Hybrid Life-Saving Appliances: a Novel Evacuation-System Concept Solution

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Abstract. This paper explores the benefits and challenges associated with the installation of a "Hybrid Evacuation System" (hereinafter "HES"), also so-called "Alternative Evacuation System" (hereinafter "AES"), in lieu of traditional survival crafts on a modern passenger ship covering three different configurations and layouts (full HES, HES and liferafts, HES and liferafts and lifeboat or Tenders). The discussion will include a detailed insight into the regulatory framework governing design. It will also address the considerations for operation, maintenance and survey of the asset throughout its life. This paper will assist the overall maritime community in further understanding this disruptive innovation.

Keywords. Alternative Evacuation System (AES), life-saving appliances (LSA), Hybrid Evacuation System (HES)

1. Foreword

The main scope of the paper is to explore the benefits and the challenges from design and operational point of view for the stakeholders involved in the passenger ship and eventually also in ro-ro passenger ship projects, where the HES would be installed. Such evacuation systems correspond also to the so-called AES. So far "International Maritime Organization" (hereinafter "IMO") neither "International Association of Classification Societies" (hereinafter "IACS") neither other Recognized Organizations including Classification Societies have developed a regulatory framework applicable for such products, therefore it would be assumed that the HES product could be type-approved (or MED) against a potential new part Safety of Life at Sea (SOLAS) Convention and Life-Saving Appliances Code requirements for the intended purpose only in the near future. In the light of above, it is excluded from this investigation any aspect relevant to the certification process (type-approval or MED). It would be also assumed that, upon satisfactory testing and assessment studies showing the equivalency to the SOLAS compliant survival crafts, the Flag Administrations would consider acceptable that on the ships flying their Flags such products can be installed on board; so far, Flag Administrations have not provided relevant public guidance. Considering the novel concept which significantly deviates from the SOLAS prescriptive regulatory framework (such product are not listed in the possible SOLAS survive craft options), upon the satisfactory issue of a suitable certification (as mentioned above), the most appropriate tool for considering acceptable the on board installation would be to perform an Alternative Design, under SOLAS Reg. III/38, together taking into account the content of the IMO Res. A.520(13) "Code of Practice for the Evaluation, testing

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and Acceptance of Prototype Novel Life-Saving Appliances and Arrangements" (adopted on 17 November 1983).

2. Description of the HES

The trend of the current market of the passenger ships and also the future ship projects, under development, are aimed at increasing the number of passengers and crew on board; nowadays there are several passenger ships hosting about 6,000 passengers and 2,000 crew. In the light of this positive growing trend, started about ten years ago, together with the increase of the overall capacity of the passenger ships, also the lifeboats, following the Alternative Design option and process (under SOLAS Reg. III/38), have increased their SOLAS-traditional carrying capacity of 150 persons (as required by the LSA Code Ch. IV § 4.4.2.1 "No lifeboat shall be approved to accommodate more than 150 persons."). In order to carry on board the lifeboats with capacity greater than 150 persons, the overall lengths of the lifeboats have been marginally increased, passing from about 10 m ("Length Overall"; hereinafter "LOA") for a 150-person lifeboats to about 13 m (LOA) for a 300-person lifeboats. On the other hand the internal seating arrangement and layout of lifeboats of greater than 150 persons have been significantly modified, generally adding more than one deck level in the lifeboat hull. The development of the carrying capacity of the lifeboats has passed from about 300 persons until the latest lifeboat option which can accommodate until 450 persons. Definitely one the main advantages of the huge-lifeboat concept is to safely and comfortably accommodate a large number of persons, but at the same time the overall encumbrance of such crafts deeply limits the arrangement and the structure of the on board surrounding spaces, where the lifeboats are stored and lowered, especially in trimmed/listed conditions, possibly jeopardizing the evacuation and abandon process. In addition to the lifeboats, SOLAS offers two craft typologies of "Life-Saving Appliances" (hereinafter "LSA") for evacuating large numbers of persons: the davit-launched liferafts and the "Marine Evacuation System" (hereinafter "MES"), which has the big benefit of being easily deployable and persons are transferred from the ships to the liferafts through chutes and slides, which reduces the risks (e. g. hook releases and crew operations) associated to the lowering of a large number of persons down the ships' sides, needed for the lifeboats. In order to combining the benefits of the lifeboats and the MES into a single concept, the HES concept has been developed by some survival craft manufacturers; the HES solution provides enhanced evacuation capability and the benefits of compact propelled crafts which can autonomously escape from the area of the ship's casualty, also in heavy seas.

Typically the HES is made of self-propelled inflatable canopied survival crafts (hereinafter named in a short manner as "life-crafts"), which are stored alongside the ship sides on the embarkation deck in storage-modules (similar to the MES box option). The storage-modules mainly contain the following three items:

- The inflatable passage-slide: it connects the embarkation deck (on the ship) to the embarkation platforms (at sea level), where persons embark into the life-crafts. The concept is very similar to the current evacuation chutes and slides provided for the MES; generally the passage-slide has a lower steepness compared to the MES one where the cutes are almost vertical.

- The embarkation platform: they are floating piers where the life-crafts are moored and accessed by the escaping persons
- The life-crafts: they are generally large inflatable canopied crafts with a capacity comparable to the latest generation of lifeboats. As on the lifeboats a seating plan is configured to maximize the capacity and keeping a high-comfort for the carried persons.

There also an equivalent concept-solution where the transferring system from the embarkation deck into the life-crafts is through a chute (similar to the MES option) leading directly the persons into the life-crafts without the need of the embarkation platforms.

When the system is deployed at sea, the three items are firmly kept together for ensuring a swift and safe transfer from the embarkation deck to the life-crafts.

3. Pros and Cons of the System Applied to the Passenger Ships

The most benefits of the HES installation is found in passenger ships carrying large number of persons, while small passenger ships with limited number of lifeboats could not significantly benefit as the footprint reduction of the occupied spaces (few lifeboats replaced by one unique HES) and the reduction of items installed are marginal.

At the moment it is difficult to identify the benefits of HES installation from a cost point of view, as in addition to the cost itself of the equipment (not yet available) there are some other cost-items including but not limited to hull strength evaluation, which cannot be easily calculated and compared to the three main actual solutions and relevant option scenarios (lifeboats combined with liferafts, lifeboats combined with liferafts and MES, etc.). One of the most evident advantages of the HES solution, compared to the lifeboat ones, is the limited footprint and the limited height encumbrance allowing to occupy only one deck level (storage-modules are less than 3 m, which is the typical distance between two decks). It is self-evident that this configuration can allow having more available spaces for dining rooms, lounges, casinos, cinemas, theatres and similar entertainment areas, external cabins with potentially obstruction-free glazing or balconies, also if fitted in the deck just above where the HES storage-modules are positioned. The supporting deck-frame structure in way of the HES storage-modules and the weight distribution is completely different from the typical passenger ships fitted with SOLAS compliant life-saving appliances solutions. The mid-ship section can be arranged and shaped with limited recessed side parts, as needed for the lifeboats, utilizing all the width for the passenger areas, as per the other decks where no HES are fitted. The level of uncertainty in determining the possible effects of installing the HES could be evident, especially in terms of weight distribution and relevant stability aspects, especially where the storage-modules are installed at two different deck levels.

3.1. Height and Position Installation

It would be expected that as reference the installation height of the HES is in principle considered in the region of the 15 m, which is the same for other SOLAS-compliant survival crafts (SOLAS Reg. III/15 refers) and the MES. Where greater installation heights would be considered, it would be recommended that upon satisfactory tests are

performed, this aspect is specifically addressed in the AD & A (under SOLAS Reg. III/38).

The position alongside the ship's sides would be driven by the requirements for other SOLAS-compliant survival crafts (SOLAS Reg. III/12), for which "particular regard to clearance from the propeller and steeply overhanging portions of the hull" is requested and the same philosophy would be kept for the HES.

It is pointed-out that considering that the chutes and slides are vital items for abandoning the ship, suitable controls (e. g. remote control and door status indication) should be arranged for avoiding interferences and/or damages between side doors and/or any other openings below the deployment positions, especially in listed conditions. Moreover noting that the HES is possibly provided with rigging system for keeping the position of the HES items, the rigging layout and arrangement should be suitably routed to avoid interferences and damages with the openings.

3.2. Operational Aspects

During deployment and when the life-crafts are deployed, at the embarkation deck sufficient spaces and proper layout and arrangements should be ensured between each storage-modules for properly managing the operations, avoiding any lack of visibility at deck level and at sea level alongside both ship's sides for crew. Generally it is understood that limited rigging system are expected to be fitted for keeping the accessing platforms and life-crafts in a position perpendicular to the ship's side, which could be very challenging especially when the ship is not still capable of effectively maneuvering and wind together current and wave forces can jeopardy the evacuation operations. Where part of the life-crafts are positioned at different deck levels, the arrangement of the rigging for keeping each HES system in the proper position could be even more challenging, because interferences can be expected to be experienced for the rigging and the life-crafts. During the deployment and the intermediate phases, noting the huge encumbrances of each single item, especially the chutes and the slides, it would appear to be difficult for the crew to keep a comprehensive panoramic view on all the HES's. To increase the level of visibility control, it would be recommended that a suitable deployment sequence is planned (e. g. from aft to foreword areas or vice-versa), avoiding lack of visibility due to a chute/slide system obscuring the ones already deployed or under deployment. Alternatively some cameras fitted alongside the ship's in the areas where lack visibility are experienced could help the crew to keep full control of the deployment process, identifying any possible criticalities, which considering the tight schedule of the evacuation, should be also promptly detected and managed.

Even if the chute option is a well-known technology, based on the consolidated MES experience, ensuring a swift controlled evacuation process, so far the Operators have generally assigned only the crew to the MES, while almost all the passengers are assigned to the lifeboats for a more comfortable environment and for avoiding possible panic situations of passengers refusing to enter into the chutes. Where the only life-saving appliances option is the HES (scenario without lifeboats and liferafts), entering the chutes for abandoning the ship is the only solution for the crew and the passengers, including elders, people with disabilities, injured persons (also on a stretcher), so this could be a social-opinion challenge to manage when HES is started to be implemented as this could lead to panic situations or unscheduled delays. On other hand the slide

option can offer a more comfortable way of abandoning the ship and also can allow the crew to climb-back on the slides for assisting the passengers in difficulties.

Considering that for both options, the crew has a full availability and redundancy of chutes and slides (generally two ways for each HES is available), it would appear to be unnecessary the installation of the embarkation ladders (SOLAS Reg. III/11.7 refers) or at least it would be considered the option of limiting the total number (not needed to be installed an embarkation ladder "at every two adjacent embarkation stations"). However this deviation from the actual statutory regulatory framework should be discussed and agreed with the Flag Administration.

3.3. Maintenance and Routine Verification Aspects

The state of the art for HES potentially allows a capability of about 1,000 persons which would in principle allow to install less HES items compared to the lifeboat option; the benefit would be expected higher for the HES installations on the passenger ships with high capacity of carrying persons. So the first benefit would be the fewer items under regular statutory and Operator maintenance scheme, however also considering that the HES is packaged and stored in a similar way to the MES option, it would be expected that every 12 months the HES's are deployed (at least the 50 % of the total capacity). A minimum time for servicing of the equipment should be set-up by the Manufacturer. The general maintenance and verification scheme should be built-up based on the Manufacturer recommendations and the feed-back received from the actual installation experiences.

Noting that the life-crafts are generally propelled by diesel or electrical engines which are vital item of the life-crafts for swiftly leaving the area of the casualty, it would be expected that the storage-modules are provided with suitable means for easily checking the functionality and the continuous readiness of the engines (without the need of dismounting parts of the HES for avoiding to impair the functionality system). Since the storage-modules are generally located in open deck areas, especially for the passenger ships sailing in cold and polar environments, proper thermal insulation protection for the engines and relevant batteries should be ensured for avoiding that engine starting-up and working performances are impaired. In the diesel engine option, focus would be driven on routinely verifying the level of the fuel in the tanks and the charge status of the batteries, while in the battery propulsion option attention would be driven to keeping the battery sufficiently charged and to avoid that thermal runaway phenomena during the recharging process are experienced; a fire in the HES unit can significantly damage the system making it unserviceable.

In order to ensure a continuous back-up of each HES unit, as a new HES unit cannot be transported in every world location in a limited time-framing, a spare HES unit should be always available on board, in case damages to a HES unit occur or a possible malfunction of the HES unit is detected.

3.4. Lighting System from the Ship

Considering that when the life-crafts are deployed in dark conditions, they are positioned perpendicularly to the ship's side, sufficient wide-covering illumination should be provided for ensuring an effective visibility during the operations at sea level and during the deployment. Comparing HES with the traditional lifeboats and life-crafts, which are lowered parallel to the ship's side, it is expected that the lighting

capacity should be increased for covering a larger strip alongside the ship's side. It would be also noted that independently of providing the chute or slide system alongside the ship's sides when the life-crafts are under deployment or deployed, it could be experienced several shadow effects due to the huge encumbrances of the HES items, especially the chutes and the slides. So in order to keep a wide visibility (without shadow areas) and therefore a full command of the evacuation process the lighting system should be suitability sized and designed accordingly.

3.5. Protection from Potential Fires and Heavy Seas

Considering that the typical installation for the HES storage-modules are installed close to the ship sides, as for the MES case, the arrangement can be comparable with the current SOLAS compliant options and exposed to similar risks. It would be recommended that the same fire-protecting approach is kept, categorizing the area where the storage-modules are located, as "Evacuation stations and external escape routes" (category 4 in SOLAS Reg. II-2/9.2.2.3) at deck level (especially where large glazing are fitted facing HSE storage-modules), but also ensuring that areas, below deployment position, are "A-30" class, as minimum, like for the liferafts/MES cases. Especially in an installation scenario, where only HES are installed, keeping the integrity and the functionality of the HES is of a paramount importance, so it is strongly recommended that where there are facing areas between the HES and potential risky areas (like accommodation and public spaces) such areas (e. g. promenades for accessing the HES) are suitably protected with a fire-fighting system and provided with a detection system for identifying any incipient fire.

3.6. Visibility from the Bridge

Where HES is installed on board, the transversal section of the ship alongside the sides is mostly flat (as a limited number of life-saving appliances is fitted), without protrusions and visibility obstructions at embarkation deck level. This ensures a greater level of visibility from the bridge wings on the ship's side avoiding the need of installation of dedicated cameras or alternatively to arrange long bridge wings for ensuring the visibility of the whole ship's sides.

4. Configuration Scenarios

Considering the current level of development of the HES product and noting that the HES is a prototype novel life-saving appliance, the following HES configuration installation scenarios with or without other life-saving appliances are envisaged:

- Full HES solution: the option does not consider the installation of other SOLAS compliant life-saving appliances and therefore the most challenging aspect would be ensuring the sufficient redundancy of the HES. In principle the hypothetical philosophy for defining the minimum number of persons should be the same adopted for the lifeboats and liferafts (SOLAS Reg. III/21.1 and 21.2). Considering the potential huge capacity of each HSE unit a high level of redundancy can be achieved with a limited number of units. Compared with the traditional survival crafts this option offers the highest

level of benefits in terms of very limited footprint, maximizing the areas for the passengers, but it does not offer any possibility of tendering from the passenger ship to shore.

- HES solution with lifeboats and/or liferafts: this solution offers a greater level of flexibility in the evacuation and abandon process; the sizing of the number of persons to be accommodate on lifeboats and liferafts (additional 25 %) should be ruled by SOLAS Reg. III/21.1.1.2 and 21.1.2.2. This combined solution would be the preferable one where an existing passenger ship would increase its actual life-saving capacity, limiting the structural modifications of the hull and keeping the same survival crafts, before the modification.
- HES solution with liferafts: this solution would appear to be the most appropriate for the short international voyage (SOLAS Reg. III/21.1.2.1 refers), where the 30 % of the persons are accommodated on the HES, instead of the lifeboats.

5. Current Regulatory Framework

The product is not still available on the market and so far specific standards and guidelines have not been developed for the design and the relevant operational and maintenance aspects of the HES. There are some local and limited initiatives of working groups where the stakeholders (including but not limited to the HES Manufacturers, Shipyards, Shipowners/Operators, Classification Societies, Flag Administrations) are focused in outlining the standards, but there not a general consensus and the system has not been included in the acceptable options considered in the SOLAS Ch. III neither in the related LSA Code.

The most appropriate methodology for starting to consider the HES as a life-saving option, reference should be made to the A.520(13) "Code of Practice for the Evaluation, testing and Acceptance of Prototype Novel Life-Saving Appliances and Arrangements", which is a specific code for the prototype novel life-saving appliances. Even if the proposed criteria are agreeable (as based on SOLAS Ch. III principles), the Code is old-dated and it is a generic tool not specific for such specific life-crafts which is revolutionary concept potentially changing the so-far universally accepted lifeboats and liferafts (and MES) proportion of SOLAS Reg. III/21.1 and 21.2.

Without a reference standard (accepted at IMO/IACS level), the route to compliance should be mainly driven by SOLAS Reg. III/4.3:

- Following the compliance framework of the SOLAS Ch. III as applicable and the relevant part of the LSA Code, it should be performed a gap analysis aimed at identifying the arrangements of the products not-equally effective as the life-saving appliances to be replaced. The satisfactory outcome of the gap analysis and of the suitable tests (e.g. in accordance with IMO A. 520(13) § 3.2 and IMO Res. A.689(17) "Recommendation on Testing of Life-Saving Appliances") would be the basis for the issue of a type-approval certificate including the installation limitations (e. g. maximum carrying capacity, maximum installation height, minimum essential on-board passenger ship, maintenance plan, etc.) of the HES.
- Upon the issue of type-approval certificate, a robust Alternative Design and Arrangement should be carried-out under the SOLAS Reg. III/38 and IMO

MSC Circ. 1212 for identifying the key-risks associated to the HES installation (including but not limited to redundancy and operational readiness) and the relevant mitigation measures.

For every HES installation-case proposal, the above process should be discussed with the relevant Classification Society, the Flag Administration and other Authorities as the USCG, where applicable, from the early design stage for an acceptance, at least in principle, of the HES on board of the passenger ship. If the industry shows interest in developing such products, it would be expected that proper guidance are developed at IMO/IACS level, but this developing process can last some years, so in the meantime it would be strongly recommended to follow the above described process properly involving all the stakeholders.

6. Conclusions

HES is a novel life-saving appliances concept which definitely ensures some benefits (including but not limited footprint and reduced maintenance activity) compared with the traditional survival crafts, so far installed. However HES is a vital and complex item, which need to be properly integrated in the ship-systems; it should be studied holistically, not as an isolated stand-alone item, for achieving the uppermost benefits. Therefore with the contributions of all stakeholders it would be encouraged the development of feasibility and conceptual studies for outlining the design of the product on board different passenger ships, identifying the key-risks which should be addressed and properly mitigated for achieving an equally safe and effective life-saving appliance product.