance position (the time at which the peak number of containers are handled in the case at hand) with respect to the x-axis (arousal level), but also with respect to the y-axis. As the curves lie in the Cartesian plane representing the Y-D law (the x and y axes are both positive), **then we must have: "*b>0*";**

— the coordinate of the intersection of the parabola with the y-axis will depend on the coefficient "*c*". If the curves are to lie within the quadrant of the Y-D function, we must have: "***c>0***";

— considering the two Y-D curves, the **curve for the simple task will have in** Eq. 1 **a lower value of *a* and higher values of *b* and *c* than the curve for the complex task;**

— the vertex of the parabola corresponds to peak performance (Eqs. 2-3). As this point lies in a Cartesian plane, then the vertices of the two curves are identified by a pair of (*x;y*) coordinates such that:

$$x = -\,{}^{b}\!/_{2 \cdot a} \qquad (2)$$

$$y = f \cdot (x) \qquad (3)$$

Some job tasks, for example gantry crane operation, require intense concentration and training. It has been observed that up to a certain point skilled operator performance may not diminish substantially, only to deteriorate irremediably thereafter

(Fadda, 1984). In this particular instance the resulting curve may be a combination of the two curves shown in Fig. 1, the first portion exhibiting the trend of the simple task, the second the trend of the complex task corresponding to a significant deterioration in operator performance (Fig. 2). As crane operators improve their skills, for example through training and refresher courses, the performance curve flattens out, the slope of the curve tail becoming increasingly gentler, similarly to the Y.D curve for the simple task, coming out of the "danger zone". Finally, by introducing training or refresher training, for example using a simulator, hard task curves tend to resemble more closely those for the easy task.

DEVELOPMENT

Application

The research work presented here was based an the analysis of data collected at Cagliari Port concerning the number of 20 ft/40 ft full or empty containers loaded/unloaded or restowed, or hatches opened/closed, every hour by a ship-to-shore crane operator[1]. Only those shifts during which the operator was engaged in handling activities for a full hour and not partial hours were considered, so as to obtain a more accurate measure of operator workload. It is important to note that operator idle times, due to unavailability of vehicles for loading/unloading or other work cycle coordination problems, can vary within the work shift from a few seconds to almost 30 minutes in one hour. These idle times can also be affected by psychophysical stress levels, operator experience and by weather conditions, so a certain degree of randomness for this variable clearly exists.

The workday in a container terminal consists of four 6 hour shifts (the last hour actually only lasts 45 minutes to enable shift handover, but the data have been made up to the hour to gauge workload more accurately):

- 1st shift (01:00 – 06:45)
- 2nd shift (07:00 – 12:45)
- 3rd shift (13:00 – 18:45)
- 4th shift (19:00 – 00:45)

[1] Containers are loaded/unloaded from ship to shore using spreaders, that are mechanically connected to the hoist motors via a beam suspended from cables and electrically connected to the crane. The container is hooked/unhooked by means of four corner flippers on the spreader. The containers are transferred from ship to shore through a combination of two movements: the spreader-container system is hoisted to the maximum clearance height, and the crane then travels with its load along the bridge rails to the buffer area. This operation is generally repeated at least 20 times an hour, the gantry crane continuously travelling back and forth between the ship and the yard.

Thus throughout the six hour shift the crane operator is exposed both to high vibration, due to cab movements, and to high noise levels generated by the very nature of the operation,. Added to this, is the discomfort caused by the bent forward posture and awkward head/neck positions that the operator is forced to assume to follow the movement of the container some 40 m below. These conditions create psychophysical stress that, over time, can lead to serious health problems and in terms of operational efficiency impair operator performance, to the detriment of container terminal productivity.

The numbers of containers handled were first treated for each hour of each shift for the entire period examined, so as to obtain a point analysis of operator performance, determining the maximum, minimum and average values and the delta (Δ=max-min).

Table 1 shows the values for each shift for the above parameters:

	Parameters	1st h	2nd h	3rd h	4th h	5th h	6th h
1st shift	*Max*	30	27	26	32	28	29
	Min	19	18	12	14	13	13
	Average	*24.6*	*22.5*	*21.6*	*21.1*	*21.1*	*20*
	Δ	11	9	14	17	15	16
2nd shift	*Max*	31	36	38	48	33	35
	Min	12	12	16	15	14	11
	Average	*21*	*23.7*	*23.2*	*22.5*	*22.5*	*22.7*
	Δ	19	24	22	33	19	24
3rd shift	*Max*	32	32	33	30	38	32
	Min	16	19	13	18	16	14
	Average	*22.6*	*24.1*	*24.7*	*22.8*	*24.1*	*22.4*
	Δ	16	13	20	12	22	18
4th shift	*Max*	40	32	33	31	29	27
	Min	15	18	14	16	18	8
	Average	*24.7*	*23.4*	*24.6*	*23.2*	*21.4*	*20.1*
	Δ	25	14	19	15	11	19

Table. 1. Parameters for the number of containers handled each hour for the four shifts

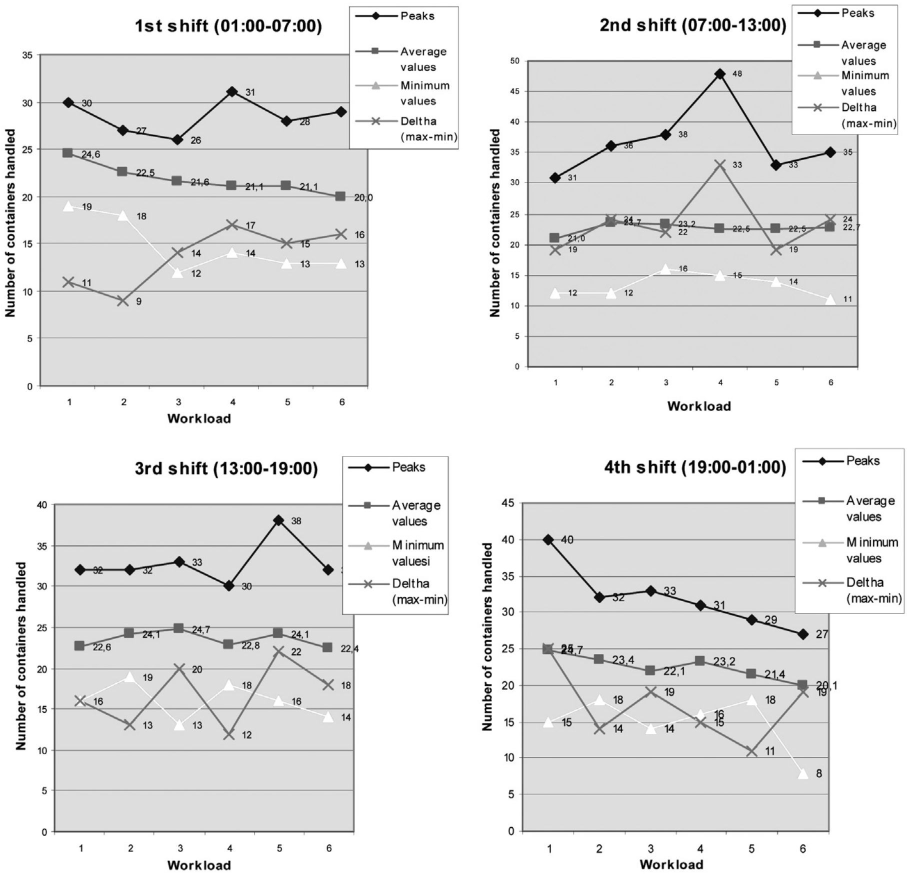
Figures 3-6 show graphically the distribution of the four parameters for each hour of the shift.

Results

The first important aspect is that the number of complete shifts on the 2nd shift was far higher than for the other three shifts. This indicates that planning of ship arrivals and a better overall organisation of the container terminal is concentrated between 07.00 and 13.00 hours, physiologically the most productive shift.

The absolute variability of each parameter was then analysed for each shift (Statistical Trial Absolute Variability – S.T.A.V.) in terms of percent increase and decrease of the maximum and minimum values for the first hour vis-à-vis those for last sixth as well as the percent variation of the average number of containers handled at the beginning and end of the shift (Statistical Trial Proportional Average Variability – S.T.P.A.V.):

— *1st shift*: absolute variability is –56.66% passing from a peak in the first hour (30 containers) to the lower value for the last hour (13 containers), while the



Figures 3,4,5,6: Performance parameter curves of (max, min, average, ?) crane operators at Cagliari port (September 2007).

variation in the average value between the beginning and end of the shift is –18.69%;

— *2nd shift*: absolute variability is + 191.66% (from a minimum of 12 for the first hour up to a maximum of 35 in the last), while variation in the average number of containers handled is + 8%;

— *3rd shift*: absolute variability is –56.25% (peak in the first hour of 32 lowest value of 14 at the sixth); variation in the average number is –0.9%;

— *4th shift*: lastly, absolute variability for the night shift is –80% (from 40 at the beginning of the shift to 8 at the end), while variation in the average number –18.62%.

The most salient aspects of the analysis can be summarised as follows:

— a significant decline in crane operator performance was observed during the 1st and 4th shifts, only a minor deterioration in the 3rd, while performance levels increase in the 2nd shift. This implies that operators become more fatigued during the night shift, unlike during the day shift, when operator performance actually improves as the day goes on;

— the 2nd shift was the most productive as the operator has been able to sleep adequately prior to starting work, performance peaking between the 2nd and 3rd hours of the shift. Note that the minimum and maximum curves in Figures 4-7 are practically constant (except for the 48 containers handled in the fourth hour), and fairly flat, closely resembling the Y-D curve for simple tasks. The shape of the curve for the 3rd shift indicates on average only minor operator fatigue, most likely explained by the time of day. In fact the operator starts his shift having already absorbed half a day's mental and physical workload, which probably explains the sharp decline in performance after the fourth hour;

— restricting the analysis to a single hour, in the 1st and 4th shifts the peaks for number of containers handled during the first hour are higher than for the 2nd and 3rd shifts. A likely explanation is that the operator is psychologically conditioned to performing well at the beginning of the shift, knowing he has to work through the night. From the second hour onwards this condition is no longer perceived;

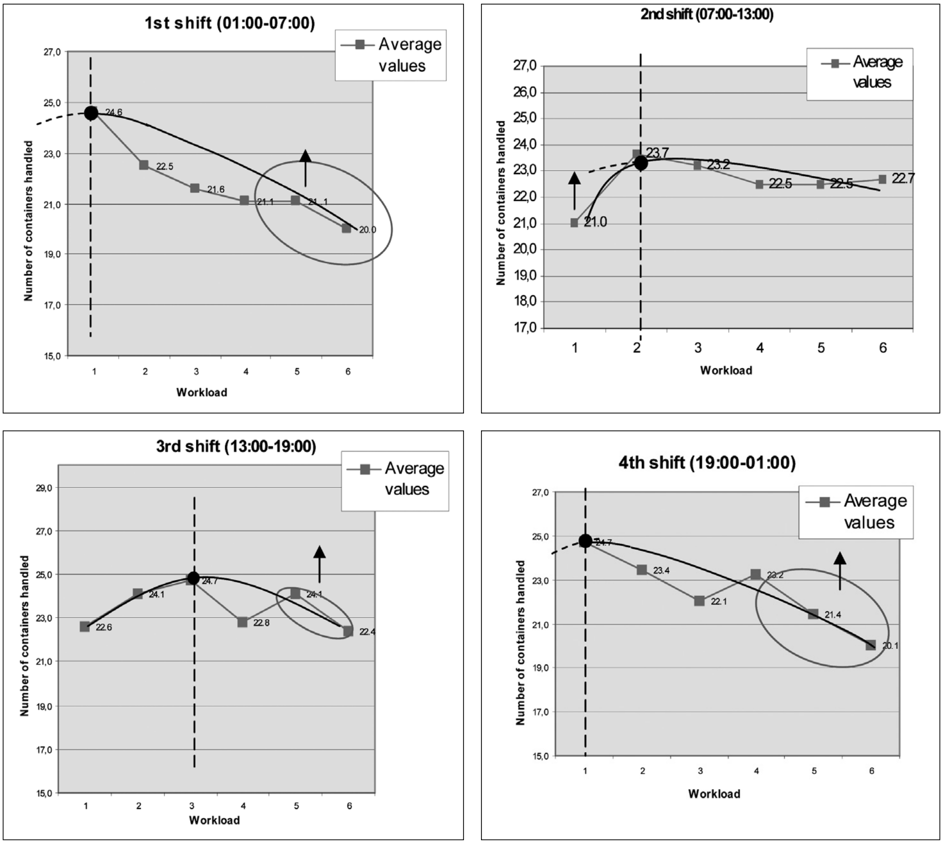
— again restricting the analysis to one hour, a clear phenomenon can be observed in the Δ curve for the 1st shift. In fact, the values are lower for the first two hours, increasing from the third hour onwards. This indicates that the number of containers handled early on in the 1st shift is fairly similar, whereas later on in the shift, probably due to fatigue, the values are very high or very low, which may well correspond to operator experience or inexperience respectively.

One last remark on the relationship between shift (biological clock) and performance of ship to shore crane operators: in the first part of the 2nd shift (between the first and second hour) performance increases by 12.85 % (from 21 a 23.7), almost twice as much as the 6.63 % in the 3rd shift for the same time (from 22.6 to 24.1). This can be explained by the fact that at that time in the morning the operator is more physically and mentally alert and certainly concentrates better than during the rest of the day.

Figures 7-10 show average number of containers handled for the four shifts and the corresponding interpolated curves which exhibit a parabolic trend in accordance with the Yerkes-Dodson law described above. The performance curves for the 1st and 4th shift are described by the right branch of the parabola, with peaks of 24.6

and 24.7 respectively. Note that the maximum values are attained at the beginning of the curve (1st hour), decreasing throughout the rest of the shift. The performance curve for the 2nd shift is an asymmetric parabola, consisting of two parabolic branches[2], and hence two different functions, having the same vertex. After an initial sharp increase in performance, the curve stabilizes, becoming constant. The trend of the curve for the 3rd shift is the only typical symmetric parabola with respect to the x-axis (peak in the 3rd hour).

In light of the above, the decreasing tail at the third hour (circled in red) for the 1st, 3rd and 4th shifts, corresponding to the "danger zone" of the Y-D" curve of Fig. 2, can be clearly seen.



Figs. 7,8,9,10. Average performance curves for the 4 shifts and corresponding parabolic trend.

2. Note that for the sake of simplicity the curve for the 2nd shift consists of two different parabola equations, but in actual fact this would have required a function study on a single trend of the curve.

Examining the equations for each parabola, the following values were obtained for the characterizing parameters (Table. 2):

	Peak (x;y)	Coefficients		
		a	b	c
1st shift	1 ; 24.6	-0.045	0.60	24.6
2nd shift (left branch)	2 ; 23.7	-0.200	0.75	17.9
2nd shift (right branch)	2 ; 23.7	-0.005	0.75	22.0
3rd shift	3 ; 24.7	-0.456	2.85	20.2
4th shift	1 ; 24.7	-0.048	0.58	24.7

Tab. 2. Parametrization of interpolation parabolas for average number of containers handled

As can be seen, performance curves for the 1st and 4th shifts are practically the same, exhibiting at the beginning the decreasing tail of the Y-D curve for complex tasks. The shape and trend of the symmetric parabola for the 3rd shift can also be typically associated with the Y-D curve, whereas the first portion of the symmetric parabola for the 2nd shift consists of a parabola branch having the characteristics of the Y-D curve for complex tasks, followed by parabola branch similar to the Y-D curve for simple tasks, from the second hour up to the end of the shift.

From the applications, indications of a general nature can be drawn for the curve structure in relation to the type of task performed. Experimental data can be used to indicatively determine the range within which the parameters (curve peak and coefficients) of crane operator performance curves lie for simple and complex tasks. (Table 3):

	Peak (x;y)	a	b	c
Easy Task Curve	$3 \leq x: \leq 6;\ y \geq 22$	0 ÷ -0.20	+3 ÷ +6	+22 ÷ +25
Hard Task Curve	$1 \leq x: <3;\ y <22$	-0.20 ÷ -1	0 ÷ +3	+10 ÷ +22

Table 3. Indicative parametrization of Y-D parabolas for crane operator

New research prospects on ship-to-shore gantry crane operator performance

The curves described above refer to average crane operator performance determined using operational data. To determine the effects on human operators of all the variables contributing to fatigue as well as psycho-physical stress using the electromedical devices described, operator tasks need to be experimentally reproduced in the laboratory, so as to provide a more realistic and reliable measure. Similarly to the simulators long employed in the aviation and aerospace sectors, gantry crane simulators are now being introduced into ports not only for training but also for research purposes.

In the maritime transport sector simulators are utilised mainly for accelerated and cost-effective operator training as well as for refresher training, to keep operators abreast of the continuous technological changes in equipment, resulting in a strong demand for highly skilled personnel. Refresher training is also important for keeping potential performance levels high in specific operating conditions that may on the one hand be detrimental to terminal productivity and on the other create a serious risk of accident.

In the case at hand, the use of the simulator allows to attenuate the decline in those parabola branches corresponding to the crucial phases of the gantry crane operator's work shift described above (arrows in graphs of Figs. 7-10).

In research applications the simulator is widely used for optimising the man-machine interface and for fatigue analysis, in an attempt to establish why humans make errors. It is also an effective instrument for transport systems design and for operator training and for this reason is widely utilised in the container handling sector, because of the need for terminals to achieve increasingly higher levels of efficiency (Rocca et al., 2007).

Simulators also prove useful for quantifying operator workload (over- or under-work). Establishing workloads involves a variety of aspects from definition of operating cycles, to determining the number and type of personnel required, to training as an integral part of the company's business and for achieving safety. Equally important is the design of suitable devices for assisting the operator in his task and consequently of minimizing performance deterioration.

In this regard a project is now under way, that for the reasons described above falls into the area of active safety and aspects concerned with human factors in container terminals, for setting up a network of simulators to be located in different areas in central-southern Italy (*cyberinfrastructure*), that will enable integrated task training, by distance testing and tests coordinated by an efficient multimedia network.

The CIREM research centre at Cagliari University, in collaboration with the Consorzio COSMOLAB, is currently constructing a **gantry crane simulator** (Fig. 11). Once completed and tested, the simulator will be used for the following activities:

- training and refresher training at port and interport terminals or directly at advanced professional training organizations;
- human performance research vis-à-vis different operating conditions using objective medical parameters;
- studying and validating new design options for crane control systems.

The project aims to quantify and evaluate the level of performance and fatigue of gantry crane operators devising research plans, currently being perfected, using advanced tools for the virtual reality simulation of crane operator tasks.

Because of the difficulties in obtaining accurate and reliable measurements of these parameters inside the gantry crane cab while the operator is actually working (confined spaces, difficulties in locating the instruments , conflicts with terminal operability, etc), also due to the numerous disturbance interactions, the gantry crane

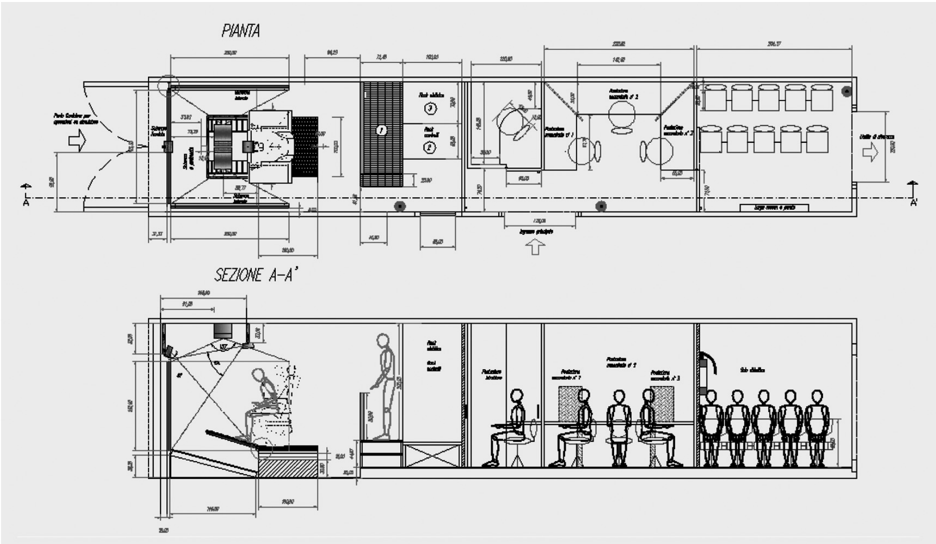


Fig. 11. Plan and cross-section of Cagliari University's containerized gantry crane simulator.

simulator will be built as a permanent laboratory for monitoring fatigue by measuring parameters such as EOG (electrooculograph), ECG, EEG, arterial blood pressure, S.N.C., flicker fusion point, heartbeat, which provide a measure of the operator's psychophysical conditions under different workloads (Rocca et al., 2007).

A simulator is a useful tool for obtaining objective undisturbed measurements of the workload (over-or underwork) and of any psychophysical stress caused by task complexity, as well as of exposure to strain and vibrations and external stimuli (reproduced in the virtual environment) associated with the onset of fatigue (Fadda, 1984).

CONCLUSIONS

The research activity described here has enabled, for the first time in the scientific panorama, to construct performance curves for each work shift of a gantry crane operator.

Analysis of these curves showed operator performance to deteriorate significantly during the early and late shifts, performance levels dropping into the downward branch of the curve considered at risk.

The ultimate objective is to reverse this downward trend, attenuating the deterioration in performance. This can also be achieved utilizing a gantry crane simulator. Thus the next step will be to evaluate the effectiveness of simulator training activities, and explore whether the performance curves can be improved after adequate training and refreshers.

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ELABORACIÓN Y ANÁLISIS DE LAS CURVAS DE PRESTACIONES DE LOS OPERADORES DE GRÚA DE MUELLE EN LAS TERMINALES DE CONTENEDORES MARÍTIMOS

Resumen

Hace tiempo que, para representar el nivel de prestaciones de un operador especializado en el sector de los transportes, se utilizan curvas que relacionan la calidad de las prestaciones con el nivel del estímulo al que es sometido el operador. Esto sucede, desde hace más de 30 años, en el sector aeronáutico, y desde antes aún en el aeroespacial.

Con el desarrollo de la tecnología y la introducción de tareas con elevado grado de especialización, también en el sector portuario ha surgido la exigencia de poder contar con instrumentos analíticos de este tipo, que favorecieran la calidad de las prestaciones de los operadores limitando el grado de fatiga, y por lo tanto la eventualidad de sucesos lesivos.

En el presente artículo se quieren representar analíticamente las curvas de prestaciones de un operador de grúa de muelle de un terminal portuario de transhipment: tales curvas son relativas a los 4 turnos de la jornada laboral y permiten verificar las fases temporales más críticas de su tarea en función de la actividad desarrollada. Los resultados del análisis evidencian cómo la determinación de las curvas para tipologías de tarea específicas debe realizarse con el empleo del simulador, capaz de representar todas las condiciones operativas, incluso las más atípicas y menos frecuentes.

DESARROLLO METODOLÓGICO

La seguridad de los sistemas de transporte, en particular en el sector marítimo, depende sustancialmente del error humano. Las actividades en ámbito portuario están caracterizadas por el alto porcentaje (entre el 80% y el 90%) de sucesos lesivos cuya causa o concausa es el error humano. La fatiga, y en general el decaimiento del nivel de prestaciones, es considerada un factor significativo en la mayor parte de los accidentes en los sistemas de transporte. La medida de la fatiga ha sido llevada a cabo en numerosos estudios de laboratorio, que han demostrado lo complejo de este proceso y el hecho de que no existen métodos disponibles de fácil empleo. Uno de los principales resultados de la investigación es la curva estímulo-prestación, que evalúa la fatiga a través de la medida del nivel de prestaciones según el tipo de tarea efectuada. Curvas de prestaciones típicas son las representadas según el modelo de la función de Yerkes Dodson.

Una tarea en el ámbito marítimo que responde a las características tanto de alto nivel de especialización, como de grado de fatiga, es la del operador de grúa de muelle de un terminal portuario: las exigencias del puesto, y la posición de trabajo anómala que el operador gruista sufre por toda la duración de su turno laboral (seis horas), ocasionan fuertes condiciones de estrés psicofísico que, desde el punto de vista sanitario, pueden conducir con el tiempo a patologías en ocasiones relevantes, mientras que desde el punto de vista operativo determinan una reducción de las prestaciones y por lo tanto un menor nivel de productividad del terminal.

El estudio de la fatiga de un operador de grúa portainer no tiene mucho eco en la reciente literatura internacional: numerosas aplicaciones, en cambio, se han referido al empleo de los instrumentos electromédicos para la valoración de prestaciones de una tarea dentro del campo más general de los sistemas de transporte.

En este artículo, el objetivo ha sido elaborar las curvas experimentales de prestaciones relativas a operadores de grúa de muelle de un terminal de contenedores elaborado según el modelo de la función de Yerkes-Dodson (Y-D).

La investigación ha permitido dibujar tales curvas, basadas en el aporte de prestaciones de los operadores de grúa de muelle del Puerto de Cagliari (Cerdeña, Italia), obtenido de un banco de datos mensual correspondiente al período de septiembre de 2007, sobre el movimiento de contenedores de los 4 turnos laborales, y reproducido por el terminal en los informes de prestaciones de fin de turno, en los que se transcribe el número de movimientos por cada gruista de muelle y por cada hora.

El artículo contiene el análisis de la evolución de las curvas, además de las ecuaciones de las curvas de interpolación parabólica relativas a los 4 turnos de la jornada laboral; de tal modo ha sido posible obtener los primeros elementos significativos sobre las prestaciones del gruista de muelle: esquemáticamente, se ha efectuado un análisis estadístico de las curvas y, analizando las ecuaciones de las parábolas específicas, se han obtenido los valores relativos a los parámetros que las caracterizan; así se han podido verificar las fases temporales más críticas de su tarea, en las que intervenir con el empleo del simulador de grúa portainer, y de los datos experimentales de las aplicaciones se han podido extraer indicaciones de tipo general sobre la estructura de las curvas según la tipología de tarea.

Las curvas obtenidas eran relativas a valores medios de las prestaciones del gruista medidos por los datos de operatividad, pero para evaluar los efectos sobre el hombre de todas las variables que influyen en el cansancio, y para poder medir con los aparatos electromédicos el estrés psicofísico en el hombre, es necesario reproducir tal tarea al laboratorio, garantizando la reproducibilidad de la misma lo más fiable y realista posible.

El CIREM de la Universidad de Cagliari, en colaboración con el Consorcio COSMOLAB, está completando la realización de un simulador físico de grúa portainer, que verá su empleo en el campo de la formación y los cursillos formativos, en el estudio del nivel de prestaciones del hombre respecto a las diversas modalidades operativas a través del empleo de parámetros objetivos de tipo médico (EEG, ECG, EOG, EMG, *Holter Monitoring,* etc.), y en la actividad de investigación y validación de nuevas soluciones proyectivas para los sistemas de control y mando de la grúa.

La acción formativa está enfocada a proveer altos niveles de especialización y calidad de las prestaciones, para mejorar por un lado la seguridad y, por el otro, la productividad del sistema.

El objetivo del proyecto de investigación, en cambio, para aportar al simulador, instrumento de apoyo típico de la disciplina de los *human factors*, será definir, cuantificar y valorar determinísticamente el nivel de prestaciones y cansancio del operador de grúa portainer, desarrollando programas de investigación, al momento en fase de perfeccionamiento, mediante el uso de instrumentos de elevada capacidad para la simulación virtual de las tareas.

De tal modo se podrá confrontar el perfil de las curvas experimentales de prestaciones, presentadas en este artículo, con las objetivas, realizadas en el simulador utilizando los instrumentos electromédicos. Se podrá valorar además la eficacia de la acción formativa del simulador, verificando la evolución de las curvas de prestaciones de los operadores, tanto en formación como ya formados, en correspondencia con las zonas críticas para la seguridad y la productividad del terminal.

CONCLUSIONES

La presente actividad de investigación ha permitido elaborar, por primera vez en el panorama científico, las curvas de rendimiento de un operador gruista por cada turno al que es sometido.

Los análisis han evidenciado que, en los dos turnos extremos de la jornada (1° y 4°), las prestaciones decaen repentinamente, situándose en el tramo descendiente de la curva considerado «de alarma».

El objetivo primario es transformar las inclinaciones de la curva, atenuando la caída de la misma. El empleo del simulador de grúa portainer puede contribuir al logro de tal resultado.

Por tanto, la siguiente fase de investigación será la evaluación de la eficacia de la acción formativa del simulador, verificando la posibilidad de poder corregir las curvas de prestaciones, después de adecuadas aplicaciones de cursillos formativos.

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INTEGRATION WORK ON THE SHIP'S BRIDGE

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ABSTRACT

As technology on board gets more automated and integrated there is the hope that seafarers will do less work. But as seen in other domains, as ships become more automated it seems that operators perform more and different work, for which many of them are ill prepared. We describe here the results of a field study on Swedish ships. With today's technologies, seafarers on ships with (and without) integrated bridge and navigation systems have to perform less manual work but more *integration work*. Integration work, as we define the term, is a process, initiated and driven by the seafarer. In particular, it is working proactively to construct a workplace that 'works' for them, given their tasks and duties. The paper discusses whether workload has really been reduced or only shifted to another mode or form.

Key words: Human Factors, integrated systems, human-machine interaction.

INTRODUCTION

As technology on board gets more automated and integrated there is the hope that seafarers will do less work. But, paradoxically as ships become more automated it seems that they do 'more' work, or different work, for which many of them are ill prepared. Seafarers on ships with today's technologies have to perform more *integration work*.

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Integration work, as we define the term, is a process, initiated and driven by the seafarer. In particular, it is working proactively to construct a workplace that 'works' for them, given the tasks and duties they have to carry out. Integration work is a traditional part of the kind of labour seafarers have performed for centuries. In fact, this work is often taken for granted by those who perform it, and seldom talked about by seafarers in any explicit way. Because this work is seldom referred to directly, it is hardly surprising that the researchers have paid little attention to it. However, with new technology like integrated bridge systems, integration work becomes more important than ever before. What is clear is that there is a fundamental difference between the situated tasks that call for integration work and the way tasks are often specified in engineering/ergonomics literature. A review of the literature on cognitive ergonomics and human factors found that there were few field studies, and even fewer that describe work in "complex, confusing, noisy, and dynamic" environments (2003) This paper adds to this literature.

BACKGROUND

A number of field studies have been performed in complex work domains, focusing on the effects of new technology and automated systems on the operator. This has been studied in nuclear power plants (Mumaw et al., 2000), healthcare (Gauthereau, 2003), aviation (Sarter and Woods, 1997) and shipping (Grabowski and Dhami, 2005). The effects have been described in terms of workload shifts (Bainbridge, 1983), new kinds of work (Dekker and Woods, 1999), automation surprises (Woods and Sarter, 2000), and loss of mode awareness (Sarter and Woods, 1995). These are all studies of effects on operators, but not much on how people cope. In the present study, during qualitative fieldwork on the impact of automated bridge systems, we began to focus on what was a neglected feature of work in this literature, integration work on the bridge.

The effects of new technolgy have not been well addressed by marine manufacturers or engineers either. Nevertheless, manufacturers are aware of this problem. At the Nautical Institute IBS conference in 2003, a representative of a large manufacturer said: **"it is becoming increasingly difficult to get people to sit down and find the problem. Complaints are often too generic. We need more input".** As part of this study several representatives of the maritime electronics industry were interviewed. They agreed with these comments. Today, they are sending out surveys, interacting with clients at trade shows, establishing training programs for dealers and customers, analysing feedback forms from customers, and their letters. In addition to this, equipment is tested on the company or customer test ships. While manufacturers and vendors tend rely on traditional Human Factors research, still they want to know more.

In the maritime literature, the usual solution to improve work on the bridge is to add more technology and/or increase automation. It is an open question however whether this will solve issues of work on the bridge. Many navigators are not convinced. One equipment manufacturer said at the NI 2003 IBS conference: **"Officers perceive IBSs [Integrated Bridge Systems] as scary but the individual components are the same as before"** If some officers perceive IBSs as scary, it could be valuable to the manufacturer to try to find out why. Rather than to simply add automation, the human factors research community have for a long time argued that what needs improvement is not the technology per se but the man-machine dialogue (Hatfield and Smith, 1975, Millar and Clarke, 1978, Wilkinson, 1974). To achieve this, naturalistic studies of work and technology use need to be performed. A number of such studies have been carried out in the maritime field by Hutchins (1995), Norros and Huuki (1998), Grabowski and Dhami (2005), Belcher (2002) van Westrenen (1999) and several Danish researchers (Andersen, 2001, Koester, 2005, May, 1999).

Studies in other domains reveal some of the adaptations human perform in response to new technology. Clumsy automation – when a system creates new cognitive and physical demands, that tend to come together at times of high demand – is overcome by two related adaptations; system tailoring where the system is adapted, and task tailoring where the user's behaviour is adapted (Cook and Woods, 1996). System tailoring is about changing the technical system and task tailoring is about adapting the work strategy. Both of these adaptations have been observed in the present study. However, while they describe how humans adapt, some believe that it is the system that should adapt more to the operator.

Hollnagel (1995) outlines three ways that machines can be adapted to humans. The first is through design. For this, the designer needs a model of the user, which can be a static model for simple domains, but a dynamic model is probably more adequate for complex tasks. This is a difficult undertaking, because it forces the designer to be explicit about what he is designing for. The second is adaptation during performance, where the system should adapt and change its performance to match operator needs. This is complementary to adaptation through design, and may be necessary since our knowledge of seafarers is necessarily incomplete at any given point in time. Adaptation during performance poses increased demands on the modelling of the operator.

The third way is adaptation through management. To help overcome deficiencies in the design of a system, management can adapt the working environment by providing support and modifying work goals. For this kind of adaptation to work, a continuous monitoring of effects is needed, and this basically constitutes adaptation by continuous redesign. Courteney (1996) warns that if standards in one area is changed (design, training or operations) then the others must follow. For example a change in design must be followed by a change in training.

One intent of automation and standardisation is to reduce the workload of seafarers. But even with the best of intentions, automation can add to rather than subtract from the workload. The result is that seafarers have had to develop strategies to integrate information from different technologies into something that allows them to get the work done. On a ship, which was built as a container ship in the 60's, rebuilt to a cruise liner in 1990 and visited by us in 2001, we found 15 different manufacturers' names on the navigation, control and communication equipment. We have also found that bridges evolve; equipment is added, but seldom taken out (Lützhöft et al., 2007). This is one reason seafarers have to perform integration work; technological resources are never constant. And while we see humans adapting, what is technology doing?

METHOD

To study this issue, the first author has over a period of almost four years (2000-2004) spent close to 300 hours distributed over 25 days, on ship's bridges (15 ships). Prior to this research she was a maritime officer, with 13 years of sea experience. Three major ship types were studied: small archipelago vessels that travel the Stockholm archipelago, larger Baltic ferries/passenger ships journeying the waters between Finland and Sweden, and cargo ships trafficking the Baltic, the North Sea and the Atlantic.

The methods used to gather data were observation and interviewing, and at times a second observer was present. Techniques to record data were field notes, sound recording, video and still pictures. When possible, copies of documents or charts were made. The interviews were both formal and informal, and were conducted with seafarers on and off ships. Recordings were transcribed, notes and interpretations were often compared and discussed with the second observer. All transcriptions and other data were analysed in an iterative manner. Early interpretations and patterns were checked against the literature and field data, and this guided the next round of data collection. Subsequent ideas and interpretations were formed and likewise tested and refined against theory and field data. Although single quotes are used to make points here, they are all backed up by observations and similar statements at other times.

Technology manufacturers and policy makers were interviewed. To some extent regulation and standardisation processes have been studied. In sum, an effort has been made to get close to the practitioners while following the requirements of science – accurate data collection, comparison and contrast of field data, matching data against the literature and locking data to theory – all this helps us 'make sense' of what is going on on the bridge.

RESULTS

While on board, not many incidents and no accidents were seen, but gradually it became clear what seafarers did to avoid accidents. From the seafarers' point of view however, they were not avoiding accidents, they were just doing their job and doing it well. This contradicts the common sense view that seafarers spend a lot of their time avoiding accidents. What we did see on board, was how seafarers cope with their work and errors, how they learn and how they perform work-arounds given new technology. We saw examples of integration on several levels: integration of human work and machine work, integration of information representations and integration of learning and practice. Integration work is always about co-ordination, co-operation and compromise. When human and technology have to work together, the human has to co-ordinate resources, co-operate with devices and compromise between means and ends.

Here we will discuss two of these levels of integration; human and machine work, and data and information. We will discuss why these kinds of integration are performed, why it is deemed necessary by the seafarer and give examples. We will link this discussion to the literature, which documents that technology has surprising effects and can impede users, but there is little there on integration work, as defined here. Handling computers, for instance, is not always straightforward. Wiener summarised it in this way:

"The machine will still be literal-minded on its highest level, and will do what we have told it to do rather than what we want it to do and what we imagine we have told it to do." (Wiener, 1985). Humans are not "literal-minded", at least not in this sense. The following is a cargo ship officer who talks about the integrated bridge system, which shows how differently humans and computers go about 'thinking'.

"When you're learning the system…at first you don't understand how it's meant to work, but then you start thinking backwards, like a computer". Many have shown that new technology often demands a new way of working. However, it also can demand a new way of thinking, with interconnected, seamless or integrated systems. Cook and Woods (1996) point out some putative benefits of technical integration: it may reduce the physical size of the device, it may reduce maintenance and it may even increase functionality. However, they argue that the value of such changes may be small, and unintended side effects can pose significant new work (and risks) for those involved. Here, integration is a process, which is initiated and driven by the seafarer who works actively to be 'part of the loop', and this can lead to significant amounts of new work. The reason seafarers perform integration work is to do work technology was intended to help them perform. However, technology at times may be solving non-existent problems, and in the process even creating new problems. As many of the interviewed seafarers said: **"When we need it the most, the technology cannot help us".**

The Merriam-Webster on-line dictionary[1] defines **integration** this way: to unite with something else, to form, co-ordinate, or blend into a functioning or unified

[1] http://www.m-w.com

whole. Also, to harmonise and synthesise. In this study, the integration of various components means that trade-offs, tailoring and adaptations have to be made. A functioning whole is to a great extent due to seafarers' work, and a unified (perfect) whole may not even be possible. There are several ways in which humans construct a functioning whole out of parts. When the seafarer's view and the machine's view do not match, the human most often has to do the changing, the harmonising and the synthesising. If machine and human together are to constitute a working navigational system, the one who has to adapt the most is the human. The seafarer is the elastic, adaptive component, and performs the integration work. It is also a part of the seafarer culture to be able to 'handle anything', and thus when a burden is added, seafarers frequently adapt and handle it.

Integration of representations of data and information

The integration of representations is performed by the seafarers as they work, mentally or by using artefacts such as displays, or pen and paper. This is similar to one of the core principles in distributed cognition 'People establish and co-ordinate different types of structure in their environment' (Hollan et al., 2000). Representations here also include what seafarers can perceive of the real world as seen out of the bridge windows. An example of such integration is the position fixing cycle Hutchins describes; how navy personnel integrated the outside view with a paper chart, via several devices and techniques (1995).

By information we mean data that has meaning for the seafarer and the task at hand. There are several reasons seafarers perform integration of data, information and reality. The most important is that it is seen as necessary, because the seafarers need to integrate or compare data to construct a plan-for-action. This construction is vital to work onboard but is not always supported by the technology – machines cannot communicate in ways seafarers see as useful or intelligible given the circumstances. Integration work is subject to external constraints as well, of which a clear example is the requirement to use and compare different means of position fixing, and not to trust one source alone. Therefore, maritime regulations can also lead to the demand for data integration.

For seafarers to construct their own integrated system takes effort, especially since what developers and manufacturers choose to integrate on screens or in systems is not always what the seafarers find useful. The comparison of two waypoint lists from two navigation devices provides an example of this. To ascertain whether the two lists were the same, the officers checked the courses between the waypoints. However, in one list the course was represented with three digits (000) and in the second with four (000.0; one decimal point). This was not seen by the officers themselves as requiring a lot of effort, but it clearly did demand cognitive work and the transformation of one kind of representation into another had to be done many times over (a waypoint list may contain up to a hundred points, sometimes more).

Double checking of this kind is performed for two reasons: at times the seafarer prefers, given the task at hand, a manual check and at times the technology cannot do it. Even when a machine can do it, this may, as one officer says, **"take too long to perform… and then the result is long lists that still have to be checked manually"** (Lützhöft, 2003). This suggests a certain amount of scepticism exists on the part of the seafarers regarding representations of information.

When using bridge technologies in combination, the units used to represent data may be incompatible. For instance, an echo sounder, tide tables and a chart may all use different measurements; feet, fathoms or meters. This adds to the workload and demands close attention on the part of the navigator and requires that a navigator perform conversions into a common, single unit. Further, on different displays, different symbols may denote the same thing, and even on (or within) a single display there may not be a consistent symbology. Nautical charts are constructed using one of several chart datums, which is a reference system to which depth soundings refer. A GPS navigation system, a paper chart and an electronic chart might all be using different chart datums when referring to the 'same' thing, and even within one ECS this can occur. This could lead to potentially hazardous errors in position, in fact has already caused one known grounding of a ship in the Norwegian archipelago. However, this is a hard problem to solve because aids come from different manufacturers or publishers. A related problem is the mental integration work performed by seafarers when using charts, radars and views out of the window, all displayed in different ways: north up, head up, course up (Porathe and Sivertun, 2002). There is no common vocabulary, 'designer' or co-ordinator for such important representational issues.

Many maritime displays typically display a single datum in digital form, from which it can be difficult to perceive, infer or track change. For example, for the display of cross-track error on board we have seen a display with a choice of two presentations, either a number "1,4 R" or "0,9 L" (right and left) or another with an analogue image showing a ship symbol and a line. Many ships have both types on different screens, and both displays are used but by different officers. One pilot comments: **'Of course, I use the image…the numbers [digital], no, [because] then you need another piece of information [that indicates which side the drift is]'**. To represent offset distance, the analogue representation collapses the two data points 'there is offset' and 'to which side it is' into one image, whereas the digital requires further work to arrive at the same point. Also, while the rate of change is not directly visible with either, the analogue allows for easier perceptual estimates than the digital.

When exact numbers are needed, digital representations are regarded as better. For instance, analogue representations of engine revolutions are accepted. To represent speed, seafarers prefer digital, as exact speed can be needed to compute arrival times. In contrast, most officers prefer the analogue ROT dial (rate-of-turn, how fast a ship is turning) over the digital, as the digital is said to lag in an unacceptable way.

It is important not to digitise just because it can be done or because it saves display space. Rather it is important to first find out how data are used and which representation makes more sense to seafarers given the task at hand. In regards to forward speed do they want exact numbers? Or can they accept a lag and lower accuracy? Then this may not be acceptable regarding sideways drift which they quickly need to perceive and react to. If it makes the job at hand easier, and lowers the mental workload – why not use analogue representations?

Seafarers want to compare and co-ordinate data and information, but in many cases the representations cannot be immediately correlated. When sensor data are combined or fused into a single representation, issues of trust, quality, age and traceability of origin can surface and this needs to be addressed.

Integration of human and machine work

Integration work between humans and machines can be described as the act of achieving co-ordination with an artefact through expert performance by a person (Hutchins 1990). Many aspects of new technology make this kind of expert performance difficult to achieve. Seafarers attempt to build working human-machine systems, to 'integrate themselves' into a co-operational system for several reasons. Firstly, they do it when they see it as necessary. When there is a misfit between humans and machines, seafarers have no choice but to rebuild the integrated systems in ways they themselves understand. Secondly, seafarers want to do this – most of them want to use new technology. They want to have control and they want to be able to use the tools they believe can provide them with this control. They also believe or at least hope that human-machine systems can relieve them of certain kinds of work and uncertainty, without the technology being an additional burden to them.

A poignant example is one electronic chart system, which allows for registering a position at which a person has fallen overboard, to simplify finding that position when having turned the ship. This is called a MOB situation (man over board), and is a critical situation with much time pressure. However, the chart system demands that the operator go through 5 steps to register the position (submenus, button pushes). At the same time, he has to start turning the ship, call the captain and crew, sound alarms and launch a special MOB lifebuoy. To ensure these steps were remembered, the crew on the ship had printed these 5 steps out on strips of Dymo tape and taped them to the frame of the screen. Because technical systems are becoming increasingly interconnected, the way to perform the 'same' tasks can become perhaps even harder to do. However, many manufacturers may claim that nothing has changed, and argue that after all these technical systems have the same components as before. Nevertheless, a 'system' is not a stable entity but a constantly changing ensemble of actors and artefacts. There are seemingly endless combinations, and the interconnections can often be hard for seafarers to see and the underlying principles of these systems may be even more difficult for them to discover and understand.

Another example: on one occasion a radar which was part of an integrated navigation system on a cargo ship did not work. When the officers had tried everything they could think of and had at hand (manuals, discussions, self-test performed on radar) the radar was switched off. Before switching off, both officers were clearly worried about what effect this would have on the rest of the system and were uncertain which of the other parts would continue to operate. This is because when devices are technically integrated their co-ordination is more hidden to users than before. This means that seafarers often have to perform more work to reconstruct and understand the system. It also requires more effort on the part of manufacturers to construct an integrated system that makes sense to those who use it.

A related problem occurs when a device does not work as expected. Several officers have said something to the effect of: **"Is there a malfunction in this device or have I made a mistake?"** The more integrated and automated systems become, the harder it is to figure out what has happened, how to carry out repairs and to make the system 'work' correctly again. Feedback from automated and integrated systems can be weak (Woods and Sarter, 2000), and what feedback there is may not be what the seafarers need or want to know at a particular time. Since tasks and situations are not stable, what is needed and wanted when it comes to technological aids also keeps changing over time. This is something else manufacturers perhaps have not taken into consideration as much as they should have.

Even when technology works as intended still integration work is needed. In archipelago piloting, large amounts of data, information and strategies have to be co-ordinated - a learning process that continues throughout a pilot's career (Lützhöft and Nyce, 2006). For this reason, officers say they would not want to leave all the work to the technology, because as one officer says: **'You can't just sit here and relax…you have to look the whole time'.** These officers prefer actively working to simply monitoring. This active work may represent the same or even more effort than just monitoring, but they believe it affords better control and integration than just monitoring. It also allows for a more effective taking over when necessary.

Therefore, the officers feel that they 'get more' out of the 'same effort'. For example, on a cargo ship with a very modern integrated bridge system, officers did not use all the available functionalities their automated devices possessed. They would rather be actively working than simply monitoring the actions of machines. This meant that they did not hand over to the bridge system all the work they knew (or suspected) it could perform. Instead, they used the techniques and devices they were familiar with to navigate; GPS, radar and paper chart, see Lützhöft (2002). In short, off-loading or sharing work between humans and systems then seems to rely on and be determined by familiarity, experience and trust, and even when something works as intended, the seafarers may continue to work in their own ways.

Earlier we discussed how humans adapt to new systems, for instance by system tailoring (Cook and Woods, 1996). This entails changing the system, and performing work to make the system compatible with the seafarers' cognitive strategies. Inherent in this is a risk that the system change may become ritualised (for instance how a system is set up before each use) and the basis of the ritual lost to the practitioners, especially if they are novices. Rituals like these may also lead to a lower understanding of the system. A second strategy is task tailoring, where seafarers instead adapt their strategies to carry out tasks, so as to accommodate constraints embedded in the new technology. Neither of these adaptation strategies is effective in the long run.

A central problem here is that understanding machine actions is not easy. The crew of the Royal Majesty knew that when the chart on the radar screen was 'chopping' (jumping) that meant it was unstable and not to be trusted, and by extension they believed that when there was no chopping, the radar chart must be safe and stable. This belief was unfortunately erroneous (Lützhöft and Dekker, 2002). Further, machines are not social. A machine is not a new crewmember, but is often intended to take the place of one. Machines are not directable in the way humans are (Lützhöft and Dekker, 2002, Woods, 2002), meaning that it is harder to for instance delegate work to them. But machines still perform 'work' as well as look and feel trustworthy. Seafarers try to integrate these new devices into the working human-machine system but what makes this difficult is that machines are not situated. They are not situated or embedded in 'reality' because models in computers and technology often reflect an impoverished, incomplete or faulty view of the world.

The view of the world that they *do* have is pre-programmed and relatively static and hardly ever matches the dynamic picture of the world that the practitioner uses and constantly reconstructs. The machine's image is unsituated because it is hard-wired, programmed into it by someone who has perhaps not 'been there' and into a machine that can never 'be there'. Someone else has chosen what the seafarer needs and wants to see and know about the world and the system. Someone has decided what the seafarer needs to do his job. Seafarers are in a sense sailing with "black boxes", whose rules are difficult to deduce or change. A machine does not 'know' where it is and what the consequences of its actions may be. The most important problem here may be that it is never 'ahead', can never really anticipate, whereas anticipation and thinking ahead is fundamental to maritime safety.

A number of suggestions have been made about how to solve this problem. First, machines may need to be more 'situated' which might not be possible in the foreseeable future. Expert systems are still very dumb when compared to the local rationality of individuals. Second, machines need to be able to give an account of or at least indicate what is going on, what Dourish (2001) calls accountability. Abstraction and system integration makes this hard. Third, some means of sharing or trading of control between humans and machines must probably be negotiated (Inagaki, 2003, Hedenskog, 2003), and some negotiation of knowledge, authority and responsibility

(Suparamaniam and Dekker, 2003, Östberg, 1988) also needs to be taken into account. It has been shown that team performance is better if a computer is used as a 'critic' instead of giving 'expert' advice. This raises questions about knowledge allocation and the roles humans and machine should play (Cook et al., 1998). It is becoming increasingly clear that allocation strategies, static divisions into 'physical' tasks, do not work well because of the dynamics of work situations.

An abstraction which it is increasingly important to represent well is how automated systems are doing. Due to the nature of automation, often human seafarers do not know how well it is doing, what it is doing and how it is doing it. The literature suggests that such representations should include three things. Firstly, they should be event-based, highlighting changes and events. Secondly, they should be future-oriented, to support the seafarers in knowing what to do and when, and thirdly, they should be pattern-based, to allow seafarers to quickly pick up abnormalities without additional cognitive work (Woods et al., 1994, Christoffersen and Woods, 2000). But all these conditions may differ or require different interpretations, given the task at hand.

Technology is often used to replace parts of or all of human work and theoretically to make work safer, more efficient or less costly. Replacement is not always straightforward, which is known as the 'substitution myth' (Dekker and Hollnagel, 1999). Research shows that often a lot of effort has to be expended to get the new system to work and that new technology, when it is not well designed or integrated, may even introduce new types of accidents (Lützhöft, 2003, Lützhöft and Dekker, 2002). However, new technology can also help seafarers shape new strategies, as for example an electronic chart system which not only helps to 'fix a position', but also helps seafarers plan trips in different ways than before. But technology can also become a barrier to work, and become something that has to be 'worked through' for example to navigate, which adds more work to the 'real work' (Lützhöft, 2003). This research confirms the axiom that when tools become visible (when they malfunction) they are ineffective because an operator has to focus on the tool instead of the task itself. Bødker calls this effect focus shift (Bødker, 1996). This must be researched further so that we do not to add to the seafarers' workload when they are performing their tasks, using new tools and aids.

DISCUSSION

A main force driving the installation and use of shipboard technology today is economics, and to a lesser extent safety (National_Research_Council, 1994). Other drivers are competition, technology development and innovation. Constraining forces are partly the same: economy, technology development, regulations, standards, and safety concerns. Courteney (1996) presents a disheartening list (from aviation) which indicates that "the trends and practices in the modern aerospace business are pulling in directly the opposite direction to that required for improvement in the 'human factors' area". Among the issues mentioned are regulations, staff turnover, success measures, commercial pressures and responsibilities – the aviation industry and the maritime industry seem to share many of the same problems. How to solve this is unclear, but a promising way forward is to study how designers and engineers construct 'user models' (Busby and Chung, 2003, Dagwell and Weber, 1983) and how to improve this process. For now, it is the integration work that seafarers perform which evens out the bumps caused by clumsy automation.

For new navigation technologies to realise their full potential, they must be accepted by the seafarer community. Evaluation at all stages, and if necessary, redesign, is particularly important because once a technology is generally adopted, it is rarely formally or scientifically assessed for effectiveness (National Research Council, 1994). One reason that evaluation schemes must be put into place is that as new technologies start to solve problems, new ones may be introduced. In other words, operational procedures and training have to be changed to be flexible enough to accommodate technological innovations and 'improvements', unintended or not. Only adding technology, no matter how advanced, can not resolve all maritime safety issues.

Designers often assume that adding additional features to a device is acceptable, because users can ignore what they do not need. A related assumption here is that users always know what they need. Unfortunately, neither of these assumptions is entirely accurate. This is particularly true on today's ships where the borders between human and machine work and consequently between innovation and failure are difficult to trace out. We need to be more involved in the design of new tools, to ensure that we provide for an efficient, effective and satisfying workplace. Integration work shows how humans are good at making things fit together and how to make use of the tools and instruments at hand. If tools and aids are not already tuned to their intended use, humans will expend effort to make them such. It is this which we here call integration work. We need to make the design of tools and aids more centred on their prospective use – for which we need to consult future users. They should be involved as experts on the use, the tasks and the work, but not as designers.

Flach *et al.* (2003) point out (using an aviation example) that, the engineer and the operator think about technical systems in different ways. The engineer uses a causal model, thinking for instance: "What happens to the craft if we apply X to it?" Our operator, the seafarer uses an intentional model: "How do I make the craft do this, or how do I apply X?" Therefore, we must find out more about the nature of practice, especially about how seafarers construct, maintain and repair a technical system of which they themselves are a part. We need to ask the question that many seafarers will recognise: "What are your intentions?", before we resort to design, redesign or simply assume that human fallibility causes systems to fail.

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EXPERIMENTAL ANALISYS FOR APPLYING AIDDED SYSTEMS

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ABSTRACT

The work is aimed at creating an integrated system capable of receiving information from different systems of navigation through the communication protocol computing NMEA 0183 is also capable of using a computer algorithm to contrast the digital signal obtained by adapting a magnetometer (not fluxgate) the magnetic compass, signal receiver and Satellite validate these results for later use in the different teams of the bridge.

Taking as its main objective to obtain the full correction and the subsequent diversion of discrimination by applying the magnetic declination (although in principle it manually). Once developed the work could be adapted to Automatic Pilots as last generation equipment as ECDIS and AIS, resulting in a great help to the figure of the pilot or navigators in general.

Keywords: Magnetic compass, Deviation table, Fluxgate.

INTRODUCTION

Currently techniques for positioning and navigation satellites have evolved since its dizzying appearance, but do not offer the required absolute accuracy, perhaps due to its nature of gratuity, for the program to be developed. However, in the very near future, with the entry into service of the Galileo system, as well as the coexistence of Galileo with other systems such as GPS and GLONASS, CNSS, etc. Supported by

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the programs augmentation WAAS, EGNOS and MSAS, will determine the integrity required because of the contractual relationship, that are doing such a satellite receivers even more essential to what they are today (Berrocoso, 2004); (Corbasí, 1998); (Ropars, 1965).

EXPERIMENTAL DEVICE

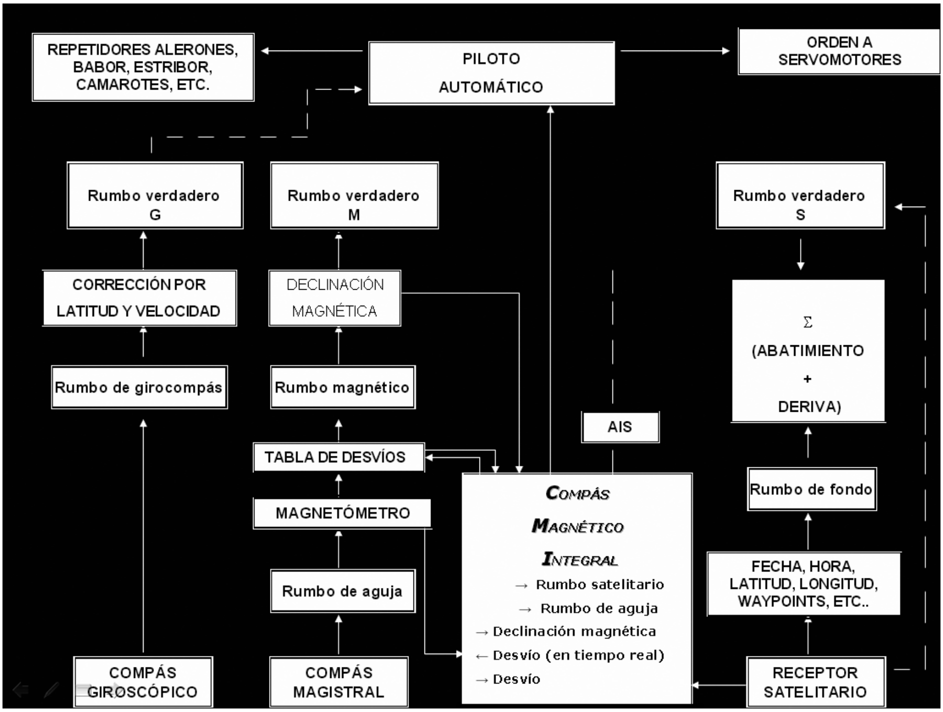

Figure 1. Block diagram of our experimental device.

The instruments used were:
That unlike conventional satellite receivers, which only provide data typical positioning, in its application to shipping, such as:

— Coordinates (latitude, longitude), Time – UTC.
— COG (Course Over Ground or Course background)
— SOG (Speed Over Ground or speed background)
— Waypoints or points of spell.

Resulting these scarce, while the compasses satellite (see figure 2), currently under development, offering a sign that more acceptable to be applied in the future to any autopilot, to be identical to that of a gyro compass, determinating virtually the true course, Moreu-Curbera and Martínez (1975); (Ropars, 1965).

Also, the magnetic compass Geomar Madrid No. 0082, Ø165mm. (see figure 3) Manufactured in Madrid Autronic-trepat with No. Registration of the mark helm 162101 / EC0735/6211/002/05/0062 Filling with liquid Geomar Ref. ISO 350.

It is for the magnetic compass or magnetic needle, which Course get the needle and the resulting chart Turnout by comparison with the magnetic Going once applied magnetic declination at Course true, (Gaztelu-Iturri, 1999); (Vila, 1994).

It represents the most autonomous and indispensable on board, the information that you provide.

The AUTONAUTIC INSTRUMENTAL company, Barcelona, with whom we worked from the outset, adapted at the bottom of the mortar that beat the magnetometer which is detailed below (see figure 4) , once achieved revises 9600 4800 bauds by its manufacturer in England to our request, precisely to coincide with the 4800 bauds on GPS and we allowed such synchronization, introducing the signal to the computer through a cable 20 meters 2 * 2 * 0.50 shielded; to enable the capture of signals from two corresponding hyperterminals one at the entrance to the beat Satellite JRC-JLR10T through a cable CFQ_ NMEA-6560 and the other a magnetometer of the mark FLUXGATE WORLD model A4020 subsystems OEM FLUXGATE COMPASS, in the version of November 2006.

Figure 2. Elements of Satellite Compass of JRC model 10T JLR.

Figure 3. Magnetic Compass Autronic-trepat Ø165mm.

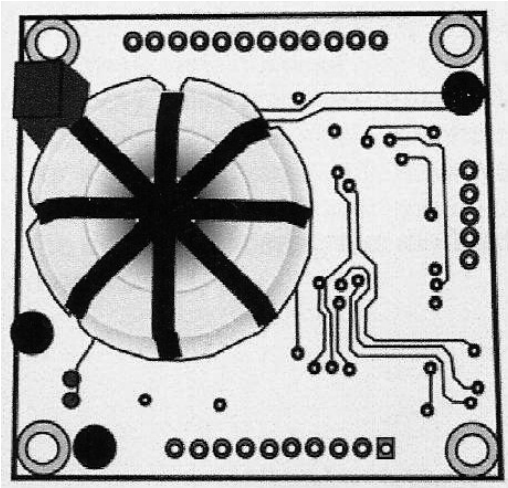

Figure 4. Magnetometer Fluxgate World Model A4020.

While conducted in Labview software (see figures 5 and 6), we could see the outlines of such a program for a graphical form, were making modifications with different programmes, making up one that was able not only programming but a rapid implementation more agile. Resulting from the latter in its real basic version 2006 (see figure 1).

The first phase of all, took place on the bridge under the School of Marine Bilbao in Portugalete, installing the double antenna of the compass satellite, cable antennas that both delimited longitudinal line bow-stern hung up the processor unit setting in the physical laboratory on second floor in Nautical School, that unit left the cable NMEA which is at the end of it, fixed a DB9 with a pin to USB adapter for the PC. This processor was fed with a transformer 24V XA Once connected both teams to check signals, we appreciate that not obtained any signal in the magnetic compass hyperterminal, we impossible the implementation of the programme, due to not being able to shut the loop, said program became crazy looking for that second figure.

In the second phase, once adapted the magnetometer to the bottom of the magnetic compass, in a more effective way, the teams were tested on the boat LAU-A "on a voyage from the Elantxobe port to Lekeitio, conducting within this Finally

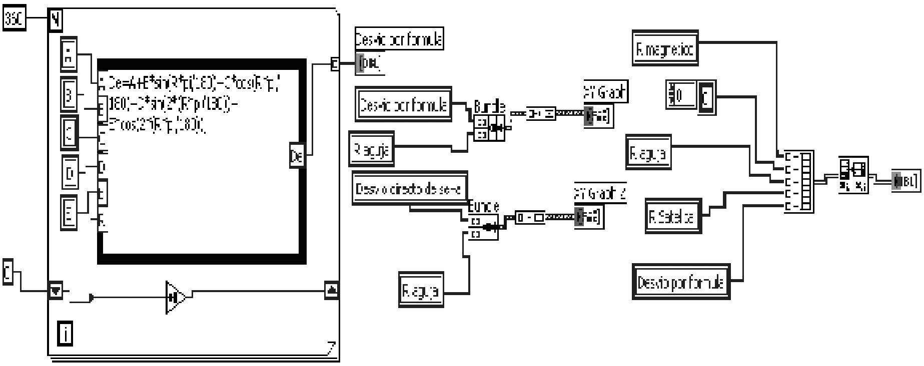

Figure 5. Deviation calculation from coefficients.

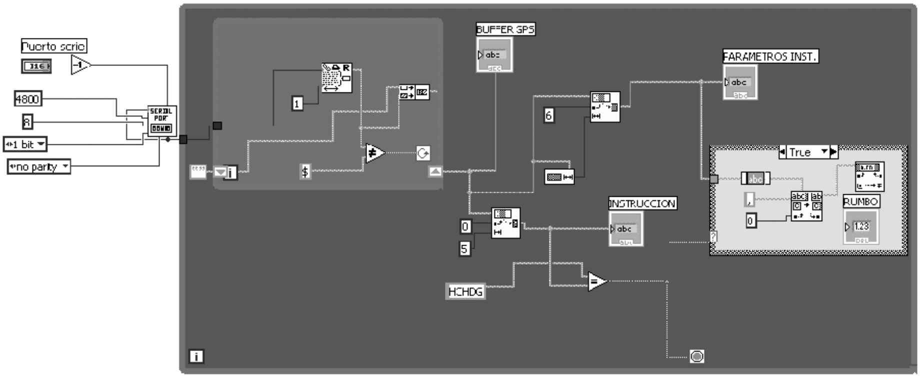

Figure 6. Information acquisition from serial ports.

port one complete revolution, which got some very satisfactory results, except for a few peaks in the graph near North and directions that corresponded to the program, not discriminated against the judgement to remedy equivalencies between the 360th and 000th causing very few data in disparate directions coming to them.

With this program, and after checking on several occasions that executing judgments adapt to the hyperterminals, in an optimal way, in addition to allowing us to create a simulation.

We embarked on board the superferry "SOROLLA" Trasmediterranea Company, which belongs to ACCIONA Group, in its journey Barcelona Palma de Mallorca-Barcelona, in order to meet our goals in this third phase, checking on a real similarity between effectiveness and signal going from the true compass and gyro compass Satellite reference.

In all tests, respected the conditions laid down the administration for the purpose of installing the magnetic needle on board, putting a meter on the deck, on a support antimagnetic, such as PVC pipe (see figure 7) of the starboard wing of the ship "SOROLLA."

Likewise, regardless of how the program works in real time, it went all the judgments NMEA0183 storing data that we were a great help as we saw later in the power readjust data for the compilation of the curves, since both at the entrances and exits of the port, it is not coming to complete all the cardinal directions, or 5 cours-

Figure 7. Magnetic Compass Integral "SOROLLA" on board.

es for the calculation of coefficients (see figures 8 and 9). Having to do the same in different tests.

This third phase of the experiment was carried out in 4 tests.

— The first appropriation to the second overall, was conducted in the ship maneouver in his departure from the port of Barcelona on Friday, June 15, 2007 at 23:00. While he was the ship docked at the station Maritime port of Barcelona, checking on the same alignment of the dock 005º until the end of the maneouver once surpassing Sierra buoy, making course to the Mallorca Island to 189º.

— The second times took place during the departure from the port of Palma de Mallorca on Saturday, June 16, 2007 at 13:30 hours.

  On this occasion was also found in the letter navigation defeat, the alignment of Peraires dock in the port of Palma de Mallorca, where the ship is docked.

— The third and rather special and meaningful was accomplished thanks to the cooperation by both the Headquarters Company Trasmediterranea fleet in the Mediterranean area, as Captain of the boat at that moment, to carry out an exercise of Man Overboard starting to (+2) 18:36:26 GMT in a situation latitude 41º11078 N, Longitude 002º13097 E up (+2) 18:43:02 GMT in a situation latitude 41º11049 N, Longitude 002º12843 E. And that allowed us during this evolution curve data storage requirements for evaluation and further study of the items.

From these tests, we note that in principle we do not consider relevant compensation for the needle since the first objective was to obtain signals from both hyperterminals, contrasting them and generate a graph that approximate real-time curve Turnout may be adapted later with the recorded data. It was considered for subsequent study, the relevance of their compensation or not, once produced and adapted the prototype Integrated Magnetic Compass physical way, the software developed.

Another factor that changed was the synchronization ranges, some of the 4800 bauds as a transfer rate of the received data (bits per second)

$ = 8 bits in the ASCII code = 1 character.

0,6 Kbits per second = 533 characters per second.

4800/8 = 600

NONE = WITHOUT PARITY = not have control digit

1 STOP = 101001, 9 para 1 (stop) o 0

NMEA 100 characters per line

From 4 to 5 lines per second

As a fourth and final phase of tests to be carried out, the computer program was implemented in the version presented here, on board of "LAU-A" boat, closed to the port Elantxobe last September, at 18:25 hours getting some desired results, allowing this modified version of the programming, making it manually calculating the curve turnout by coefficients.

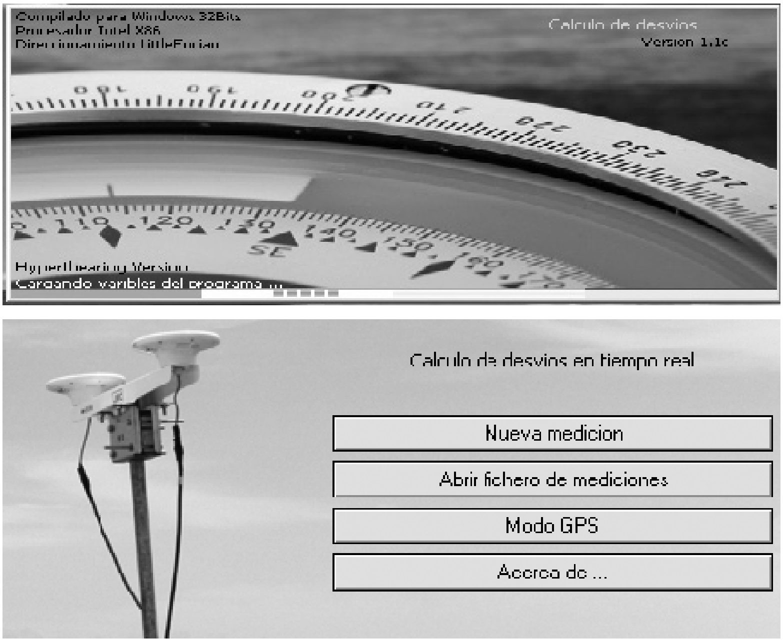

Figure 8. Presentation initial lead of the programme.

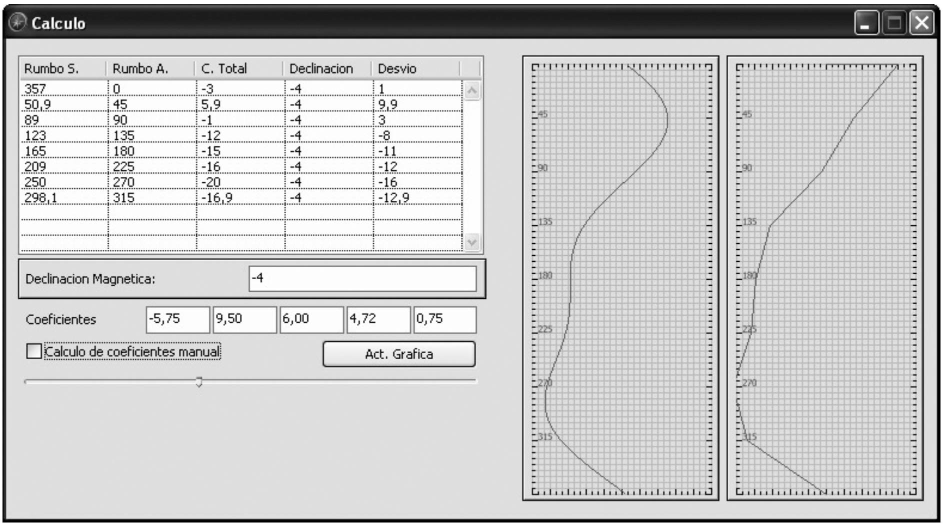

Figure 9. Lead of programme in function.

CONCLUSIONS

Following the completion of the work, we intend to complete and may present a prototype consisting of a device containing such integrated programme which will enable us to get these differences between the signals from different directions for subsequent use, having reached the following requirements:

1. Develop a computerized algorithm for the development of the diversion of the magnetic needle in real time, allowing thanks to a control system in its closed loop used in subsequent applications.
2. Establish a program that complies with the parameters of error required by the international administration IMO (International Maritime Organisation), would be able to ensure proper output signal to autopilot.
3. Achieve develop a single program that included both the development of the tablet Turnout, as the necessary signal for a given value and onward transmission through the Automatic Identification System, as well as the option to have a database of parameters earned.
4. The development of an integrated system, fully compact, offering a guarantee not only of maintaining avoiding manipulation by unqualified personnel, but to adapt to new models of satellite receivers that can be developed in the future, depending on Systems Global Navigation Satellite which are in service, not being restricted to one, if not possible adaptation of other systems that operate on open, thus ensuring the upgrade. Being easily applicable improvements in the elements of the circuit.
5. Finally, it will create a "chip" through integration of algorithmic calculations, which provide the necessary correction to the magnetic Course, for the final signal to be sent to any autopilot any type of vessel, regardless of the true Course.

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SISTEMA PARA APLICACIÓN A INSTRUMENTOS DE AYUDA A LA NAVEGACIÓN

Debido a la evolución tan vertiginosa en las técnicas de posicionamiento y navegación desde su aparición, en los sistemas globales de navegación por satélite (GNSS) que aunque actualmente americanos y soviéticos, con gps y glonass, son los únicos en servicio, se pretende en adelanto a futuros sistemas en un plazo relativamente corto, como el europeo galileo o el chino cnss, apoyados por sistemas de aumentación como waas, egnos, msas, etc… un aprovechamiento de los mismos, ya que nos ofrecerán tanto la precisión como la integridad necesaria para la ejecución de dichos programas (Berroso, 2004) (Corbasí, 1998).

En esta investigación se desarrolla y utiliza la combinación de los mismos con las ventajas que presentan los diferentes programas informáticos.

Por otra parte se pretende, no solo la integración de dicho sistema informático para una posible sustitución de los imanes de compensación, si no que dando el valor absoluto al imán como elemento de medida, evitaremos cualquier tipo de rozamiento al sustentarse la rosa con dicho imán, únicamente en líquidos de diferentes densidades, obteniendo dos tipos de lecturas, una visual directa próxima al timón y otra mediante un lector óptico de la que saldría la señal digital del rumbo de aguja según protocolo NMEA.

Así tendremos una memoria visualizada mediante un “lead” con la ***tablilla y curva de desvíos correspondiente a dicho compás en tiempo real,*** además de su posible adaptación tanto a Pilotos Automáticos como a equipos de última generación como E.C.D.I.S. y A.I.S.

A diferencia de los receptores satelitarios convencionales, que únicamente proporcionan datos característicos de posicionamiento, en su aplicación a la navegación marítima, como:

Coordenadas (latitud, Longitud),
Hora UTC,
C.O.G. (Course Over Ground o Rumbo de fondo),
S.O.G. (Speed Over Ground o Velocidad de fondo)
Waypoints o puntos de recalada.

Resultando estos escasos, mientras que los compases satelitarios, actualmente en desarrollo, ofrecen una señal mas que aceptable para ser aplicada en un futuro a cualquier piloto automático, al reproducir casi de forma idéntica su señal a la de un compás giroscópico, determinando así el rumbo verdadero (true course).

Corresponde al compás o aguja magnética, de la que obtenemos el Rumbo de aguja y la consiguiente tablilla de desvíos por comparación con el Rumbo magnético una vez aplicada la declinación magnética al Rumbo verdadero, (Delgado, 1979); (Gaztelu-Iturri, 1999).

Representando este al elemento más autónomo e indispensable a bordo, por la información que nos proporciona.

Mientras un software realizado en Labview, nos permitía visualizar los esquemas correspondientes de dicho programa de una forma gráfica, se fueron realizando modificaciones con diferentes programas, hasta confeccionar uno que fuese capaz no solo de rápida programación sino de una ejecución más ágil. Resultando este último el de real basic en su versión 2006.

Tras la realización del presente desarrollo, pretendemos concluir pudiendo presentar un prototipo consistente en un dispositivo que contenga dicho programa integrado el cual nos permita obtener dichas diferencias entre las señales de los diferentes rumbos, para su posterior aprovechamiento, alcanzado como exigencias mediante el funcionamiento en tiempo real gracias a un sistema de control en lazo cerrado mediante un algoritmo computerizado, la elaboración de los desvíos de la aguja magnética en tiempo real, para permitirnos su utilización en posteriores aplicaciones.

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Farthing, B. (1987) *International Shipping.* London: Lloyd´s of London Press Ltd.

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