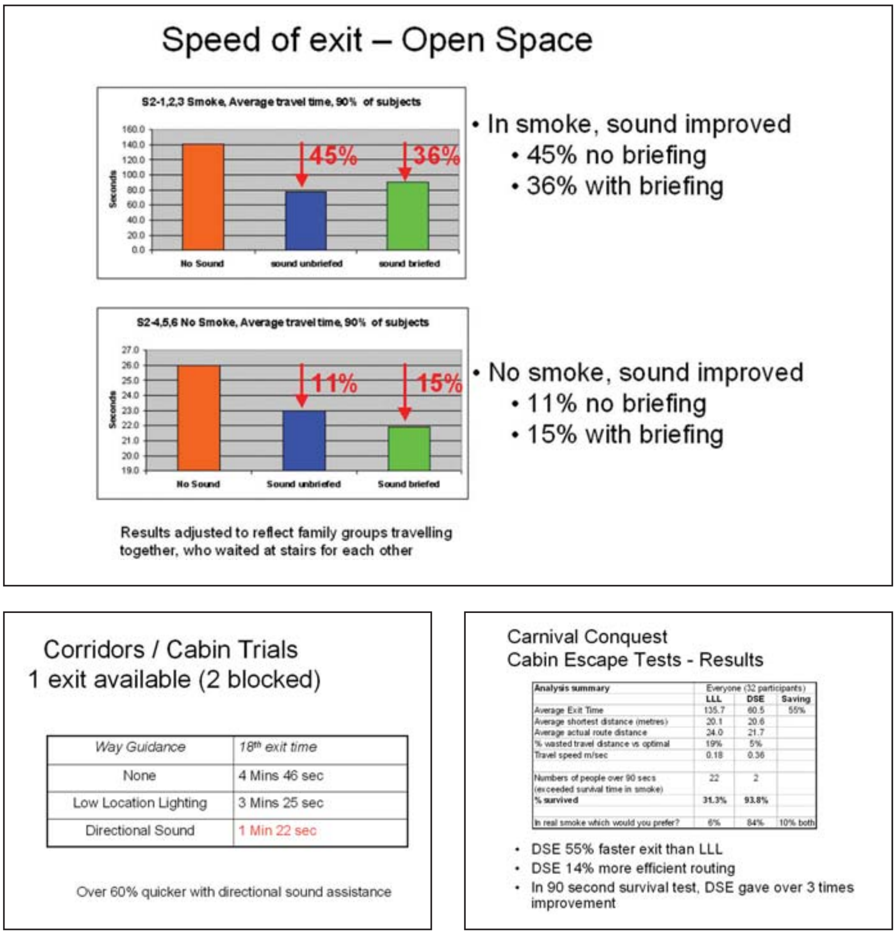
Directional sound: an important new escape aid

SEVERAL interesting new safety technologies, including the now commonly used emergency low-location lighting in various forms, have resulted from some of the high-profile marine disasters of the last 26 years. These have particularly arrived since the *Herald of Free Enterprise* accident in 1987, but other important catalysts have included the fire on *Scandinavian Star* in 1990, the *Estonia* disaster of 1994, and a relatively unpublicised incident on *Nieuw Amsterdam* in 2000, in which electro-luminescent low-location lighting was called into question.

Nevertheless, none of the new technologies can perhaps be considered so revolutionary (yet perhaps so simple) as a novel one being promoted today, which uses a human being's basic sense: sound. Audible alarms are, of course, in everyday use on board ships, but until now, none have been specifically harnessed to improve lifesaving; that situation is however changing with the introduction by a UK-based company named Sound Alert Technology of what is known as directional sound. Its technique, named Localizer, won the Royal Institution of Naval Architects' 2002 Safer Ship Competition.

Localizer, designed to help guide people to exits in the dark but, perhaps more importantly, under smoke conditions when exit and sign visibility is severely restricted, evolved from a chance incident that Professor Deborah Withington, a sound specialist at Leeds University, in the UK, experienced. While in a taxi, she heard a police or ambulance siren but realised that she could not identify the direction from which it came, due to the frequency used in such equipment.

The resulting technology (which was the subject of papers earlier this year at The Royal Institution of Naval Architects' Passenger Ship Safety conference and at the Warship 2003: Airpower at Sea conference*) instead uses broad-band, multi-frequency sound that is easily and quickly located by the human ear. All current alarms sound in the range between 1kHz and 2.5kHz because the human brain is very sensitive to these levels; unfortunately, no directional information is given at these frequencies, so a new spectral cue is required, hence the term broad band (frequencies from 20Hz to 20,000Hz). The special sound technique developed by Sound Alert Technology has been patented. Directional sound is already being introduced on land and is being considered for aircraft.



Some figures and diagrams compiled by the UK MCA, which illustrate the attractions of directional sound in speeding escape from various parts of a ship.

IMO's concerns over the new generation of very large passenger liners led to a UK working party being set up (Maurice Storey and Alan Cubbin from the Maritime & Coastguard Agency, John Rugg, from Lloyd's Register, and John McNeece, formerly with the McNeece design consultancy). They considered sound to be a positive aid for evacuating public spaces and accommodation, and were optimistic over its future - and brought it to the attention of their IMO colleagues on the Large Passenger Ship Safety working group of the MSC.

Subsequent marine trials appear to have proved that sound is much more effective in guiding passengers to exits than photo-luminescent and electro-luminescent light-based systems. It is especially interesting to record that even technical staff intimately familiar with cabin arrangements on particular ships became totally disorientated in escape trials under smoke conditions.

A further driver for sound-based systems has been the very poor survivability time for humans in heavy toxic smoke - as little as 1.5min, according to some researchers. Indeed, 90sec is used by the aircraft industry as the measure of an aircraft's ability to quickly evacuate passengers.

Localizer beacons at strategic exit positions could be especially useful, believes Sound Alert Technology, in the large restaurants, casinos, and lounges that tend to characterise the modern generation of giant cruise liner and where escape points could be very difficult to find under smoke conditions. Under current SOLAS regulations, low-location lighting is not needed in such rooms - perhaps regrettably considering the large numbers of people congregating in them - but if it were to be made mandatory here, some believe that it would be ineffective, given the size of such spaces.

The UK MCA has taken a leading role in promoting sound technology, and a most interesting series of trials - devised in conjunction with Leeds University and the University of Strathclyde were carried out in June and October 2001. These took place, with the assistance of Tom McNeil, technical

* 'Directional sound evacuation - an improved system for way guidance from open spaces and exit routes on ships', by Prof Deborah Withington, School of Biomedical Sciences, University of Leeds, and Mike Lunch, Sound Alert Technology Plc. Presented at RINA headquarters, London, at The Royal Institution of Naval Architects' international conference on Passenger Ship Safety, March 25-26, 2003, and also at the Warship 2003 conference on June 25-26, 2003.

director of Caledonian MacBrayne, onboard two CalMac moored ferries (at-sea trials were not possible due to insurance restrictions). A total of 360 volunteers from local towns were recruited (all ages from 17-67), including blind and deaf people, and of both genders) to test Sound Alert Technology's system using theatrical smoke.

Apparently, real smoke with its toxic gas causes reflex closing of the eyes and is eye-watering, thus making escape even more difficult for passengers. Water-mist fire extinguishing systems - efficient though they are - also have a side-effect of making smoke fall to the deck quicker thus making public space exit even more hazardous. The CalMac ferry trials also included tests with electro-luminescent low-location light-based systems.

A second series of tests was also carried out in October last year at one of the Fincantieri shipyards on a new Carnival cruise liner, *Carnival Conquest*, shortly before delivery. For one of these, the nine-deck-high atrium was filled with smoke, and directional-sound alarms fitted to all 26 exits (20 of which were on the lower three levels, which created a confusing acoustic scenario). Apparently, volunteers found suitable exits very quickly.

For a cabin test in the complex crew area on the same ship, directional sound gave 55% reductions in average escape times when compared with low-location lighting. The public address and general alarm systems were operated in both sets of test but had no impact on the sound system's effectiveness.

The MCA appears to be impressed with such figures, given the limitations of trials scenarios; it is particularly interesting to note that this organisation records that low-location lighting was little used in the trials 'since in 3% density smoke, lighting assistance was not visible.'

One piece of legislation that may hasten the introduction of directional sound is the US Americans with Disabilities Act, which now applies to passenger ships; since blind people cannot see low-location lighting, directional sound would be a highly desirable feature. Meanwhile, last year, both the UK and German marine administrations have formally proposed directional sound evacuation to IMO as an equivalent to low-location lighting within SOLAS regulations. It is believed that Italy also supports the technology in principle.

Unfortunately, as most readers will know, the wheels of IMO turn exceedingly slowly and it could be several years for this equipment to be formally approved. Nevertheless, according to Sound Alert Technology, directional sound could still be introduced, using the provisions of SOLAS 2-II, Regulation 17; this allows for 'alternative design and arrangements' to be examined and approved, subject to fire safety engineering and risk analysis. However, some work by owners and yards would be needed.

Installation of a sound system could be very attractive to shipyards - it is much simpler than a low-location lighting design (some versions of the latter are understood to be very labour-intensive to fit due to the many short sections, each of which must be wired from both ends for redundancy). It could readily be integrated within a public address or general alarm circuit using established SOLAS practice, using a second loop for redundancy in each fire zone and additional sets of loudspeakers. New direct-addressable digital technology for such circuits could also be included. An alternative is a free-standing arrangement, but this would have to go through a lengthy approval process.

A performance-based specification for directional sounders has recently been published by the British Standards Institution (PAS41:2003). Notwithstanding all this optimism, it seems likely at the present time that few operators will be bold enough to install the new technology prior to formal IMO approval - except perhaps to meet their obligations under disabilities legislation. ⚓

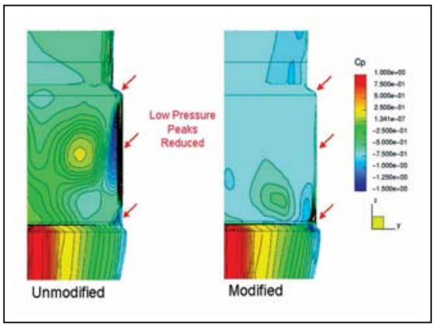
Reducing rudder erosion on fast ships

WITH recent increases in ship speed and propeller loading, there is increased danger of cavitation on the propeller and on appendages such as rudders, pods, and struts. The German model basin HSVA recently conducted several full-scale observations on semi-balanced rudders, revealing quite dramatic cavitation occurrences and cavitation-induced erosion damage.

Rudder cavitation erosion is of concern if it occurs within the range of rudder angles a=±5 deg while course-keeping. Different types of cavitation occurr on rudders, such as bubble, sole, gap, vortex cavitation, and cavitation caused by surface irregularities. HSVA believes that principal emphasis must be given to the area around the pintle. There, details of gap size and geometry, as well as exact workmanship, are of paramount importance.

Model tests

Model tests can help in the early stage of design, especially when they are performed in a sophisticated test facility, and with a special aim to predict those types of cavitation occurrences. Rudder cavitation is not only influenced by the geometry of the rudder, but also by the inflow to the rudder and propeller. Therefore, tests in 3D inflow, behind the whole ship model, to give full propeller/hull interaction, are necessary to obtain a clear view of cavitation behaviour. If the danger of cavitation-induced erosion is large for specific areas such as the pintle, additional tests in a smaller tunnel with even higher Reynolds numbers are recommended.



These diagrams illustrate an improved pressure distribution, thus less cavitation danger due to a change in rudder geometry.

For the scenario mentioned above, part of a large rudder model was tested in HSVA's large cavitation tunnel. These tests could prove that there are mainly two critical areas where cavitation occurs: the gaps between the moveable part and the fixed part, and the areas downstream of the maximum thickness of the rudder sections. On the part-rudder model, complicated interactions between the flow through the gaps and the cavitation phenomena were observed.

One solution to improve cavitation behaviour is to keep cavitation - which cannot be avoided - away from the rudder surface in order to avoid erosion damage at those points, which are sensitive with respect to strength. To achieve this, use was made of wedge-shaped spoilers. The final rudder exhibits the following modifications (compared with the original rudder):

- width alteration of the horizontal gaps and lower vertical gap in order to obstruct flow through gaps
- spoiler at the lower end of the upper vertical gap (upstream of medium horizontal gap)
- spoiler on the lower pintle, in order to direct cloud cavitation away from the rudder surface
- fitting of a horizontal plate below the lower horizontal gap, extending downstream of the lower vertical gap.

These modified rudders have been in use on two ships for six months, and diver reports show an improvement regarding observed erosion damage.

Numerical investigations

Before model tests, CFD calculations can be used to check cavitation behaviour of different rudder designs. With simple potential theoretical techniques, pressure distributions can be determined for the rudder profiles. Thickening was observed - often used because of strength considerations - which leads to significant low-pressure drops in the region of the pintle bearing.

This is the most critical area of the rudder, and 3D viscous-flow calculations reveal complicated flow behaviour in this region. The water is sucked in, comparable to the behaviour of a scoop, into the gap between rudder horn and rudder blade. By a change of geometry in front of the gap, the quantity of water passing through the gap could be reduced, resulting in improved pressure distribution and therefore less cavitation danger. ⚓