Seq. No.	Name	Survey Date	Location
11	Bogo LB	May 10, 1991	Bogo City, Cebu Island

Outline of Facility

- Tower is inclined towards western side due to strong waves
- A portion of the foundation, under water, is partially destroyed.
- The light color does not harmonize with the tower surface.

Maintenance & Operation

- Unmmanned operation

Evaluation

	Excel-lent	Good	Ave-rage	Poor	Very Poor
1. Location		v			
2. Building				v	
3. Light				v	
4. Operation					v
5. Maintenance			v		

Recommendation for Improvement

- Wider foundation/base should be constructed and designed to withstand strong wave and water action.
- Both color of light and tower surface should be harmonized, using the same color.
- Solar panel should be moved to the upper platform.

Seq. No.	Name	Survey Date	Location
12	Macabaran Pt. LB	May 12, 1990	Cagayan de Oro City

Outline of Facility

- Structure is of steel and power is from local power supply system. Lighthouse keeper's dwelling is located at the foot of the tower and is made of concrete. Land area occupied is about 150 sq.m.

Maintenance & Operation

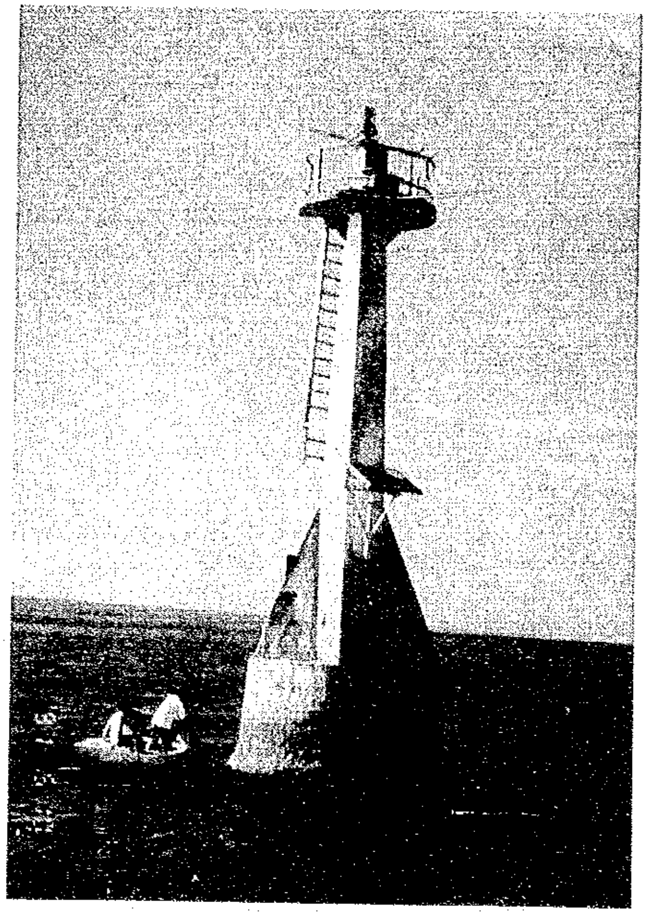
- Switching of light is manual, as soon as the sun sets.
- Lantern bulb used is an ordinary incandescent bulb. Spare bulbs are easily available any time and anywhere.
- Steel tower already corroded and may pose some danger during strong typhoons.
- Visible light range is limited to 4 nautical miles.
- No alternative power source during power brownouts.

Evaluation

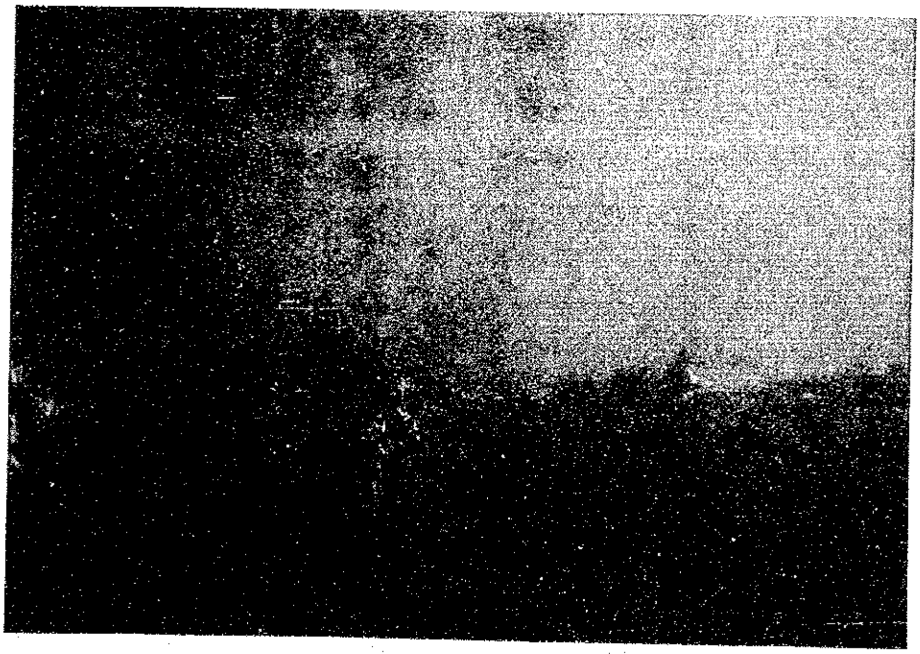
	Excel-lent	Good	Ave-rage	Poor	Very Poor
1. Location	v				
2. Building			v		
3. Light				v	
4. Operation				v	
5. Maintenance				v	

Recommendation for Improvement

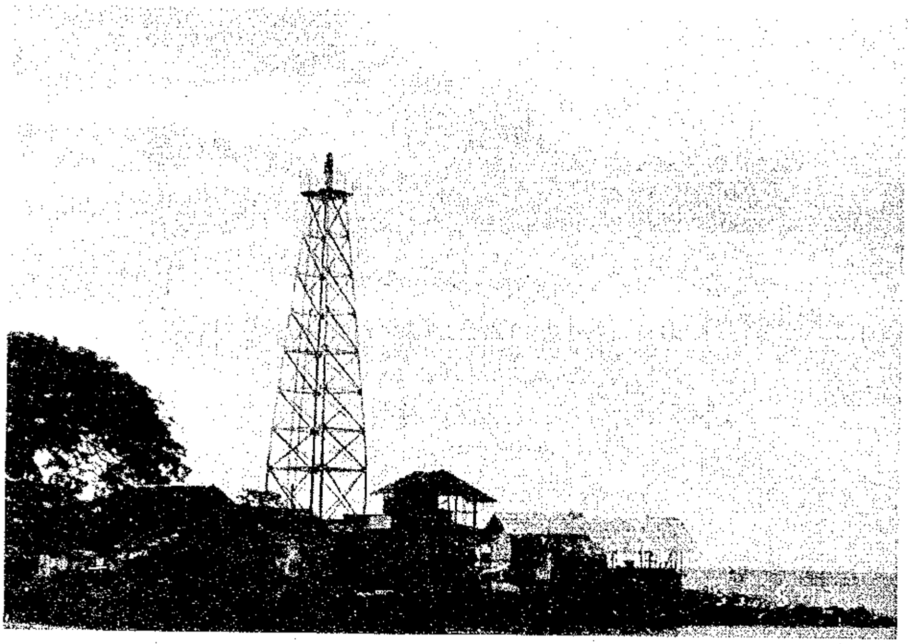
- New lantern should be installed to improve visibility.
- Stand by generator should be provided, in case of brownouts.
- Steel tower should be properly maintained, if it is to be preseved; if possible a concrete structure should be built instead.
- Lightkeeper should be trained in the proper maintenance of the lighthouse.



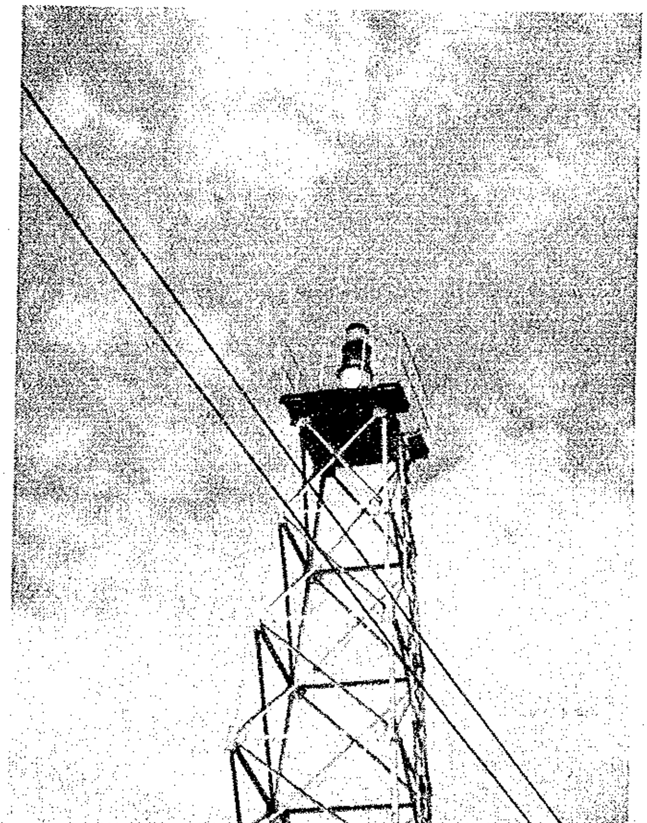
Picture 11-1 Inclined Structure



Picture 11-2 Shaved Base



Picture 12-1 : Overview
of Macabaran Pt. LB



Picture 12-2 Upper Part of LB

Seq. No.	Name	Survey Date	Location
13	Sulauan Pt.	May 13, 1991	Sulauan Pt.

Outline of Facility

Site Examination

- Well located, as a middle size light beacon, to guide vessels to/from Cagayan de Oro Port.
- Condition of planned site: 7.8 meters above sea level
  Electrical lines will be difficult to install.
  Uncertainty in the nature of the soil.
  Ruins of old Spanish fort/port in same site.

Proposal for Construction

- It will be necessary to build a middle size light beacon at the top of Cape Sulauan.
  Roughly, specifications should be as follows:

Necessary visible range	:	Over 10 nautical miles
Tower	:	Light module structure, 10 m. height
Electricity	:	Solar panels
Light Fixture	:	300 mm lantern
Operation	:	Unmanned system

Evaluation	Excellent	Good	Average	Poor	Very Poor
1. Location					
2. Building					
3. Light					
4. Operation					
5. Maintenance					

Recommendation for Improvement

Seq. No.	Name	Survey Date	Location
14	Opol (San Miguel Port)	May 13, 1991	Cagayan de Oro

Outline of Facility

Tower : 7.5 high concrete tower, located within San Miguel Beer plant.
Facility is under construction, no lighting apparatus still installed.

Evaluation	Excellent	Good	Average	Poor	Very Poor
1. Location		v			
2. Building			v		
3. Light					
4. Operation					
5. Maintenance					

Recommendation for Improvement

None

Picture 13-1 Planned Site

Picture 14-1 Overview

Seq. No.	15	Name	Balingoan LB	Survey Date	May 13, 1991	Location	Cagayan de Oro City

<u>Outline of Facility</u>

- The facility was not in operation due to the construction of a PPA warehouse, which blocks the effectiveness lighthouse to navigation.

<u>Maintenance & Operation</u>

- The lighthouse is not presently being operated, but is being maintained by the Philippine Coast Guard.

<u>Evaluation</u>	Excel-lent	Good	Ave-rage	Poor	Very Poor
1. Location	v				v
2. Building				v	
3. Light					
4. Operation					
5. Maintenance					

<u>Recommendation for Improvement</u>

- Location of lighthouse should be immediately transferred.

Remarks

- There is a proposal from the municipality of Balingoan for the transfer of the lighthouse.
- Existing port can be transferred to a nearby island.

Seq. No.	16	Name	Iloilo Jetty Light (red/green)	Survey Date	May 20, 1991	Location	Iloilo City

<u>Outline of Facility</u>

- Two small jetty lights (red/green), on both sides of a water way in Iloilo River.
- Tower made of concrete, is 5 meters high, and painted white.

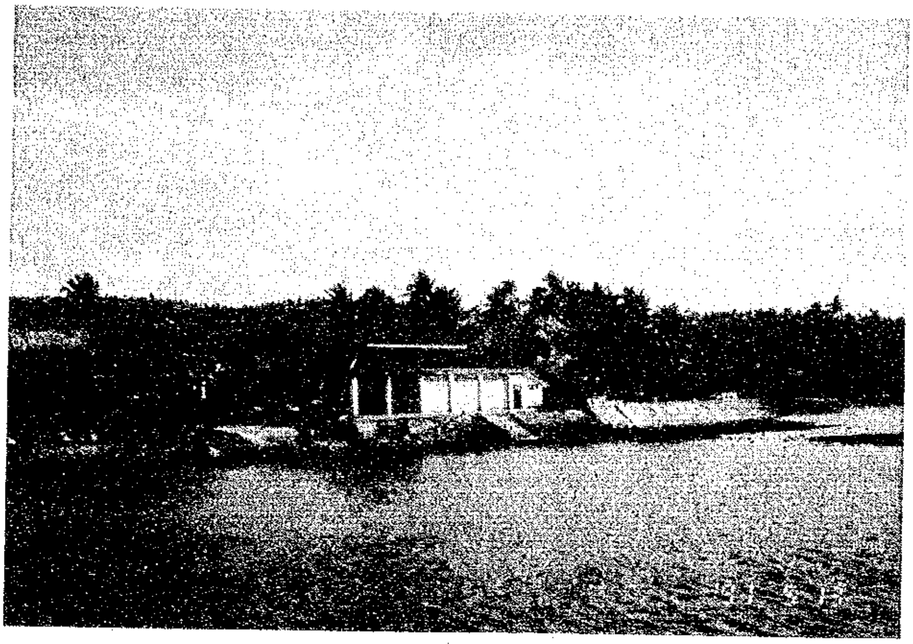
<u>Maintenance & Operation</u>

- Red light is operated, maintained by Pilipinas Shell Corporation.
- Green light is operated, maintained by local pilots association.

<u>Evaluation</u>	Excel-lent	Good	Ave-rage	Poor	Very Poor
1. Location	v				
2. Building		v			
3. Light		v			
4. Operation		v			
5. Maintenance		v			

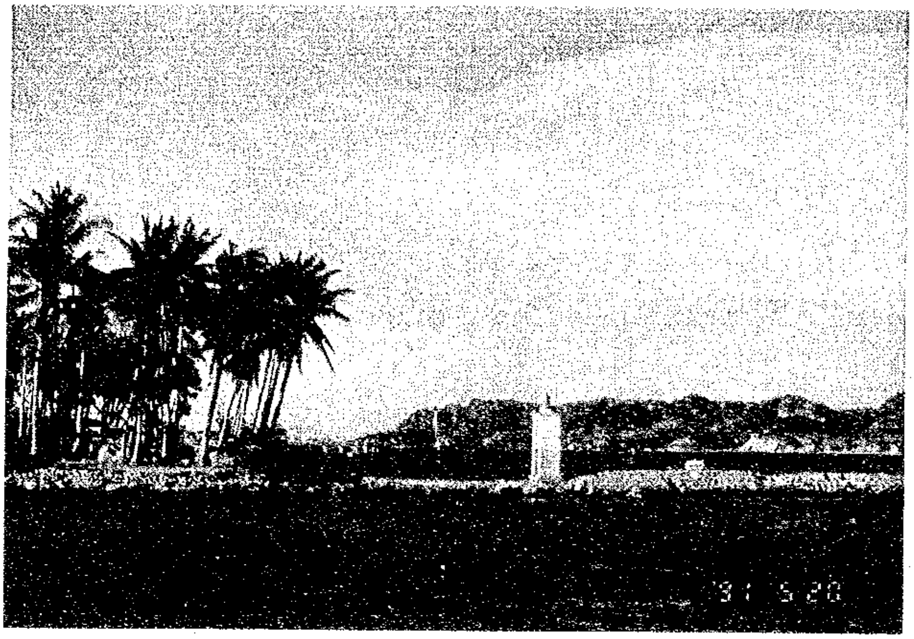
<u>Recommendation for Improvement</u>

None

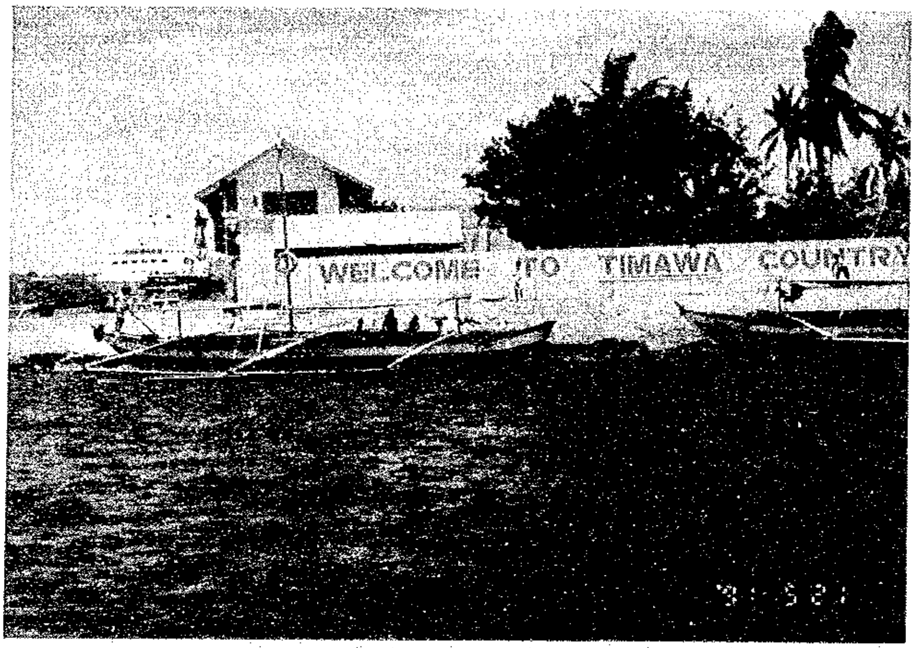


Picture 15-1 :
Balingoan LB behind PPA's Warehouse

Picture 15-2 Overview of Balingoan LB



Picture 16-1
Iloilo Jetty light (red)



Picture 16-2 :
Iloilo Jetty Light (Green)

Seq. No.	17	Iloilo Strait	Survey Date	May 21, 1991	Location	Off Iloilo

Site Examination

- A long bank stretches along the south waterway. Lrge size vessels must navigate through these banks, which have a width 200 meters. However, there is no aid to navigation to indicate the ends of the bank and the navigable waters. Nautical Chart 4448 records a buoy, but actually the buoy was carried away 10 years ago. The Iloilo Pilots Association has requested that the buoy be rebuilt or a new leading light be built on the the side of Guimaras Island.
- There are also many small banks along the north waterway. However, the two buoys, mentioned in the chart, have also been missing for a long time. The Iloilo Pilots Association have also requested that 2 or 3 buoys be established at proper locations, for guiding vessels along this waterway.

Proposal for Construction

- It is necessary to install at least 1 buoy along the south waterway and 2 or more buoys along the north waterway.

Evaluation	Excellent	Good	Average	Poor	Very Poor
1. Location					
2. Building					
3. Light					
4. Operation					
5. Maintenance					

Recommendation for Improvement

Seq. No.	18	Name	Capiz Jetty Lights (Red/Green)	Survey Date	May 12, 1991	Location	Capiz

Outline of Facility

- Located at top of breakwater.
- Lantern is placed on tower.
- Door is broken; there is no ladder.

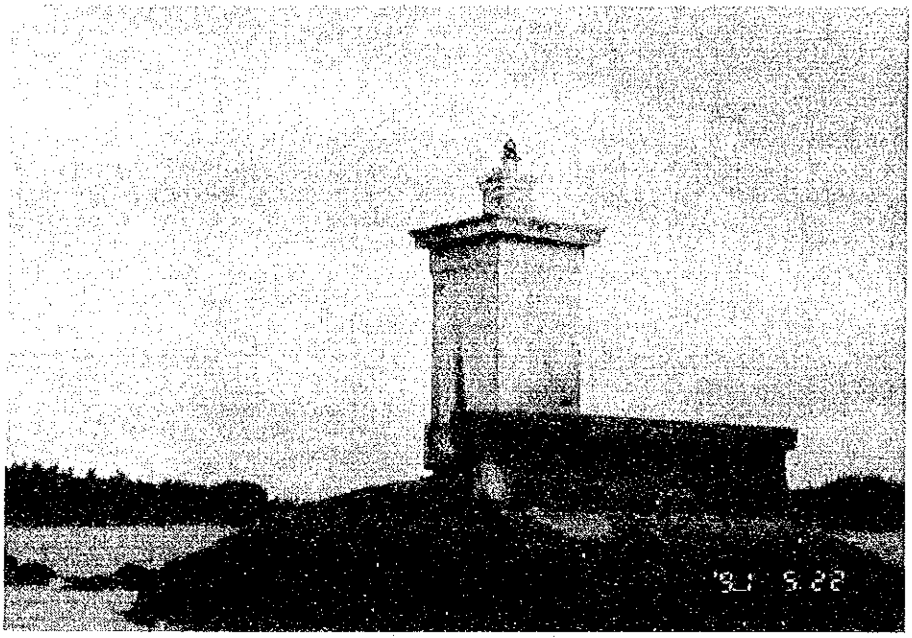
Maintenance & Operations

- One lighthouse keeper is assigned to inspect the area twice a day.

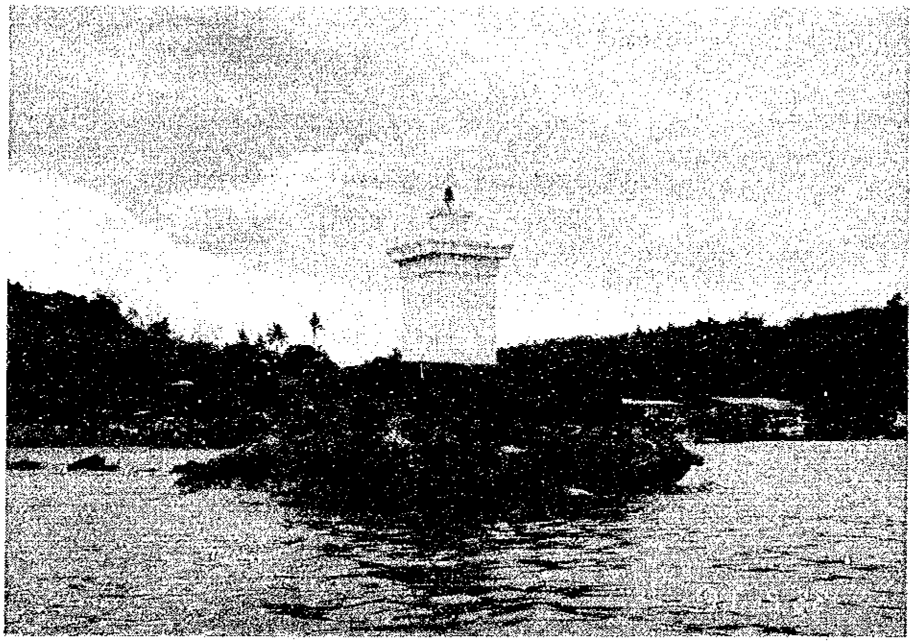
Evaluation	Execellent	Good	Average	Poor	Very Poor
1) Location		/			
2) Building			/		
3) Light			/		
4) Operation			/		
5) Maintenance			/		

Recommendation for Improvement

- Door should be repaired; tower should be equipped with ladder.
- Solar panels should be installed for power supply.



Picture 18-1 Capiz Jetty Light
(Red)



Picture 18-2 Capiz Jetty Light
(Green)

Seq. No.	Name	Survey Date	Location
19	Culasi Pt. LH	May 23, 1991	Roxas City

Outline of Facility

Tower : Initially constructed of reinforced concrete, with access to the lantern chamber by vertical ladder platform.

Building : Wooden building, used for office space, residence, etc. destroyed by typhoon. What remiains is the power house, although even this is partially damaged.

Maintenance & Operation

- The station is classified as manned; with 1 lighthousekeeper assigned to carry out the tasks of operating the emergency generator, to charge batteries every 2 to 3 days. At present, no living quarters are available.
- The station is not equipped with any drawings of the existing structures, instruction manual for apparata. could not be carried out.

Evaluation	Excellent	Good	Average	Poor	Very Poor
1. Location	v				
2. Building					v
3. Light				v	
4. Operation				v	
5. Maintenance					v

Recommendation for Improvement

- Abovementioned buildings should be rebuilt.
- Connection should be made to commercial power supply (distance from Roxas CG station to lighthouse is approximately 350 meters).
- Lighting apparatus, emergency generator, batteries should be replaced.
- Measuring instrument, minimum tools, instruction manuals should be provided.

Seq. No.	Name	Survey Date	Location
20	Manigonigo LH	May 23, 1991	Manigonigo Island

Outline of Facility

Tower : Made of steel, 9 meters high, access by spiral steel stairway to the top; totally corroded.

Building : Large buildings with space for office, residence, made of blocks. However, entire roof is destroyed, except over emergency generator building.

Apparatus : Replacement of small scale lantern, solar panel, etc., in good condition, but has insufficient light intensity.

Maintenance & Operation

- The station is classified as manned; with 1 light housekeeper assigned, although there is no dwelling space.
- Door, access to tower, was locked. No light housekeeper at time of inspection; inspection of tower interior could not be carried out.

Evaluation	Excellent	Good	Average	Poor	Very Poor
1. Location	v				
2. Building					v
3. Light				v	
4. Operation					v
5. Maintenance			v		

Recommendation for Improvement

- Tower, lighting apparatus should be replaced.
- Associated building, residence area for lighthouse keeper should be rehabilitated.
- To increase visible range, small scale lantern solar panel should be replaced by larger one.

Picture 19-1

Picture 19-2 Broken associated building by typhoon

Picture 20-1

Overview

Picture 20-2 Locked door

II. REFERENCE OF AIDS TO NAVIGATION SYSTEMS

GENERAL DESCRIPTION OF AIDS TO NAVIGATION SYSTEMS

It is not possible to accurately predict the future development of aids to navigation. For hundreds of years the mariner has relied on his own faculties of sight and hearing to assist his navigation, but it is obvious that modern technology is playing an increasingly important role.

The desire of ships' operators to reduce crew numbers and the increasing numbers of small craft sailors willing to purchase sophisticated equipment have led to greater availability of equipment and more competitive pricing.

There is likely to be a role for the traditional aid for many years to come, although the requirement for powerful lights will continue to diminish. Fog signals may well be phased out altogether. Nevertheless there will be a continuing requirement for buoys to mark the boundaries of channels, indentify the existence of wrecks and other offshore hazards and to act as a confirmatory mark to support the data being produced from electronic aids. The use of electronic aids will increase particularly as their greater production is likely to result in them becoming relatively inexpensive.

With more vessels of all sizes carrying some form of electronic position fixing system the justification for the provision of powerful lights diminishes. This is particularly relevant to those Lighthouse Authorities having Light Vessels and Lanbys. These aids to navigation are expensive to maintain yet the requirement for their size is based on the need to house equipment to power the light, with the added justification of providing a prominent daymark. Some of these large aids have been replaced by buoys equipped with racons owing to the greater use of electronic aids by the mariner, and this trend is likely to continue.

This trend is noticeable even before the full introduction of GPS with it's anticipated high level of accuracy. With GPS comes the possibility of even greater accuracy through Differential GPS. The long term impact on traditional aids to navigation could be significant.

Some Governments are currently debating whether there is a need to provide a land based system in addition to GPS. Perhaps only time and experience will provide the solution to this particular question.

Another innovation that is emerging is the electronic chart. The use and impact of the electronic chart is currently difficult to assess. The mariner may place greater dependence on electronic charts as he becomes more familiar with the equipment. It is certain that Lighthouse Authorities will need to be more accurate when positioning their aids to navigation.

It is important for Lighthouse Authorities to closely monitor the situation, to keep aware of developments and trends, both in the production and in the use of aids, and to continue to provide as economically as possible the correct mix and level of aids to enable the mariner to make safe and expeditious passage.

This Paper reviews the existing aids to navigation systems for marine navigation. Each system is given brief description. The purpose of the system is briefly discussed and the performance criteria are stated.

The term "system" as used in this chapter includes all aids to navigation external to the ship. Thus this review includes traditional aids to navigation as well as radio aids, and VTS. The VTS service is implemented by the responsible authority to improve the safety and efficiency of navigation and to protect the environment.

A section is also included in which mixed of aids to navigation systems are considered.

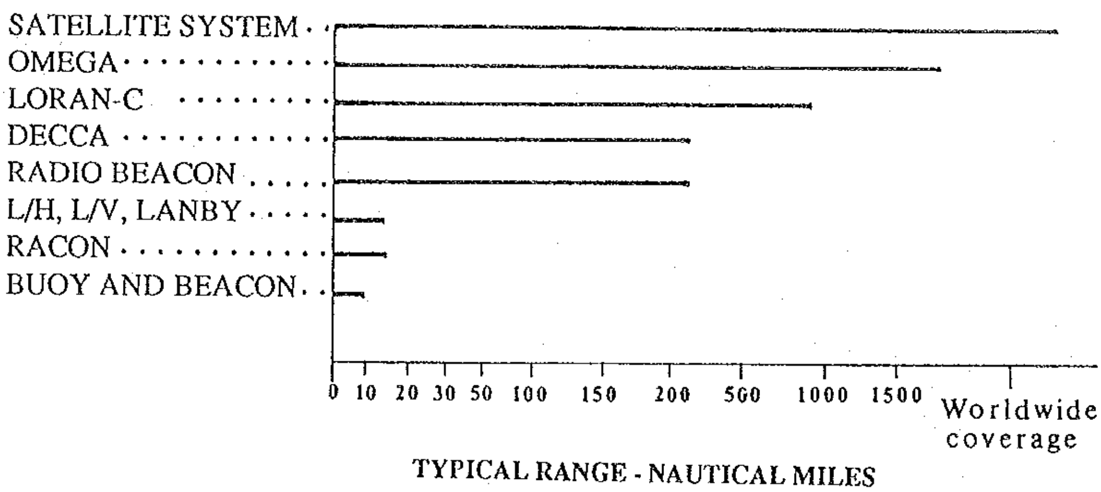
In the descriptions, reference is made to IALA Recommendations and Guidelines. The reader is urged to consult these documents if more details are required.

IT SHOULD BE NOTED THAT ALL MARINE AIDS TO NAVIGATION MUST CONFORM WITH THE APPROPRIATE IALA RECOMMENDATIONS.

In general, terms such as long range, medium range and short range may lead to misunderstandings if the aid involved is not mentioned. For example, long range for a visual aid may be short range for a radio aid.

Typical ranges of the various aids to navigation systems are shown in the following diagram.

AID TO NAVIGATION SYSTEMS



VISUAL AIDS TO NAVIGATION

Each Lighthouse Authority should establish:

- where, when and for what length of time an aid to navigation is required;
- the type of aid to be provided;
- who will be paying for the aid;
- how, when and by whom maintenance will be carried out.
- what tools, means and personnel are required for maintenance;
- how, when and by whom changes or malfunctions of aids to navigation will be promulgated.
- when and how the operation and positioning of aids is monitored.

Bearings, directions of leading (range) lines and limits of sectors are always given as seen by the observer towards the Aid to Navigation.

Visual aids to navigation may, depending on the circumstances be equipped with a light, racon, radar reflector, topmark, dayboard, traffic signals, retro-reflecting material and means of identification, such as a name, number or letter or a combination of these.

In this connection a topmark indicates the type of the mark within the buoyage system. Where a mark does not conform to the shape laid down in the buoyage system it is particularly important that the appropriate shape topmark be fitted.

Names, abbreviations of names, letters and or numbers on visual aids to navigation must correspond with those on the chart.

Visual marks are distinguished by their

- type
- range
- characteristics.

THE NATURE OF A MARK

A mark can be either natural or man mode. Natural marks are conspicuous points on the land or in the sea which can be used for navigation. These may be headlands, mountain tops, rocks etc. Man made marks can either be specially designed for navigation or although designed for another purpose can still be used for navigation, for example church towers, minarets, monuments, chimneys, etc.

Lighthouse authorities must ensure that aids to navigation are not obscured by trees, buildings or background or misleading lighting.

THE RANGE OF A MARK

The range of a mark depends upon one or more of the following:

- meteorological visibility
- contrast and background
- radar reflecting properties
- properties of any retro reflecting device in use
- light intensity

- height above sea level

- observer's height of eye.

The range at which the mariner initially detects the existence of an aid is known as "detection range".

The range at which an aid can be positively identified is known as "identification" or "recognition range".

The range at which a symbol of a certain height can be identified depends upon the visual acuity of the observer. However, as a rule of thumb it can be assumed to be 4 minutes of arc, thus:

$$\text{Identification range} = \frac{\text{Symbol Height}}{\tan 4'} = \text{Symbol Height} \times 860$$

Optical devices such as binoculars will increase the detection and identification range.

GEOGRAPHICAL RANGE is the maximum distance at which an object or light from a light source can theoretically be seen by an observer, as limited only by the curvature of the earth, the refraction of the atmosphere, the elevation of the object or light and the height of eye of the observer. A Geographical Range table is given below.

GEOGRAPHICAL RANGE TABLE IN NAUTICAL MILES

HT.OF OBS. EYE IN METRES	ELEVATION OF SEAMARK IN METRES										
	0	1	2	3	4	5	10	50	100	200	300
1	2.0	4.1	4.9	5.5	6.1	6.6	8.5	16.4	22.3	30.8	37.2
2	2.9	4.9	5.7	6.4	6.9	7.4	9.3	17.2	23.2	31.6	38.1
5	4.5	6.6	7.4	8.1	8.6	9.1	11.0	18.9	26.9	33.3	39.7
10	6.4	8.5	9.3	9.9	10.5	11.0	12.8	20.8	26.7	35.1	41.6
20	9.1	11.1	12.0	12.6	13.1	13.6	15.5	23.4	29.4	37.8	44.3
30	11.1	13.2	14.0	14.6	15.2	15.7	17.5	25.5	31.4	39.8	46.3

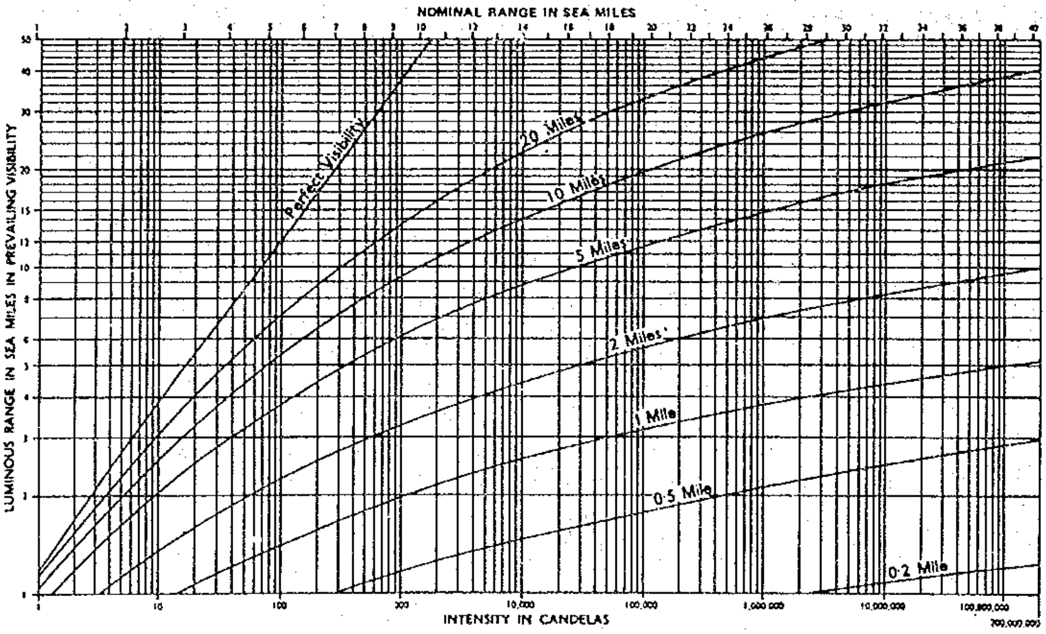
VISUAL RANGE is the maximum distance at which contrast of the object against its background is reduced by the atmosphere to the contrast threshold of the observer. The term visual range is used instead of luminous range in daytime viewing.

THE LUMINOUS RANGE is the maximum distance at which a given signal light can be seen by the eye of the observer at a given time, as determined by the intensity of the meteorological visibility prevailing at that time. It takes no account of elevation, observer's height of eye or the curvature of the earth (See Luminous range diagram.)

NOMINAL RANGE is the luminous range when the meteorological visibility is 10 sea miles, equivalent to a transmission factor of T = 0.74.

Generally the nominal range is used on charts and in lists of lights. However, some countries used luminous range in their publications. The most commonly adopted meteorological visibility is 20 miles, equivalent to a transmission factor of T = 0.85.

LUMINOUS RANGE DIAGRAM



LUMINOUS RANGE DIAGRAM-This diagram enables the mariner to determine the approximate range at which a light may be sighted at night, in the meteorological visibility prevailing at the time of observation.

The diagram is entered from the top border, using the nominal range of the light or from the bottom border using the intensity of the light.

The figures along the curves represent the estimated meteorological visibility at the time of observation, and those along the left-hand border the luminous range under those conditions.

Example:

A light of an intensity of 100,000 candelas has a nominal range at night of about 20 n.miles. When the meteorological visibility in 20 n.miles the light would be sighted at about 33 n.miles, given a sufficient elevation and height of eye; and when 2 n.miles, at about 5.5 n., miles.

The diagram can also be used to obtain an approximate meteorological visibility; when, for example, a light of an intensity of 100,000 candelas is sighted at 12 n.miles, the meteorological visibility will be about 5 n.miles.

CAUTION - When using this diagram it must be remembered that:

1. The ranges obtained are approximate.
2. The transparency of the atmosphere is not necessarily consistent between the observer and the light.
3. Glare from background lighting (see below) will reduce considerably the range at which lights are sighted at night.

Approximate sighting ranges may be obtained by entering the diagram with the listed intensity divided by 10 for minor background lighting, and by 100 for major background lighting.

Example: A light of 100,000 candelas has a nominal range of about 20 n.miles; with minor background lighting as from a populated coastline this range will be reduced to about 14 n.miles, and with major background lighting as from a city or from harbour installations to about 9 n.miles.

Note: For detailed information see the IALA Recommendation for the Notation of Luminous Intensity and Range of Lights, November 1966 and the IALA Recommendation for a definition of Nominal Daytime Range of Maritime Signal Lights intended for the Guidance of Shipping by Day, April 1974.

BACKGROUND LIGHTING

Excessive background lighting from street lights, neon signs etc. frequently causes an aid to navigation light to be lost in the general background clutter.

The light can be made more conspicuous by increasing its intensity, changing its colour or by varying its rhythm.

GLARE

Glare can be caused by bright lights emitted from the shore, such as car headlights, or from another vessel indiscreetly using a search light. Glare can also be caused by an aid to navigation light which is too bright at close range, especially when the focal plane of the light and the observers' eye are at the same height.

INFLUENCE AND PREVENTION OF GLARE

In the case of shore lights, glare can only be prevented by adequate screening. For aids to navigation lights it is generally accepted that the illuminance at the eye of the navigator produced by a light must not exceed 0.1 lux. If the background is very dark this figure must be reduced to 0.01 lux. (see the IALA Recommendation for Leading Lights of May 1977)

To cope with glare it is possible:

- To raise the focal plane of the light.

- To reduce the intensity of the light.

This can lead to installing two lights instead of one. That is to say one for short range navigation and one for longer range navigation.

The reduced intensity can be obtained by:

- reducing the illuminance of the light source.

- reducing the size of the optic.

- masking the optic.

The method used should enable the calculation of the new intensity of the light and maintain the general shape of the luminous beam.

More especially the light source should not be defocussed or fitted with translucent screens. Equally, obscured glass lanterns should not be used.

THE CHARACTERISTICS OF A MARK

Depending upon the requirements of a waterway, marks can be provided with or without a light.

If night navigation is required, sufficient lighted marks (or floodlit marks) are needed to ensure a safe passage. Night navigation can, to a limited extent, be made possible if unlighted aids are provided with retro reflecting material. For day navigation unlighted marks may be adequate. However, it must be borne in mind that unlighted aids to navigation can in themselves represent a collision hazard at night.

If visual aids are advertised for navigation purposes their availability should be better than 95%. Otherwise they are of very limited used to the mariner and cannot be relied on.

Visual aids must be conspicuous against the background, their shape, colour and light character being determined by the national lighthouse authority in accordance with the appropriate IALA Recommendations.

The light characteristics should differ from other lights in the vicinity.

The design of aids to navigation can be varied to suit local circumstances and requirements.

FLOATING AIDS TO NAVIGATION

Floating aids are not always as reliable as fixed aids due to the environmental forces to which they are subjected. The effect of wind, wave action, currents and sometimes icing reduces their mission time. Because of these operational limitations the establishment of floating aids must be given careful consideration.

The strains on mooring, collisions etc. can cause floating aids to go off station. Court cases have been brought against Lighthouse Authorities in this connection. The liability of Lighthouse authorities for the correct functioning of floating aids is generally limited. Warnings to mariners to this effect are given in Light Lists. The following typical text is from the British Admiralty List of Lights:

> No reliance can be placed on floating aids always maintaining their exact positions. Buoys should, therefore be regarded with caution and not as infallible navigating marks, especially when in exposed positions; and a ship should always, when possible, be navigated by bearings of fixed object or angles between them, and not by buoys.
>
> The lights exhibited by light-buoys should not be relied on, as the apparatus may get out of order, or the light may be extinguished.

A prudent mariner knows this and does not base his navigation solely on floating aids. They are used to facilitate and simplify navigation. The basic function of floating aids as confirmatory aids is documented in court cases. A Lighthouses Authority could be found liable if any negligence in its positioning or maintenance is proved. The importance of a single floating aid is determined according to other aids to navigation in the area.

To ensure the correct position of floating aids they must be subject to regular surveillance:

- large floating aids can be fitted with instruments for continual monitoring of their position based on telemetry links, Decca etc.

- in VTS-zones the monitoring is best accomplished by radar

- depending on traffic density and importance of the floating aid, the position is checked weekly, monthly, yearly or after storms. The check can be carried out by service personnel, pilots or reports from mariners.

A floating aid to navigation, which is out of position, adrift or during the night is unlighted, may itself become a danger to navigation.

When a floating aid is out of position malfunctioning, navigational warnings must be given. A prepared plan for failure response time is an advantage.

POSITIONING OF FLOATING AIDS TO NAVIGATION

The positioning of floating aids to navigation requires a higher degree of accuracy than general navigation. As the buoy laying vessel has more time and may not be moving, it has the ability to make a more accurate fix. The general principle is to use the best system available.

The most common method is by several cross bearings and/or horizontal sextant angles using fixed visual marks, natural or man made. Complex calculations can be avoided by using a calculator. High accuracy radio position fixing systems may also be used close to land. Radar can also be used if good radar targets are available but it is not as accurate.

For floating aids out of sight of land only radio position fixing systems will be available.

The crew of the buoy tender should submit a report detailing the systems used to ensure that the best system or systems have been utilised.

POSITIONAL ACCURACY

The charted position of a floating aid is the sinker or anchor position. As the aid is moored its visible part is generally not exactly at the charted position but within a so called Watch Circle which in fact is usually an ellipse. The radius of a watch circle depends on the water depth, the length and the scope of the mooring line and the influences of wind and current.

In confined waters some lighthouse authorities chart the coordinates for buoys on the channel edge. The buoys are, however, laid inside clear swept waters. The distance to the channel edge depending on buoy type.

Sometimes the visible part of a floating aid has the same or nearly the same position as the sinker in the case where it is moored to a heavy sinker with a very short mooring line or is attached to the sinker itself.

The position of a sinker, however, is not always accurate due to the following:

a. The extent to which a lighthouse service navigator is able to determine his position in a given area:

- if a radio navigation system is used, the limitations and the accuracy of that system;
- if marks and visual object are used, the visibility conditions and/or the availability of these marks and objects;
- the skill of the navigator who determines the position of the aid.

b. The accuracy to which a sinker or anchor can be positioned because of:

- possible sideways movements of the sinker or anchor during positioning due to the current, the nature of the sea bed, etc.;
- the horizontal difference in distance between the chain stopper and the receiver antenna of a radio aid or the position of the navigator or operator;
- the skill of the operator or crew;

c. A possible instability of the sinker position:

- Experience shows that sinker may move from its original position before it settles, particularly in bad weather. Such movement may also be caused by the slope of the sea bed.

The need for an accurate position of a floating aid also depends upon the purpose of the aid to navigation. In some cases a better accuracy of position is required than in others depending upon navigational and other requirements.

1. LIGHTHOUSES INCLUDING LIGHT PLATFORMS AND STRUCTURES

DESCRIPTION

A Lighthouse is a conspicuous structure on land, close to the shore line or in the water. By day it may be identified by its shape, colour and daymark. Most light platforms and structures exhibit a name and/or a number. Generally, it is provided with a powerful light. In addition it may be provided with a racon, radio beacon, sound signal and/or one or more sector lights.

They can be manned or unmanned. When manned the crew may also be involved with coastwatching tasks due to their isolated location.

PURPOSES

A lighthouse may be used:

- To indicate dangerous shoals, sandbanks, rocks, etc.;
- To obtain a LOP
- To indicate landfalls, headlands, entrances to estuaries/ports, etc.;

It may also have ancillary tasks, such as:

- look-out point for coastwatching or coastguard and as a co-ordination point for SAR activities;
- signal station;
- part of a VTS.

PERFORMANCE CRITERIA

- Generally, a lighthouse can be detected at a range of 10 n.miles or more depending on visibility conditions, its conspicuousness, light intensity and its height above sea level.
- The availability of a lighthouse is generally better than 99.8%.
- The light character should differ from other lighthouses in the vicinity.

2. LEADING (RANGE) LINES

DESCRIPTION

A leading line allows a vessel to be guided with precision along a straight route. It comprises at least two structures which may each carry a light. They are so placed that when observed to be in line, a ship can follow a known bearing with safety.

If unlighted, the leading line can only be used by day. If lighted, or fitted with retro reflecting material the leading line can also be used by night. Leading lights can be used by day if the light intensities are adaptable for night and daytime use. If only lights are used, the structures need not have daymarks.

Natural features and objects other than aids to navigation can be used as leading lines, such features may be charted.

In some countries racon leading lines are in operation.

PURPOSES

A leading line may among other things have the following purposes:

- To indicate the navigable channel where it is not evident.
- To indicate to deep draught vessels the deepest part of the waterway;
- To indicate the navigable channel where fixed and floating aids to navigation are not available or do not satisfy accurate navigation (e.g. in waterways where due to ice conditions the aid may be drifting or destroyed);
- To provide a safe approach to a harbour or river entrance, particularly where there are cross currents,
- To separate two way traffic.

PERFORMANCE CRITERIA

Good leading lines are such that:

- The navigator can see them far enough from the danger to enable the axis to be followed to be safely reached

- A navigator can detect very quickly a tendency to move from the axis and the extent and direction of this tendency.

This enables efficient steering resulting in stability of course and speed.

This stability is particularly valuable in narrow channels where the underkeel clearance is small. In this case unexpected movements may result in a speed less than that required to maintain a safe manoeuvrability of the ship.

The requirements for accuracy and sensitivity of a leading line depends upon the needs of the user and local conditions.

The performance of leading lights should be in accordance with the following IALA Recommendations:

- Recommendation for Leading Lights, May 1977

- Recommendation for a definition of Nominal Daytime Range of Maritime Signal Lights intended for Guidance of Shipping by Day, April 1974.

TECHINICAL CONSIDERATIONS

- Rhythmic leading lights may be synchronised in such a way that they can always be observed together.

- Lighthouse Authorities must ensure that the lower or the front light does not have too high an elevation. Smaller vessels may be misled because the lower light may appear as the higher light;

- if lights are to be used by night and by day, the light intensities should be adapted for day and night use in order to avoid glare by night.

OTEHR FORMS OF LEAD

A direction light can be used when the establishment of leading lights is not possible. A direction light is considered to be a more specialised type of a sector light, and a further description is given in the section "Sector Lights", "Direction Lights"

A special kind of leading line can be established with a single lighted panel using the optical effect of the moiré pattern. This is created by light passing through superimposed closely spaced gratings. Small relative movements create large changes in the pattern on the moiré screen. The leading mark can be designed so that it shows a vertical black line in the middle of the moiré screen if the observer is on the centre line. Any deviation from this line will cause the moiré to show an arrow pointing towards the centre line.

PURPOSES

A sector light may indicate one or more of the following:

- the boundaries of a navigable waterway;
- change of course position
- shoals, banks etc.
- an area or position (e.g. an anchorage);
- the deepest part of a waterway;
- position checks for floating aids.

DIRECTION LIGHTS

A direction light is visible over a very narrow angle to indicate a direction to be followed. The sector can be bounded by other sectors of different colour (or character) which define its margins with small angles of uncertainty.

Only the case of direction lights with white sector bounded by other sectors is considered here.

A direction light can be used when the establishment of leading (range) lights is not possible.

In a direction light, the angles of uncertainty are practically non-existent. Hence, a mariner enters or leaves a sector abruptly which may result in frequent and possibly dangerous manoeuvres.

Whereas it is possible with leading lights to assess the leeway of a ship, this is not possible with direction light.

Caution is thus required before installing a direction light to mark a narrow strait, more especially when there is a strong cross current.

3. BEACONS

DESCRIPTION

Structural details of beacons may vary greatly depending upon local environmental conditions, traditions, available materials and technology.

A beacon can vary from a complex lattice structure to a simple branch with twigs (withy). The latter being one of the oldest and cheapest marks still in use.

Beacons may be established instead of buoys where operational and engineering considerations make installation of fixed marks desirable and possible.

The signals displayed by a beacon which is performing with the same function as a buoy should, insofar as practicable, duplicate those of an equivalent buoy.

The design of a beacon structure may complicated the display of colour, shape, and topmark features thus:

- colouration of structures may be impractical.

- beacon shape may be determined by structural considerations.

- topmarks may be undersized in relation to large beacon structures.

It may be advantageous to provide a beacon with colour, shape, and topmark features by means of large panels (or "dayboards") which display all three features.

Where such panels are installed, the colour and shape of the structure itself become insignificant, and separate tomparks become unnecessary. Structure colours should not conflict with the colour of the mark.

The large size of such panels, and the desirability of partially obscuring structures of nonspecific shape and colour, may indicate that panels be installed near, but not above the top of the structure.

For more details reference can be made to the IALA Maritime Buoyage System Guidelines.

PURPOSES

A beacon may:

- mark a landfall position,
- be a part of a leading (range) line
- mark an obstruction or a danger in or near a channel,
- indicate the lateral limits of a channel or navigable waterway,
- indicate an area.
- indicate a turning point or a junction of the waterway.

4. LIGHTVESSELS, LIGHT FLOATS AND LANBYS (LNBS)

DESCRIPTION

Large floating aids to navigation such as lightvessels, light floats and lanbys are comparable in performance and importance to a lighthouse and are generally placed in a position where the establishment of a fixed structure is impracticable and/or uneconomic.

These large aids are sometimes manned, but the trend is towards making them automatic, often with remote control. These aids are outside the scope of the IALA Maritime Buoyage System (IMBS), and there availability is general higher than that of the other aids within the system.

A light vessel, light float or lanby carries a light with a high luminous intensity and in addition it may be provided with a racon, sound signal and/or radio beacon.

It should be borne in mind that it is anchored to a very long chain, and as a result, the watch circle is large. Its approximate position, however, can be expected to be reliable.

IALA has published a recommendation on Light Vessels, Light Floats and Lanbys not in position. The following is an extract from that recommendation:

"When any Light Vessel, Light Float or Lanby (LNB) manned or unmanned is out of position such that it could be misleading to navigation, all its aids to navigation (Lights, Sound Signals, Racon, Radio Beacon) should be discontinued.

To avoid the risk of collision with passing vessels, waning lights should be continuously displayed as follows:

Two all round red lights in a vertical line similar to those prescribed by Rule 27 of the COLREGS for a vessel "Not under command".

If the appropriate Administration requires a sound signal to be operated, it should be coded MORSE "D" as prescribed by Rule 35 of the COLREGS for a vessel "Not under command".

If the appropriate Administration requires a Racon to be deployed, it shall be coded MORSE "D".

PURPOSES

A lightvessel, light float or lanby may have one or more of the following purposes:

- to mark dangerous shoals, banks, rocks, etc.;
- to mark a landfall position or the entrance of a TSS;
- to indicate a turning point in a precautionary area;

PERFORMANCE CRITERIA

- The floatation body should have good stability:
- The signal light must have a substantial range;
- if equipped with a racon it should preferably transmit in both X and S bands;
- a sound signal is normally required only in a hazard warning role;
- the float should be painted in distinctive colours and display its identification clearly;
- in case of a failure mariners should be warned immediately.
- if unmanned, its position and performance should be monitored regularly;
- the availability is high. 99.0% or more because, if manned, it is checked by the crew or, if unmanned, it is usually remotely controlled.

5. BUOYS, SPARS AND OTHER SMALL FLOATING AIDS TO NAVIGATION

DESCRIPTION

A buoy, spar or other small floating marks used for navigation can be designed in many forms. Its dimensions depend on local condtinons such as water depth, wind, sea and current conditions and its purpose. It can be lighted or unlighted.

Care must be taken in the positioning of unlighted aids in areas where night navigation takes place.

Usually a floating aid carries identification either a name or a number.

The applicaiton of new energy systmes such as photovoltaic systems may distort the shape and colour of a floating aid.

Identification of an unlighted aid by night can be enhacned by the use of retro reflective material.

The position of a floaitng aid can be unreliable due to external conditions (bad weather, ice, etc.); it may be off station or adrift.

For more details reference can be made to the **IALA MBS Guidelines.**

PURPOSES

A floating aid to navigation can be used for marking, among other things:

- a lateral limit of a channel or waterway;
- a navigational danger or hazard;
- an obstruction which can be dangerous to certain categories of navigation;
- a landfall position;
- a mid channel position;
- a special area or feature;
- a submerged ODAS;

- a turning point;
- traffic separation;
- bifurcation.

6. VESSEL TRAFFIC SERVICES (VTS)

Vessel Traffic Services (VTS) share the basic aims of other aids to navigation, namely:

- to enhance the safe and expedient flow of traffic and,
- to protect the public and the safety of the environment.

Introducing a VTS should be considered in those cases where the application of other measures in the field of eg. buoyage or traffic separation have been proved or are suspected to be insufficient to obtain the required level of traffic safety.

The type of services rendered and the level at which these services are provided, should be determined after careful analysis of the local situation and current practices. The opinion of the users should be taken into consideration.

An authority planning a VTS is recommended to follow the Guidelines for VTS as laid down in the IMO Resolution A578 (14) 20 November 1985.

Services provided may range from the provision of simple information to extensive management of traffic within a port or waterway.

Interaction with the traffic and direct response to that traffic may be regarded as an essential part of a VTS.

The basic functions of a VTS, as laid down in the above mentioned IMO Guidelines, are:

- **DATA COLLECTION** on fairway, traffic, movements, ships reports, operational status of aids to navigation and general conditions;
- **DATA EVALUATION** monitoring, interpreting, coordinating and collating;
- **INFORMATION SERVICE** either by general broadcast to shipping in general, or in exchange with vessels;
- **NAVIGATIONAL ASSISSTANCE SERVICE** if requested by the vessel or deemed necessary by the VTS centre; to assist vessels in current difficult navigation circumstances.

- **TREAFFIC ORGANIZATION SERVICE** Forward planning of movements to prevent the development of dangerous situations and to provide for the safe and efficient movement of traffic in the VTS area.

- **SUPPORT OF ALLIED ACTIVITIES** such as pilotage; pollution control, port services and SAR actions.

The authority operating a VTS determines which functions will be performed by the VTS and to what level.

The equipment used may vary from VTS to VTS but the guidelines recommend;

- communication facilities such as VHF radio equipped to use the appropriate frequences including the international distress, safety and calling frequences;

- where appropriate to the task performed a surveillance radar and other equipment;

The merits of VHF direction finding and an appropriate data management system for identification is stressed. A database should be maintained to avoid repetitive information messages.

Navigational aids and aids to navigation play an important role in the safe and expedient flow of traffic in VTS. Where movement within a VTS area is taking place according to an agreed sailing plan, the vessel must have the ability to determine its position at all times and under all circumstances in order to monitor progress and adhere to the sailing plan.

Participation in a VTS may be mandatory for certain categories of ships and voluntary for others. Particulars of VTS should be promulgated appropriately. Insertion into a World VTS Guide is recommended by IALA, IAPH, IMPA and IFSMA.

7. RADIO AIDS TO NAVIGATION
GLOBAL POSITIONING SYSTEM(GPS)

GENERAL

The Global Positioning System (GPS) is a space-based, radio positioning, navigation and time-transfer system having three major segments: space, control and user. The GPS space segment, when fully operational, will be composed of 21 satellites, plus three operational spares in six orbital planes. The satellites will operate in circular 20,200km orbits at an inclination angle of 55° and with a 12-hour period. The spacing of satellites in orbit will be precisely arranged so that a mininum of four satellites will be in view to any user, thereby ensuring world-wide coverage. Each satellite will transmit L1 and L2 signals. L1 will carry a precise (P) signal and a coarse/acquisition (C/A) signal. L2 will carry a P signal only. Superimposed on these signals will be navigation and atmospheric-propagation correction data, and satellite clock-bias information.

The control segment will include a number of monitor stations and ground antennas located throughout the world. The monitor stations will GPS receivers to track passively all satellites in view, and thereby accumulate ranging data from the satellite signals. The information from the monitor stations will be processed at the master control station (MCS) to determine the satellite orbits, and to update the navigation message of each satellite. The updated information will be transmitted to the satellites via the ground antennas, which will also be used for transmitting and receiving satellite control information.

The user segment will consist of antennas and receiverprocessors that will provide positioning and navigation data to the user.

PURPOSE

GPS is a position-fixing system which will be used for general navigation on land, sea and air. It will also have survey and timing applications.

SIGNAL CHARACTERISTICS

The GPS concept depends upon having accurate and continuous knowledge of the spatial position of any satellite in the system, in terms of the time and distance of the satellite from the user. Each satellite transmits

its own ephemeris data. This data is periodically updated by the control station, and is based upon information obtained from five widely dispersed monitor stations.

The GPS receiver automatically selects appropriate signals from three or four of the satellites that give the best view as based on the optimum satellite-to-user geometry. In then solves time-of-arrival difference quantities to obtain the distances between the user and the satellites. This information establishes the user's position with respect to the satellite system. A timecorrection factor then relates the satellite system to earth co-ordinates. Each satellite continuously transmits a composite spread-spectrum signal at 1227.6 (L2) and 1575.42 (L1) MHz that contains a precise navigational signal, a coarse navigational signal, satellite ephemeris data, atmospheric-propagation correction data and clock-bias information. The user equipment measures four independent pseudo-ranges and range rates, and translates these to a three-dimensional position, a velocity and a system time.

ACCURACY

Reference System. The geodetic reference system selected for use by the Global Positioning System (GPS) is the World Geodetic System (WGS) . The GPS currently uses the 1984 version, which is designated as WGS 84. Datum transformation will permit coordinates to be transformed between WGS 84 and most of the major and local datums is the world.

The GPS provides two services for position determination.

The Precise Positioning Service (PPS) will provide predictable positioning accuracy of 17.8m (2 dRMS) horizontally and 27.7m (2 sigma) vertically, velocity accuracy of 0.2m/sec (2 sigma) in each of the three dimensions, and timing accuracy. The PPS will be limited to the US and allied military and federal government users. Limited civil use may be authorised to those who can demonstrate a need for the accuracy that cannot be obtained by other means, is in the US national interest at can satisfy US national security requirements.
The Standard Positioning Service (SPS) will provide a lower level of accuracy than the PPS. The SPS will be made available to civil, commercial and other users at the highest level of accuracy that is consistent with national interests of the USA. The current policy of the American Department of Defense (DOD) is to provide the SPS at an accuracy of 100 m (2 dRMS).

COVERAGE

The GPS will provide world-wide three dimensional coverage.

INTEGRITY

In accordance with the DOD GPS concept, GPS satellites are monitored more than 95 percent of the time by a network of five monitoring stations around the world. The information collected by the monitoring stations is processed by the Master Control Station at Colorado Springs, Colorado, USA and used to update periodically the navigation message (including a health message) transmitted by each satellite. The satellite health message, which is not changed between satellite navigation-message updates, is transmitted as part of the GPS navigation message for reception by both PPS and SPS users. Additionally, satellite operating parameters such as navigation data errors, signal availability, anti-spoof failures, and certain types of satellite clock failures are monitored within the satellite. If such internal failures are detected, users are notified within six seconds. Other failures detectable only by the coutrol segment may take 15 minutes or longer to rectify.

The DOD GPS user equipment can utilise the information contained in the navigation and health messages, as well as self-contained satellite geometry algorithms and internal navigation solution-convergence monitors, to compute a figure of merit. This number will indicate the estimated overall confidence level of the position information.

The GPS will provide availability approaching 100 per cent, to be refined based on orbital experience. This depends. This depends upon a 21 satellite constellation plus three orbital spares, with four satellites in view above a five degree masking angle.

Operational reliability figures for the GPS satellites will be obtained when they have been launched. However, a GPS staellite has a design life of 7.5 years. With the planned replenishment strategy, a constellation of 21 satellites, plus three orbital spares, will provide a 98 per cent probability of having 21 more satellites operational at any time.

FIX RATE

The fix rate is essentially continuous. The actual time to a first fix depends on the user's equipment capability and initialization with satellite almanac data.

FIX DIMENSIONS

A three-dimensional fix can be obtained, as well as velocity and an extremely accurate time signal.

CAPACITY

The capacity is unlimited.

AMBIGUITY

The GPS has no ambiguity.

USER COMMUNITY

Widespread national and international civil use of the GPS Standard Positioning Service (SPS) is anticipated. Because of US national security considerations the GPS Precise Positioning Service will be restricted to US Armed Forces, US Federal Agencies, and selected allied Armed Forces and governments. While GPS/PPS has been designed primarily for military radionavigation needs, it will nevertheless be made available on a very selective basis to US and foreign private sector (nongovernmental) civil organizations. Access determinations will be made by the US Government on a case by case evaluation that:

1) Access is in the US national interest.

2) There are no other means reasonably available to the civil user to obtain a capability equivalent to that provided by GPS/PPS.

3) Security requirements can be met.

The US Government is currently developing policy for submitting applications, granting approval for user access, and establishing operational procedures and compliance requirements for accessing data from GPS/PPS. This guidance will be established in detail prior to GPS/PPS being made available to the private sector civil community.

The US DOD has requested that the US DOT establish an interface office for civil GPS users. The DOT has proposed the establishment of the civil GPS Service (CGS) in response. The CGS would consist of the Civil GPS Information Center (CGIC) and Civil PPS Office (CPO) .

The CGIC would provide information to, and be point of contact for, civil users of the GPS system. The CPO would disseminate GPS/PPS service to qualified civil users.

Establishment of the CGS depends on execution of necessary agreements between the US DOD and DOT, and agreements between the latter and other interested civil government agencies.

FUTURE DEVELOPMENT

The GPS constellation and control segments are scheduled to be fully operational in 1994. Initially, GPS will be integrated into military aircraft which are equipped for instrument flight and contain inertial navigation systems or other forms suitable for attitude heading reference systems. These aircraft will be flight tested to ensure that they meet established standards for operation in the US national airspace. Prior to 1992, there is expected to be significant civil use of the system (at the user's risk) to obtain accurate three-dimensional positioning, velocity and time, for geodetic surveying, land and sea navigation, and many other applications. Initial civil aircraft use will probably be as a supplementary system for en route domestic and foreign operations.

For GPS to become a sole means civil aviation radionavigation system (for oceanic en route, US domestic en route, terminal and non-precision approaches) it must provide at least five satellites in view above mask angle of ten degrees in which all combinations of four out of five satellites have 100m 2 dRMS accuracy or better. At least five satellites are required so that if one fails, unaided GPS navigation may continue. The current US civil aviation requirement for non-precision approaches is that the navigation system provide a warning to the pilot or removal of the signal from service within ten seconds after the signal has gone out of tolerance.

8. DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS)

GENERAL

In the differential Global Positioning System (DGPS), a local reference station will use an all-in-view GPS receiver to make continuous measurements of the distances to all the satellites in view. The station will be at a surveyed location and can therefore calculate the range errors associated with the satellites. The errors, or differential corrections, can be communicated by a suitable link to local GPS receivers, where they can be used to modify the calculations made in the receivers. The system is still under development, but it is expected to provide a much better accuracy than the 100 m (2 dRMS) given by the Standard Positioning Service of the GPS. Radiobeacons may be found to be a suitable means of communicating the differential corrections to GPS receivers.

PURPOSE

Differential GPS is a precise positioning system with potential applications in surveying, dredging, pipe and cable-laying, buoy positioning and certain types of fishing.

ACCURACY

The accuracy for navigation should be better than 15 m, and for positioning better than 10 m (2 dRMS).

COVERAGE

The area over which a DGPS reference station's corrections can be used is a circle of radius up to 200 M. The coverage of a correction transmitting station depends on its power and its frequencies.

9. TRANSIT (NNSS)

GENERAL

TRANSIT is a space-based radio positioning and navigation system, run by the U.S. Navy, consisting of four or more satellites in approximately 600 M polar orbits. The phasing of the satellites is deliberately staggered to minimize time between fixes for users. In addition, TRANSIT has four ground-based monitors. The monitor stations track each satellite while in view and provide the tracking information necessary to update satellite orbital parameters every 12 hours. Tsikada is a similar system established by the former U.S.S.R.

PURPOSE

TRANSIT is a general navigation system for marine users principally in the ocean phase.

ACCURACY

Predictable positioning accuracy for a single fequency receiver is 500 metres (2 dRMS), for a dual frequency receiver it is 25 metres (2 dRMS). Repeatable positioning accuracy in 50 metres (2 dRMS) for single frequency and 15 metres for a dual frequency receiver. Relative positioning accuracy of less than 10 metres (2 dRMS) has been measured through translocation techniques. Navigational accuracy is heavily dependent upon the accuracy with which vessel course, speed, and time are known. A one knot velocity input error can cause up to 0.2 M fix error.

COVERAGE

Coverage is worldwide but not continuous due to the relatively low altitude of the TRANSIT satellites and the precession of satellite orbits.

10. LORAN-C

GENERAL

Loran-C is an all-weather, highly accurate and reliable radionavigation system. Originally established in the 1960's to meet U.S. Department of Defense (DOD) requirements, Loran-C is widely available in the Northern Hemisphere to all using a commercially available receiver. US-operated Loran-C provides an extensive international radionavigation service. There are fourteen Loran-C chains managed by the US Coast Guard world-wide. Each of these chains is made up of three to five transmitter stations, one control station and one or two monitors. They are operated by the US Coast Guard either directly or through national agencies in countries hosting the Loran-C stations. Other chains have been established, and are operated by Saudi-Arabia, Egypt and France. The Soviet Union operates a similar radionavigation system called Chayka.

PURPOSE

Loran-C is a general navigation system for air, land and sea users. In addition to its position fixing capability it can be used for timing purposes.

SIGNAL CHARACTERISTICS

Loran-C is a hyperbolic system operating in the 90-110 kHz frequency band. Each station of a chain is separated by several hundred miles with each transmitting a series of eight precisely timed RF pulses.

Chain differentiation is provided by Group Repetition Interval (GRI). Selection of specific GRI may be coordinated with the US Coast Guard to a avoid interference.

The system is based on the measurement of the differences in the time of arrival of signals form the stations in a chain. the measurements of the Time Difference (TD) are made in a receiver which achieves high accuracy by comparing a specified cycle zero-crossing within the transmitted pulses of the master and secondary stations of a chain. The comparison is made at the 30 us zero crossing to avoid sky-wave interference. Additionally, the phase of the pulses is alternated in a predetermined pattern over two groups of eight pulses to limit the effects of long delayed sky waves. Precise control over the pulse shape ensures the proper comparison at the 30 us zero-crossing.

ACCURACY

Within the defined coverage area, Loran-C provides the user using an adequate receiver with a predictable accuracy of 0.25 m (2 dRMS) or better. The repeatable and relative accuracies range between 18 and 90 m. Accuracy is dependent upon the Geometric Dilution of Precision (GDOP) at the user's location, the measurement error (signal-to-noise ratio) and chart or local area calibration. The Loran-C ground wave is primarily used for navigation; precise time measurement and time interval dissemination are also derived from the Loran-C signal.

Sky-wave navigation is feasible, but with a significant loss in accuracy. Like ground waves, sky-wave to some extent may also be used for time dissemination. Loran-C was originally designed to be primarily a hyperbolic navigation system. However, with the advent of the highly stable frequency standards, Loran-C can also be used in the range-renge (rho-rho) mode of navigation. This is accomplished by a comparison of the received signal phase with a known time reference to determine propagation time and, therefore, range from the stations. It can be used in situations where the user is within reception range of individual stations, but beyond the hyperbolic coverage area. The rho-rho method using Loran-C requires that the user has a very precise and stable time reference. The high cost of equipment limits the use of this mode.

The accuracy of the Loran-C system makes it a suitable candidate for many land radiolocation applications. Loran-C can be received in mountainous areas where VHF and UHF systems are terrain limited. Some distortion of the hyperbolic grid is to be expected since the 100 kHz signal's time of arrival and strength are affected by the soil conductivity and terrain. Propagation anomalies may be encountered in urban areas where the proximity of large man-made structures affect the signal. The existence of these anomalies is predictable and can be compensated for, usually by surveying the area. The long range of the Loran-C system makes it particularly desirable for application to remote areas, or where the user population is too low to justify the cost of a large number of short-range facilities.

COVERAGE

Expansion of the U.S. Loran-C system, to meet the requirement for the U.S. coastal waters of the conterminous 48 United States and southern Alaska was completed in late 1979. Loran-C service also provides overland coverage to about two-thirds of the land area of the conterminous 48 United States and is being expanded to provide complete coverage. Plans are now being executed that will complete coverage over the 48 conterminous states and improve land coverage in southern Alaska. The US and Canada in cooperation operate Loran-C chains that provide coverage to the Canadian West Coast, Canadian East Coast and Labrador Sea. Overseas, U.S.-operated Loran-C coverage is provided in the Norwegian Sea, Labrador Sea, portions of the North Sea, majority of Mediterranean Sea, Bering Sea and northern Pacific in and around Japan. The chains operated by the Soviet Union, Saudi-Arabia, and France provide coverage in the Black Sea, Baltic Sea, Sea of Okhotsk, Sea of Japan, Arabian Gulf and Bay of Biscay (rho-rho). China is constructing a Loran-C chain that will provide coverage into the South China Sea.

INTEGRITY

Loran-C stations are constantly monitored. The accuracy of the system timing between the master and a secondary station is controlled to +/-50 nanoseconds. The first two pulses of the secondary stations are "blinked" (turned on and off) when established timing tolerance for a master-secondary pair is exceeded; for the US coastal confluence zone this tolerance is +/-100 nanoseconds. Blink is initiated within sixty seconds of the occurence of an abnormality. Individual station reliability has exceeded 99.9% with fix availability exceeding 99.7%.

FIX RATE

A continuous fix rate is available from Loran-C from two or more LOP's to provide a two-dimensional fix.

FIX DIMENSIONS

A two-dimensional fix is provided.

CAPACITY

An unlimited number of receivers may use Loran-C simultaneously.

AMBIGUITY

As with all hyperbolic systems, theoretically the LOP's may cross at more than one position on the earth. The ambiguous fix is at a great distance from the desired fix, outside the designed coverage area, and is easily resolved.

USER COMMUNITY

Initially, the major user of Loran-C was the military. Civil marine use was limited due by the high cost of Loran-C receivers and the lack of coverage. Technological advances have rapidly lowered used receiver costs and coastal coverage limitations have been eliminated by system improvements and expansion. As a result, there is presently extensive civil marine use of Loran-C. There has been a tremendous increase in users in the U.S. civil aviation community in recent years.

FUTURE DEVELOPMENT

In the U.S.,Loran-C is expected to continue in operation at least until the year 2005. This estimate is based on the adoption and use of this system by a very large user population. It is anticipated that there will be little future change in the Loran-C coverage provided for the continental U.S. Except for eliminating the mid-continent gap for civil aviation. Some minor changes may be made to improve the system's performance in selected areas.

The overseas chains operated in support of the U.S DOD will be closed or transferred to the host nations when the U.S.DOD requirements are phased out. All current DOD service plans call for phase-out of Loran-C in favour of GPS. Assuming the 21-satellite version of GPS is in operation in 1994, the U.S.DOD has a continuing requirement for existing overseas Loran-C coverage until 1994 at current performance levels.

Possible expansion of coverage in Europe is currently under discussion. Agreement has recently been reached between the U.S. and former U.S.S.R. on interoperability of Loran-C and Chayka stations in the Bering Sea, which will lead to expanded coverage there.

11. RACON

GENERAL

Radar beacons (radar responders, racons) are receiver/transmitter devices operating in the maritime radar frequency bands and intended for improving identification of radar targets. A racon responds by sending a characteristic pulse when triggered by a received radar pulse. The response can appear on the display of the triggering radar thereby providing range, bearing and identification information. The displayed response has a length on the display corresponding to a few M and is often coded as a morse character for identification. The advantage of a racon over a light is that its signal can be received under nearly all circumstances, in particular reduced visibility. There are three different types of racons.

- slow sweep racons where the transmitter frequency slowly changes from the lower band limit to the higher limit. When triggered by a received radar pulse the racon transmits a pulse on its actual frequency. Since the sweep time is typically between 1 and 2 minutes the radar is displaying the response for only a few aerial turns when the racon frequency is within the passband of the radar receiver. The equipment is fairly low cost.

- fast sweep racons vary the transmitter frequency rapidly over the entire band in a few microseconds whereby the radar can display the response every aerial turn. The trace on the radar display appears as a dotted line which also can be coded. The equipment is fairly low cost.

- frequency agile racons respond on the same frequency they are triggered on and hence the response can be seen continuously on the radar screen. The response can be coded and is usually switched off for some time every minute to clear the radar display from the masking effect of the racon trace. The equipment has a higher cost than the previous. Frequency-agile racons can also be made User-selectable. This system of which ITOFAR (Interrogated Time Offset Frequency Agile Racon) is a technical solution involves introducing time delays in the racon response and the radar, thereby allowing the racon response to be removed from the display or shown without the other returns.

From a technical point of view there are major similarities between racons and transponders and in fact in some applications identical equipment can be used for both services only with different coding.

PURPOSE

A racon can be used for one or more of the following purposes:

- ranging of and identification of positions on inconspicuous coastlines
- identification of aids to navigation, both seaborne and land based
- landfall identification
- centre and turning point identification in precautionary areas or TSS
- to mark new and uncharted hazards
- to indicate navigable spans under bridges
- as leading line racons

SIGNAL CHARACTERISTICS

Racons operate in the band 9300-9500 MHz (X-band), with horizontal polarisation, or in the band 2900-3100 MHz (S-band) with horizontal or vertical polarisation. Some racons however, offer combined service in both bands. If racons are installed near or in international shipping routes, it is recommended to install racons for both bands or a combined X/S-band racon. The transmitted signal is a coded or noncoded pulse with a duration of about 25 s. In case the signal is morse coded it should always start with a dash. The morse code 'D' is reserved for new dangers such as wrecks and the racon should operate continuously and on a non-selectable basis.

ACCURACY

Angular accuracy depends entirely on the interrogating radar while distance accuracy is also affected by the racon. The inherent delay in the racon causes the response to appear behind the echo from the structure on which the racon is mounted. This delay is in the order of 0.5 s but can vary for different models of equipment. The stability of this delay affects the accuracy and the racon response should not be used for distance measurements. When used in a leading line application an accuracy of about 0.3 degree can be expected.

COVERAGE

The range of a racon depends on many factors of which the most significant is the height of the racon and the height of the interrogating radar. The power output of the transmitter and the sensitivity of the receiver also contribute. A comprehensive report on racon range has been prepared by IALA (Recommendations for Slow Sweep X-band Racons) but as a typical figure and omnidirectional range of 5 n.mile for a buoy and 15 n.mile for a lighthouse installation can be quoted. The racon aerial is usually omnidirectional but the vertical beam width may depend on the application. It is about 8 degrees for a racon mounted on a fixed structure and about 25 degrees for buoy mounted racon.

INTEGRITY

Racons are usually low power all solid state equipment with very high expected reliability. They do not so far contain any facilities to give alarm or inform the user of corrupted coding or other erroneous function.

FIX RATE

The slow sweep type racon gives a fix for about 5% of the time depending somewhat on radar bandwidth and aerial rotational speed. For fast sweep and frequency agile racons the fix rate also depends on the programming of the transmitter active period.

FIX DIMENSION

A two dimensional fix is provided.

CAPACITY

Since the racon receiver is blocked when the racon is transmitting there is a theoretical possibility that a pulse from a radar will not be responded to. One investigation into frequency agile racons indicates that even with some 300 ships within the racon range only very minor detrimental effects will be observed.

AMBIGUITY

When the radar is very close to it the racon will be triggered by sidelobes from the radar aerial, resulting in multiple responses on the radar display, which besides the ambiguity effect also causes unwanted masking of other targets. Different technical approaches to eliminate side lobe triggering have been made for the different types of racons. The most efficient and also most costly type of side lobe suppression can be done on the frequency agile racon whereas other less expensive solutions applied to all types of racons give unwanted side effects.

USER COMMUNITY

All types of vessels equipped with radar may use racons. 'User selectable service' require modifications to the users radar equipment.

FUTURE DEVELOPMENT

Development will probably be in the area of user selectable services and the racon type which is most suitable for this is the frequency agile type using interrogated time offset (ITOFAR) to provide the extended service. The ITOFAR racon can be controlled from a slightly modified standard marine radar to give on demand Racon Only or Radar Only display. Further development could be data communication between the racon and the interrogating radar in which case the racon would behave more like a transponder.

12. RADAR TRANSPONDERS

GENERAL

Transponders in the maritime radiodetermination service are receiver/transmitter devices which automatically transmit when being interrogated by a characteristic signal. Transmission can also be initiated by a local command. The transmission may include a coded or noncoded identification signal and/or data. Shipborne safety transponders are used with the purpose of reducing collision and other accidents and are proposed for the following applications:

- identification of certain classes of ships
- identification of ships from shore based surveillance as in VTS
- search and rescue operations
- identification of individual ships and data transfer

Transponders and racons are very similar from a technical point of view and in some cases the same equipment can be used for both services, but with different coding.

To reduce or eliminate interference on the transponder response signal it is often offset in frequency or time from normal radar echo (clutter) signal.

At least two transponder systems have been more thoroughly studied and tested, MRIT (Maritime Radar Interrogator-Transponder) from the U.S.A. and SIT (Shipborne Interrogator Transponder) from the former U.S.S.R. Neither of these has come into wide use.

The MRIT transmits a coded burst at a specific frequency either through an omnidirectional aerial or through the normal scanner when interrogating other transponders in the area. Coded responses from these are received through an omnidirectional aerial.

The SIT system utilizes an S-band transceiver integrated into the existing X-band radar. Interrogation is done by a coded pulse burst by the SIT transmitter 12 microseconds ahead of the normal radarpulse and at a different frequency. The SIT operates in both interrogation and response mode.

The complexity of both systems indicates a high cost. High output power is required due to the use of omnidirectional aerials at both ends.

Transponder functions are also proposed on the ITOFAR principle (Interrogated Time Offset Frequency Agile Racon) which is tested in numerous racon applications. Such transponders can provided the required service with a number of advantages, such as lower power level, better utilization of the existing radar system using only a simple add-on equipment, sufficient data transfer capacity and moderate cost.

A transponder for search and rescue purposes intended for use on life-rafts and small boats has been developed in Japan, SART, (Search And Rescue Transponder). The transponder operates in the X-band (9200-9500 MHz) and responds when triggered by a radarpulse within the band. The response pulse has a duration of 100 s and its frequency is swept 20 times over the entire band during the pulse interval. This causes the response to appear on the radar PPI screen as a series of 20 dots with a total length corresponding to 8 m. It is a low power, low cost design and designed to meet operational requirements from the GMDSS (Global Maritime Distress and Safety System).

PURPOSE

Transponders are intended to give an automatic response to an interrogating signal for purposes of identification, for location (SAR) or to transmit or define position of moving objects.

Transponders are not confined to use at radar frequencies but can also be used in other frequency bands. Combinations of radar and VHF frequencies are used in a Norwegian system which is intended for VTS purposes.

SIGNAL CHARACTERISTICS

Shipborne radar transponders operate in the band 2930-2950 MHz, 5470-5480 MHz and 9280-9300 MHz. Exception is the SART which operates over the entire band 9200-9500 MHz. The coding of transponders must be such that confusion with radar beacons is avoided.

ACCURACY

Transponders are not used on fixed marks and therefore should not be used for absolute position fixing.

COVERAGE

Range of coverage depends mainly on the height of the transponder and the height of the interrogating radar.

INTEGRITY

Radar transponders could be equipped with facilities to give an alarm or inform the user of corrupted coding or other incorrect function.

FIX RATE

Not applicable.

FIX DIMENSION

Not applicable.

CAPACITY

Since the transponder receiver is blocked while the transponder is transmitting, there is a possibility that not every pulse from the radar will produce a response.

AMBIGUITY

Ambiguity problems can be overcome by a suitable coding scheme.

USER COMMUNITY

Transponders can be used for SAR and other safety and identification purposes.

FUTURE DEVELOPMENT

Development of radar transponders with characteristic codes for safety purposes is under discussion at international level. There are proposals to use symbols on the radar displays in place of codes. There are close similarities between radar beacons and transponders and a future trend could be to use the same equipment for both services. User-selectable transponders could offer advantages and the ITOFAR principle appears to be the most promising.

Transponders will be an important component in the GMDSS (Global Maritime Distress and Safety System).

13. RADAR REFLECTORS

GENERAL

A radar reflector is a passive device which enhances the echo of a target by increasing its radar cross (also called echoing or backscatter area).

PURPOSE

The main objectives of its use are:

- improved target detection at long ranges (for example landfall navigation)
- improved target detection in areas of sea or rain clutter.
- As a by-product, improved protection of these aids against damage by collisions.

PERFORMANCE CRITERIA

Basically three parameters determine the radar performance of a target equipped with a radar reflector:

- the type of the reflector
- its size
- its height above water level.

For an effective use of a radar reflector, minimum requirements have to be established for all of these parameters.

TYPES OF RADAR REFLECTORS

Two different types of radar reflectors can be applied. One type is the Luneberg lens, the other the corner cluster.

The Luneberg lens is basically a spherical lens made of foam material. On the other hand, the corner cluster is a metallic reflector made of a certain number of corners in different configurations. The well known octahedron is a simple form of a corner cluster.

The vast majority of radar reflectors used in the maritime field are of the cluster type, since this reflectors is more rugged and cheaper than Luneberg lenses.

The radar properties of a radar reflector are determined by its maximum radar cross section (RCS) and its angular coverage.

Since the radar reflector should give a strong return regardless of the target's motion at sea, the required angular coverage in the horizontal and vertical planes is closely related to the floating stability of the target.

REFLECTOR SIZE

The size of the reflector in conjunction with the reflector type determines the RCS which in turn determines the maximum possible range and target visibility in clutter.

Depending on range requirement and prevailing clutter environment the required RCS varies between 10 and 18,000m^2 which results in reflectors sizes of about 0.3 to 1.5 m diameter.

REFLECTOR HEIGHT

The necessary reflector height above sea level is given by the "line of radio sight condition". With lower radar antenna height and increasing range a greater reflector height is required. This is identical to the optical situation.

For a rough estimation of the required reflector height, the formula of the optical range can be used. But it should be kept in mind that larger variations in height and range may occur as a result of the multipath effect.

ACCURACY

The accuracy of position fixing depends entirely on the performance of the interrogating radar.

COVERAGE

The effective range of a radar reflector does not only depend on its own characteristics (RCS, angular coverage, height) but also on the properties, of the interrogating radar (i.e. transmitter power, receiver sensitivity, antenna height).

CAPACITY

As a passive method of echo enhancement no limitation in user capacity.

AMBIGUITY

No ambiguity but problems of masking by clutter can occur if radar reflectors with small RCS are used.

USER COMMUNITY

All vessels carrying marine radar.

Further information about radar reflectors is given in the IALA Maritime Buoyage System Guidelines.