IALA

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MAINTENANCE OF AIDS TO NAVIGATION

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DOCUMENT REVISION

Revisions to this IALA Document are to be noted in the table prior to the issue of a revised document.

Date	Page / Section Revised	Requirement for Revision
December 2005	Entire document	Reformatted to reflect IALA documentation hierarchy
May 2008	Entire document	Reviewed and updated at the IALA Floating Aids (April 2008) Workshop and EEP11. The Painting Guideline (1015) is now withdrawn
December 2009		Title updated Adding sections on maintenance strategy, maintenance methods and condition based maintenance

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1. INTRODUCTION

Maintenance is required to ensure that Aids to Navigation (AtoN) equipment and systems continue to perform at the levels required by mariners to safely navigate the world's waterways. A maintenance system should be adopted to ensure that AtoN assets deliver the desired performance while minimizing Total Ownership Cost. This performance is normally defined as the level of availability required. Depending on the criticality or category of the AtoN, the same AtoN type might require different maintenance approaches to deliver the required availability outcome in a given location.

This guideline provides information to help develop a maintenance strategy. Several annexes are attached to provide detailed information on the activities involved in the maintenance of buoys, moorings, AtoN structures, signal equipment, and power equipment. Other annexes provide examples of maintenance processes and procedures.

2. GUIDING PRINCIPLES FOR MAINTENANCE STRATEGY

The following guiding principles may assist Authorities in developing their overall AtoN maintenance strategy. AtoN service delivery is composed of user requirements, system design, and system maintenance. Although this document is intended to address maintenance, the interrelationship with requirements and design must be taken into consideration. Where the costs of maintaining systems are excessive, it may be appropriate to revisit the original designs and user requirements. AtoN service delivery should be considered an iterative process of requirements, design, and maintenance, with the overall goal of providing a signal to the mariner at an acceptable cost to the Authority.

2.1. MINIMISE THE COST OF OWNERSHIP

AtoN service providers are accountable to their stakeholders for the provision of a reliable AtoN network that meets international standards for a reasonable cost. Maintenance strategies adopted by authorities should be seeking to reduce the total cost of ownership of their AtoN.

Authorities may be able to reduce their costs by:

- Introducing new technologies in AtoN equipment and materials;
- Considering future maintenance requirements during the design phase;
- Selection of suitable equipment for the application and operating environment;
- Extending the intervals between visits for both floating and fixed AtoN;
- Use of electronic AtoN such as AIS to refine the mix of physical and virtual AtoN;
- Optimizing the use of in-house and/or contract provision of maintenance services.

The traditional focus when designing a system of equipment is to reduce the initial cost of acquisition. However, this short-term goal does not take into account the total ownership cost over the life of the system. The total ownership cost includes an entire spectrum of activities, each with their individual associated costs: design and development; procurement and production; maintenance and support; and final disposal. Of all of these factors, a large portion of the total ownership cost is incurred during the maintenance and support phase of a system's life cycle. Therefore, any costs saved in the initial acquisition would be wasted if the resulting system has low reliability or is difficult or expensive to maintain over the long term. On the other hand, increasing reliability and reducing the cost of maintenance can result in significant savings for the organization in terms of the personnel, logistics, equipment, spare parts, and facilities required to fulfil this function.

2.2. DESIGN FOR MAINTENANCE

The majority of maintenance costs are determined by the design of the equipment itself. Maintenance costs are the most significant component of the total ownership cost of the equipment or system. Therefore, it is crucial to account for long-term maintenance and logistics support early on in the design process. The goal should be to reduce the need for maintenance, extend the time interval for required maintenance, enable maintenance upon the evidence of need (condition-based maintenance), facilitate the maintenance task by the servicing personnel, and reduce the 'logistics footprint' required for maintenance and support. All of these factors will contribute to reducing the total ownership cost over the entire life cycle of the equipment or system. To accomplish this, the focus of the design effort should be on ensuring that the attributes of 'reliability,' 'maintainability,' and 'supportability' are key components of the equipment or system. These three factors contribute to AtoN availability.

1 **Reliability** is the degree to which the equipment or system will perform as designed in its operating environment without failure.

2 **Maintainability** is the ease, speed, and accuracy with which equipment can be restored to its required operating condition.

3 **Supportability** is the efficiency of providing the various elements of logistics support (personnel, facilities, processes, tools, parts) to maintain the system throughout its life cycle.

These key attributes should be optimized and 'designed into' the equipment, not dealt with as an afterthought when the equipment is already in service and changes become significantly expensive to implement. It is therefore critical that maintenance and support requirements be developed concurrently with the equipment design, and that personnel in these fields work as a team with the designing engineers during the design and development processes.

2.2.1. RELIABILITY

The AtoN maintenance strategy should aim to increase the reliability of the AtoN. Responding to outages is normally expensive and has the potential to disrupt planned work thereby causing delays in delivering an overall maintenance program.

Tools such as remote monitoring can assist in tracking AtoN performance and is also a useful tool in providing early warning reports to maintainers on potential outages. This early warning offers maintainers an opportunity to respond to the irregular equipment condition in a planned manner prior to it failing e.g. it may be a possible to attend an AtoN that is reporting a problem and repair it prior to total failure as part of a planned maintenance mobilisation.

Designing equipment for increased reliability can add to the initial acquisition cost. However, as noted earlier, this higher initial investment can pay huge dividends from the savings realised in reduced maintenance overhead throughout the life of the system. Fundamental to increasing reliability is to design robust systems capable of withstanding the rigors of the marine environment. This would include such things as:

- Incorporating methods of corrosion control;
- Considering the impact resistance and watertight integrity of key components;
- Utilizing materials for equipment fabrication that are specifically intended for long-term use in a marine environment;
- Optimising designs with least possible number of parts;
- Providing redundancy in the system design.

This could be 'external' redundancy, in which the navigation plan of the area takes into account the possibility of failure of one of the AtoN and ensures that the system of other navigational aids (including AtoN and other navigational aids like aids carried by vessel) is sufficient to provide the appropriate level of service to the mariner.

‘Internal’ redundancy consists of using more than one equipment, which can provide a back-up if one of them fails.

Once the system is designed, the quality of the resulting product must be assured. Clear and concise specifications should be developed, including strict and thorough quality assurance and testing requirements. Suppliers should be chosen who have a track record of successful performance with similar systems and equipment.

A more thorough discussion of reliability can be found in IALA Guideline 1035, Availability and Reliability of Aids to Navigation - Theory and Examples, Edition 2, December 2004.

2.2.2. MAINTAINABILITY

The intent here is to minimize the cost and time required for maintenance through the design of the equipment itself. The following are factors which contribute to maintainability:

- **Access**. Components requiring frequent inspection and maintenance should be visible and accessible to the maintainers;

  Access for corrosion inspection and mitigation should also be provided.

- **Modularity**. Components should be packaged in a way that permits 'removal and replacement' rather than having to carry out on-site repairs;
- **Interoperability**. Components should be compatible with standard interfaces to permit rapid change-out. Designs should ensure that alignment and mating of components is achieved simply;
- **Safety**. Risks to maintenance personnel working on the equipment should be designed out.

An example would be reducing or eliminating the use of hazardous materials in the design (which would also reduce disposal costs). Any further risks should be accounted for and the compilation of a 'Method statement' undertaken, which identifies the risk and gives a practical solution for the reduction of the risk to a practical minimum.

Sophisticated electronics may be used to detect trends which could lead to failure. These can then be used to pre-empt failures, and to improve the overall maintainability of the system. These can be either embedded within the system or be external to the system. Examples include:

- **Diagnostics**. Monitoring/recording devices and software which provide enhanced capability for fault detection, thus reducing the time to repair.

  Emphasis must be on accuracy and thus the eradication of false alarms.

- **Prognostics**. Monitoring/recording devices and software which monitor various components and indicate out-of-range conditions or the probability of imminent failure.
- **Fail Safes**. In the event of a failure, systems can be designed to revert to a safe mode to avoid additional damage or secondary failures.

2.2.3. SUPPORTABILITY

The goal of supportability is to reduce total ownership cost by increasing readiness, managing the logistics footprint, reducing the dependence on spares, and requiring fewer support personnel. Design considerations in this regard include the following:

- **Minimization**. The overall number of parts in a design, as well as the number of different parts, should be kept to a minimum;

  When possible, the design should enable the same type of part to have multiple uses. Every part has a cost. By minimizing the number of parts, the overall cost of the product and especially the cost to support the system is reduced.

- Commonality. The use of common parts is preferred over more intricate or complex parts that are harder and more expensive to manufacture;

  Common parts potentially could be produced by a large number of suppliers, and costs could be reduced through economies of scale.

- Standardization. Equipment designs should be standardized to permit common maintenance procedures throughout the inventory;

  Repairs should be designed to be accomplished using standard parts and tools. Support equipment, such as test, measurement, and diagnostic equipment, should consist of standard designs that can be used for a broad range of applications. Technical documentation and training materials should be in a consistent and standardized format.

- Configuration management. This is a process for maintaining the consistency of an item's functional and physical attributes throughout the life of the system, which thereby ensures the standardization of inventory and maintenance.

  The configuration management process involves identifying, documenting, verifying, and recording these characteristics, and then controlling any changes to the item and its associated documentation. Configuration management is a standard industry practice, and considerable information about it is available from many public sources, including the Internet.

2.3. MINIMISE IMPACT ON THE ENVIRONMENT

Legislative obligations and community expectations require AtoN authorities to ensure that their activities do not have an adverse impact on the environment. Cleaning up after pollution incidents and the associated rehabilitation of the environment can be costly.

Authorities can reduce their impact on the environment through:

- Extending the intervals between site visits;
- Planning activities and site visits to take into account the breeding seasons of birds and animals;
- Reduction in the use and storage of hazardous materials;
- Increased use of environmental friendly products and materials;
- Reduction in the reliance on air and sea heavy lift operations;
- Disposal/recycling of materials during the entire lifecycle should be considered in the design/upgrade process of AtoN hardware and systems.

Additional information on this topic is available in IALA Guideline 1036, On Environmental Considerations in AtoN Engineering. In addition, the ISO 14001 standard details the requirements for Environmental Management Systems.

2.4. COMPLY WITH LEGISLATION AND INTERNATIONAL STANDARDS

AtoN authorities are required to ensure that AtoN maintenance is carried out in compliance with their local legislation. AtoN services should also be delivered in accordance with international standards and best practice to ensure that a seamless worldwide network of AtoN is provided for mariners.

IMO SOLAS requires contracting governments to provide suitable aids to navigation according to the volume of traffic and degree of risk. The IALA categorisation of AtoN is also based on importance to the mariner as a function of the associated risk.

In order to comply with relevant legislation, Authorities may need to include the following in their maintenance strategy:

- Environmental considerations e.g. operating in remote areas or sensitive marine parks may require additional operating procedures to be implemented;
- Safety considerations e.g. operating from small craft or working at heights may require additional training and safety procedures to be implemented;
- Heritage AtoN and their supporting structures may require increased levels of maintenance and monitoring to be carried out;
- AtoN with a higher IALA category or importance may require a more intensive maintenance regime to ensure that the required level of performance is achieved;
- Relevant standards should be referenced in the design phase of new AtoN to ensure that new AtoN comply with the most recent standards.

2.5. CONSIDER HEALTH AND SAFETY OF WORKERS AND PUBLIC

Authorities should be aware that many of the activities described in this document have applicable worker health and safety requirements. These requirements vary from region to region, and Authorities should comply with the specific requirements in their area. The health and safety of workers and the public is of paramount importance. Maintenance strategies should include training and awareness programs to ensure that all staff are adequately trained in the activities and tasks that they are required to carry out.

Injuries to staff and public can have significant effects on staff moral and the Authority's reputation. There is also a cost associated with rehabilitation and return to work programs and additional temporary staff required to cover injured personnel. It is essential that the design of equipment and systems take into consideration the subsequent safe maintenance of these systems. If any maintenance activities present an elevated risk to personnel, equipment redesigns or procedural controls should be implemented to minimize the risk.

2.6. ASSESS AND IMPROVE PERFORMANCE

A continuous assessment of reliability, maintainability, and supportability should be undertaken to permit the ongoing improvement of equipment design and maintenance procedures. Consistent feedback on equipment performance from the maintenance personnel is fundamental to this process. Keeping track of maintenance is absolutely necessary to measure and thus improve the efficiency of a system.

2.6.1. MAINTENANCE RECORDS

- allow a better analysis of the system and help to make improvements to the design and the system policy;
- enable informed diagnostic work on the specific equipment and type.

Systems should be implemented that monitor and record maintenance activities to ensure that maintenance work is carried out such that it delivers repeatable high quality outcomes.

Many Authorities and external service providers currently have systems in place or are putting systems in place that comply with the requirements in ISO 9001 for Quality Management Systems.

These management systems call for the necessary policy and procedures to be put in place to ensure that:

- Systems are documented;
- Necessary training programs are in place;
- Changes are controlled and monitored;
- Equipment and material selection is controlled;
- Processes are audited;
- Deficiencies can be identified, reported and corrected;

- Improvements can be realized.

Detailed recording of maintenance activities and the condition of AtoN equipment will allow Authorities to monitor and analyse equipment performance over time. Analysis of this data may lead to improvements being identified and implemented resulting in improved overall equipment/system performance.

3. MAINTENANCE PHILOSOPHIES

Breakdowns to AtoN systems can have a significant impact on the cost of service provision. Thus, maintenance of systems to ensure continuing performance is critical. There are two main ways to carry out maintenance: corrective maintenance and preventive maintenance. Corrective Maintenance restores the functions of an item after failure has occurred, or performance fails to meet stated limits. Preventive maintenance may be carried out at planned intervals (Planned Maintenance) or according to condition-based criteria (Condition-Based Maintenance) to reduce the probability of failure or degradation in order to retain the functioning of an item or to detect a hidden fault. Corrective Maintenance (CM), Planned Maintenance (PM), and Condition-Based Maintenance (CBM) will be discussed below. At the end of this Section is a flowchart which can help decision makers identify the appropriate methodology (or mix of methodologies) appropriate to their particular equipment and system environments.

3.1. CORRECTIVE MAINTENANCE (CM)

The rapid repair of failed equipment is critical to business success, and the process of addressing equipment breakdowns after occurrence is known as Corrective Maintenance (CM) CM can be defined as the maintenance which is required when an item has failed or has worn out in order to bring it back to working order. CM is probably the most commonly used approach in wider industry, but it is easy to see its limitations. When equipment fails, it often leads to reduce availability. Also, if the equipment needs to be replaced, the cost of replacing it can be substantial. It is also important to consider health, safety and environmental issues related to malfunctioning equipment. Some failures are acceptable if the consequences of failure (such as availability loss, safety, environmental impact, failure cost) are tolerable compared to the cost of preventive maintenance. This results in a planned 'run to failure' approach to maintenance. However, in other cases, the implications of equipment breakdown can be far-reaching. For instance, labour and transport costs can be significant and the risk of vessel accidents can increase from a failed AtoN.

3.2. PLANNED MAINTENANCE (PM)

With PM equipment is routinely inspected and serviced in an effort to prevent breakdowns from occurring. PM is performed at pre-determined fixed intervals (based on calendar time, operating hours, number of cycles), and consists of regular refurbishment or replacement of an item or its components. The goal is to avoid failure before it occurs. As you cannot possibly maintain your equipment constantly you will need to decide the appropriate maintenance intervals. This is often determined by risk analysis, manufacturer's recommendations, or records of performance of similar equipment in similar environments. The term 'Intelligence-Based Maintenance' is used to describe planned maintenance in which site-specific conditions and historical equipment performance are taken into account to adjust inspection intervals. Intelligence-Based Maintenance requires the collection of historical maintenance data and trend analysis for effective implementation.

3.3. CONDITION-BASED MAINTENANCE (CBM)

CBM is making maintenance decisions on the evidence of need, based on actual equipment condition, rather than time or usage interval. Ideally, condition-based maintenance will allow the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and time spent on maintenance. CBM is based on the correct interpretation of real-time data (or data collected at appropriate intervals) to prioritize and optimize maintenance resources. Observing the state of the system is known as condition monitoring. Such a system will determine the equipment's health, and act only when maintenance is actually necessary. Developments in recent years have allowed for the instrumentation of equipment, and together with better tools for analysing condition data, allow maintenance personnel to make informed decisions about the correct time to perform maintenance on a given piece of equipment. Visual inspections and physical measurements are also important tools for the implementation of effective CBM.

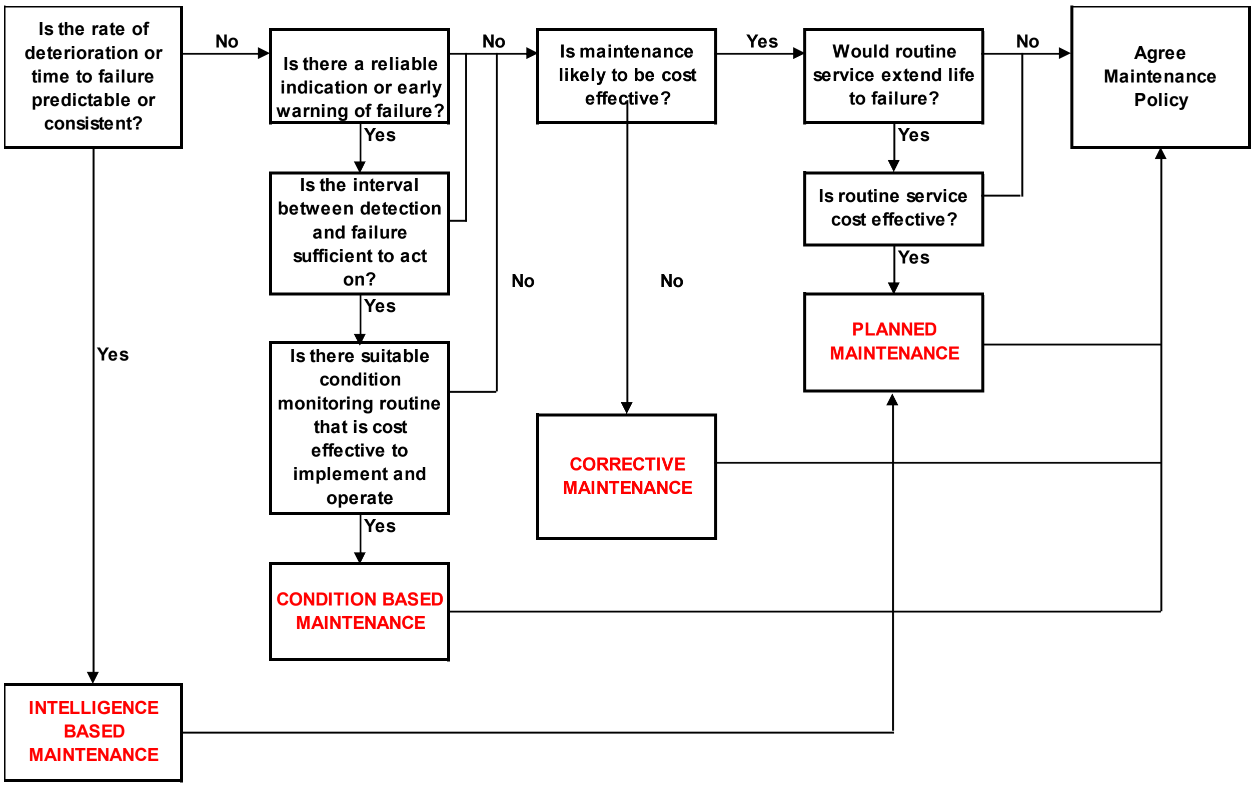

Figure 1 Maintenance decision diagram

4. ACRONYMS

AIS	Automatic Identification System
AtoN	Aid(s) to Navigation
CBM	Condition-Based Maintenance
CM	Corrective Maintenance
DGPS	Differential Global Positioning System
GRP	Glass-Reinforced Plastic
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
ISO	International Organization for Standardisation
LED	Light Emitting Diode
PLC	Public Limited Company
PM	Planned Maintenance
PPM	Planned Preventative Maintenance
SOLAS	International Convention for the Safety of Life at Sea
TH	Trinity House
UV	Ultraviolet

ANNEX A MAINTENANCE OF BUOYS

A 1. STEEL BUOYS

A 1.1. MAINTENANCE ON SHORE

Steel buoys must be replaced on station periodically and the old buoys brought ashore for repair and refurbishment and made ready to return to sea. In areas with extreme climates, this may be an annual event (e.g. when buoys are removed when winter ice sets in, and replaced with refurbished buoys in the summer). In more benign areas, buoys can usually stay on station much longer between overhauls. The overhaul of a steel buoy generally includes the following processes, which will be discussed in detail below: gas-freeing, blast cleaning, steelwork repair, and painting.

A 1.1.1. GAS FREEING

Be aware that combustible gases could be present in a buoy hull. Before beginning any 'hot work' (blast cleaning, cutting, or welding) on a steel hull, remove the battery pocket covers and batteries and test the battery pockets and hull for combustible gases with a combustible gas monitor or explosive meter. If combustible gases are detected, purge the hull with compressed air to displace the combustible atmosphere.

A 1.1.2. BLAST CLEANING

Servicing units should remove the majority of fouling to the greatest extent possible before dropping buoys off at the maintenance facilities. This avoids transporting marine growth from one environmental area to another, which might disrupt the ecosystem by introducing invasive species. Also, heavy fouling should not be allowed to dry on the buoy. Dried fouling is very difficult to remove, and it creates a strong and unpleasant odour. Fouling may be removed by high-pressure water washing or by scraping. Special attention should be given to removing the fouling from underneath the counterweights of flat-bottom buoys, and from inside whistle tubes. Any remaining fouling should be removed by the buoy maintenance facilities prior to blasting, since fouling can clog up and damage the blasting equipment when continuous grit recycling systems are used. In addition, removing the fouling prior to blasting will reduce the amount of residual blast waste that must be disposed of. Heavy accumulations of oil, grease, and dirt should also be removed from the buoy prior to blasting. Foreign material of this type will become embedded in the steel during blasting, and will prevent the paint from sticking properly.

Components that could be damaged by blasting should be removed from the buoy before blasting. Some examples include electrical wiring, power equipment, signal equipment, bells, gongs, and whistles. In addition, vent valves should be removed and the vent lines plugged. All threaded surfaces should be covered for protection. Depending on the design of the buoy, parts such as the superstructure or counterweights must also be removed before blasting.

All exterior surfaces of the buoy hull, and the inside surfaces of whistle tubes and battery pockets, should be blasted to near-white metal or as recommended by the coating manufacturer. The surface profile after blasting should comply with the coating manufacturer's recommendations. Blasting media should be of a recyclable variety, such as steel shot, steel grit, garnet grit, etc. When blasting aluminium, only non-ferrous grit should be used. Coal slag, copper slag, sand, or crystalline silica should not be used due to the negative health and environmental effects of the dust created by these materials. Ultra high pressure water blasting (hydroblasting) is another option. A variation on the hydroblasting process is abrasive water jetting, in which abrasive particles are carried in the high pressure water jet. After blasting, buoys should be fresh-water washed to remove salts and contaminants.

A 1.1.3. REPAIR OF STEEL HULLS, SUPERSTRUCTURES, AND APPENDAGES

If workers must enter a buoy hull to effect repairs, ensure that appropriate safety requirements for confined space entry are followed.

The integrity of lifting eyes is vital to the safety of buoy handling operations. Lifting eyes are subjected to repeated heavy loads while in service, which can weaken the weld and the surrounding metal. Failure of a lifting eye could lead to serious injury of the ships' crew or the shoreside maintenance personnel. Therefore, it is paramount to ensure the fitness for use of this critical component. Two methods of doing this would be load testing or non-destructive inspection (e.g. magnetic particle method).

Buoy hulls should be repaired or replaced when the hull thickness reaches the minimum allowable level (this varies depending on the buoy design and Authority policy). Buoy hull thickness can be easily measured with ultrasonic equipment. Any damage that penetrates the hull should be repaired. Severe dents and creases should be repaired, returning the buoy body to its approximate original shape. Buoy hulls and battery pockets that have been repaired should be pressure tested prior to repainting to ensure airtight integrity.

Bent counterweight tubes should be replaced. The welds at the junction of the tube and the buoy body should be inspected and repaired as necessary. Bent mooring arms should be straightened or replaced if they do not function properly. Repair or replace counterweights and counterweight mounting bolts and brackets.

Bent tower legs should be straightened. Radar reflector panels should be at the angles required by the design specifications, and should be straightened if necessary. Lantern mounting surface and lantern ring should be parallel to the waterline. One item of particular importance is the inspection/repair of the access arrangements (ladders, working platforms, fall arrest systems, etc.) to ensure safe and easy access for maintenance personnel.

Battery pocket closures should be inspected, and the battery pocket cover gaskets should be replaced. Vent lines should be inspected for damage or obstructions that would impede air flow or allow flooding of battery pockets, and repaired or replaced as necessary. Crossover vent tubes within battery pockets should be inspected for damage or obstructions that would impede air flow. Make sure the tubes are free of blast grit, paint chips, dirt, or other foreign material.

Worn mooring eyes should be repaired or replaced. Mooring eyes can be repaired by building them up to their original size by welding, or by inserting sleeve bushings. Hardfacing material should be used when weld build-up is the chosen repair method. Ensure that this material is compatible with the shackles that will be used in service. When replacing a mooring eye, ensure that the mating surfaces between the mooring eye and buoy hull are properly prepared before welding.

Repair or replace cathodic protection systems (e.g., anodes). In all repair work, ensure that dissimilar metals are insulated from each other in the final assembly to prevent galvanic corrosion (i.e. separate materials with physical insulators or an insulating medium).

A 1.1.4. PAINTING

Implement appropriate worker safety procedures for the application of the coating system, and ensure the procedures are strictly followed. Guidance on worker safety requirements specific to a given paint system is available from the paint manufacturer.

Operators must be fully trained in the use of all equipment and also in the mixing and application of all the types of paint they will use. The paint manufacturers are usually helpful in arranging operator training. It is important that operator training is updated if paint types are changed.

The surface to be painted should have the following characteristics: free of rust and scale except for slight shadows, streaks, or discolouration; free of blasting grit, weld spatter, and slag; free of old paint, oil, grease, and dirt. In order to achieve this, it may be necessary to carry out a secondary, light blast cleaning just prior to painting to ensure the proper surface conditions.

The types of coatings used on steel buoys vary from Authority to Authority, depending on product availability, operating conditions, and the level of environmental regulation in the region. Also, parts of the buoy that are made of different materials (such as an aluminium superstructure) may require specialized preparation and primer paints. There are various opinions regarding the use and effectiveness of antifouling paint, and. National regulations may restrict the type of antifouling that can be used. For the colour of surface coats, refer to IALA Recommendation E108. Regardless of the type of coatings used, they should be high-performance products designed for use in the marine environment. Paints are normally applied by brush, roller, or spray, depending on the surface area involved and the facilities available. All of the paints applied to a given buoy should be from the same manufacturer. This is to provide compatibility between coats, validate the manufacturers' warranties, and ensure the Authority receives adequate technical support to correct problems and increase productivity.

Follow the manufacturer's instructions for correct application of the coating system. This includes complying with temperature, humidity, and dew point restrictions; storage, mixing, and induction time requirements; and specific requirements related to equipment and application techniques. All welding, machining, cutting, drilling, forming, or any other operation that would damage the coating system should be performed prior to painting. Sharp corners, edges, and other hard-to-coat areas should be pre-coated (striped) before each full coat is applied, to ensure adequate paint thickness in these areas.

Note: Do not paint conductive connections such as anode mounting studs or earthing (grounding) points.

The methods of handling newly painted buoys must be carefully considered. There is little point in providing a high quality paint coating and then damaging this by careless handling before the buoy is in the water. Pallets can be designed which allow buoys to be moved by fork lift trucks; otherwise extreme care must be taken to prevent crane hooks damaging new paint. Chocks must be carefully padded if the buoy has to be laid on its side, as must lashings used aboard ship.

Upon completion of painting, install retroreflective tape, letters, and numbers, and any safety signage required (e.g. explosive warnings on the battery box).

A 1.2. MAINTENANCE ON STATION

A 1.2.1. GENERAL

Prior to starting the work, disconnect power connections to all AtoN equipment that could cause harm to the workers or damage the equipment (e.g. foghorns, racons). While performing maintenance on the buoy, care should be taken not to damage the signal equipment and power systems installed on the buoys. Before re-deploying the buoys, verify that all of the equipment is operating to specification.

A 1.2.2. REMOVAL OF FOULING

Fouling from marine growth may be so severe that the buoy will have to be lifted and cleaned at regular intervals. During servicing, fouling should not be removed with mechanical scrapers. These will cause serious damage to the paint film and shorten the life of the paint system. Remove fouling with water jetting using a suitable pressure that will not damage the paint system.

A 1.2.3. HULLS

Buoys should be checked for flooding and inspected for damage that could affect their watertight integrity. Cutting or welding may be required to repair this damage on station. Extreme care must be exercised because combustible gases could be present in a buoy hull. Before beginning any ‘hot work’ (cutting or welding) on a steel hull, remove the battery pocket covers and batteries, and test for combustible gases with a combustible gas monitor or explosive meter. If combustible gases are detected, purge the hull with compressed air to displace the combustible atmosphere.

A 1.2.4. SUPERSTRUCTURE AND APPENDAGES

Battery pocket closures should be inspected for damaged flanges, covers, swingbolts, and gaskets. The vent valves should be inspected to ensure that the balls are free to move. The tower legs and feet should be inspected for cracks and broken welds. Swing arms, mooring pins, and mooring eyes should be inspected for excessive wear. Any problems with these items should be repaired if possible, or the buoy brought ashore for an overhaul. Repair or replace cathodic protection systems (e.g. anodes).

A 1.3. PAINTING

Complete repainting of buoys on station is not recommended due to the cost in materials and time, and the difficulty in meeting the environmental requirements for proper paint application (e.g. temperature, humidity, etc.). However, touch-up painting is sometimes done to restore the proper signal colour of the buoy. Prior to painting on station, prepare the buoy surface by wire brushing, scraping, or high-pressure water washing to remove as much dirt, rust, guano, fouling, loose paint, grease, and salt as possible. When using these methods, care should be taken to remove damaged paint, but to leave areas with ‘good’ paint intact. If high-pressure water washing is used, follow the manufacturer's recommendations for a pressure setting that will clean the buoy thoroughly but will not damage the underlying coatings. The surface must be dry before painting. Wet surfaces should be blown dry with compressed air or wiped off with clean rags. Follow the manufacturer's instructions for the correct application of all paints. Ensure that the paint has properly cured in accordance with the manufacturer's recommendations before redeploying the buoy in the water.

A 2. SYNTHETIC BUOYS

Synthetic buoys can be grouped in the following four categories, based on their primary material of construction: glass-reinforced plastic (GRP), polyethylene, polyurethane (elastomer)-coated foam, and all foam. Each of these is addressed below. Guidance in the design and use of these type of buoys can be found in IALA Guideline 1006, On Plastic Buoys. In general, maintenance of these buoys is performed on shore. Maintenance on station would usually be limited to the removal of fouling, minor patch repair, and possibly some minor touch-up painting to restore the signal colour. The steel/aluminium components of all types of synthetic buoys may require painting or re-galvanising, and in the case of mooring eyes, re-surfacing. The integrity of any internal load bearing structure must be regularly monitored to ensure handling safety, as components may suffer corrosion, fatigue, or abrasion damage.

Synthetic buoys can have a wide range of lifting eye configurations, depending on the specific buoy design. The integrity of these eyes is vital to the safety of buoy handling operations. It is recommended that Authorities have testing procedures in place to ensure the fitness for use of these critical components over the full service life of the buoy. Consult the buoy manufacturer for guidance on suitable testing procedures.

If any maintenance work is done on station, first disconnect power connections to all AtoN equipment that could cause harm to the workers or damage the equipment (e.g., foghorns, racons). While performing maintenance on the buoy, care should be taken not to damage the signal equipment and power systems installed on the buoys. Before re-deploying the buoys, verify that all of the equipment is operating to specification.

A 2.1. GRP

GRP is the usual abbreviation for glass reinforced plastic (fibreglass), which in its most common form consists of glass matte bonded by polyester resin. Repair of GRP is usually straightforward, but does require high levels of cleanliness and high working temperatures that may be difficult to achieve. Effective drying of damaged laminates or foam cores may also be difficult in cold climates. It may be necessary to use infrared heaters to warm and dry damaged areas and to ensure effective curing of the repair. The use of laminating resins and solvents is subject to increasing control by health and safety regulations.

A 2.1.1. HULL REPAIR

When a GRP buoy has been in service for any length of time, the gelcoat will begin to fade from exposure to ultraviolet (UV) radiation. Loss of gloss and ‘chalking’ can also occur, where the surface gradually breaks down to a powder. Polishing with marine grade wax polish may delay this, but eventually a paint system may be needed to protect the gelcoat surface and provide the required glossy colour finish. If the gelcoat is extensively grazed, flaking, blistering, or contains many bubbles, then the gelcoat should be removed by power sanding or grit blasting. This should be undertaken by experienced personnel to ensure that the glass fibre structure of the buoy is not damaged. The buoy should then be pressure washed with fresh water and allowed to thoroughly dry in conditions of controlled temperature and humidity. Coatings of solvent-free epoxy are then applied, again in controlled climatic conditions, to form an impermeable barrier on the surface of the GRP moulding. Four or five coats are usually necessary, and these may be followed by colour coats in areas where the signal colour of the buoy is required. More guidance on painting is provided in the following paragraphs.

A 2.1.2. PAINTING

Prior to painting, the surface must be prepared to ensure proper adhesion of the coating system. Special releasing agents are used during the manufacturing process to allow the removal of the buoy from its mould. It is essential that these agents be removed from the surface before painting. The buoy must be cleaned with a degreasing agent, which can be obtained from the paint manufacturer. This is usually left on the buoy for 10-20 minutes before washing off. Afterwards, wash the surface again with fresh water. If the surface is completely clear of grease, the water will spread out evenly on the surface. If grease is still present, the water will form small droplets, which indicates more cleaning is necessary with the degreasing agent. Any minor cracks and blemishes can be filled with an epoxy filler. Only epoxy-based fillers should be used to ensure long-term adhesion and water resistance. To ensure good adhesion of the paint, the surface must be abraded with a fine grade abrasive paper. Wet and dry abrasive paper may be used if a high gloss finish is required. All sanding dust should be removed before painting proceeds.

For the best long term protection, a coat of an epoxy primer should be applied prior to the selected finish coat. If the surface is in very good condition, it may not be necessary to apply a separate primer as the undercoat for the paint will provide the necessary adhesion. If the surface has become ‘chalked,’ it can absorb solvents from the paint system, which can cause microblistering problems later. To avoid this, an epoxy primer system should be applied to the surface. This will seal the surface and provide a stable base for the paint system. Submerged areas of the buoy that do not form part of the colour daymark may be painted with at least three coats of an underwater epoxy system to provide a water barrier for the GRP structure. All of these paints can be applied by brush, roller, or spray, depending on the surface area involved and the facilities available.

All coatings should be high-performance products designed for use in the marine environment. All of the paints applied to a given buoy should be from the same manufacturer. This is to provide compatibility between coats, validate the manufacturers' warranties, and ensure the Authority receives adequate technical support to correct problems and increase productivity. Follow the manufacturer's instructions for correct application of the coating system. This includes complying with temperature, humidity, and dew point restrictions; storage, mixing, and induction time requirements; and specific requirements related to equipment and application techniques. Implement appropriate worker safety procedures for the application of the coating system, and ensure the procedures are strictly followed.

A 2.2. POLYETHYLENE

Buoys of this type are typically fabricated by rotational moulding.

A 2.2.1. HULL REPAIR

The polyethylene skin can be repaired, depending on the extent of damage, by hot air welding (also known as hot fusion welding). Another option is to resurface the buoy by flame spraying new plastic onto the surface of the original moulding. This involves using a spraying system which projects plastic powder through a gas flame to deposit a molten layer of new plastic, and a considerable thickness can be built up as required.

Large plastic buoys are generally modular in construction, so it is possible to salvage parts of these buoys that are still in good condition and reuse them to replace damaged parts and extend the life of other buoys. Other repair and options may be available from the buoy manufacturer, and the plastic is generally recyclable.

A 2.2.2. PAINTING

Painting of polyethylene buoys can be challenging due to surface adhesion problems. This is because polyethylene is naturally slippery. Some success has been obtained by abrading the surface of the plastic with a medium grade abrasive paper or by using flame treatment, and then painting with an appropriate coating. The effectiveness of this process may vary depending on the grade of polyethylene used in the manufacture of the buoy. The flame spraying process described in paragraph A 2.2.1 can also be used to restore or change the colour of plastic buoys. Also, vinyl adhesive sheeting may be used for specialty markings.

A 2.3. POLYURETHANE COATED FOAM

These buoys typically consist of a thick, flexible polyurethane elastomer skin covering a flexible closed cell foam core. The polyurethane may be repaired with two component pouring or trowelling compounds. Correct working conditions are critical (temperature and humidity), and detailed health and safety precautions must be observed.

A 2.4. ALL FOAM

These buoys are usually constructed by wrapping closed-cell foam sheets around a central structural core, the layers of foam being heat sealed together during the wrapping process. A typical material for this application would be foam made from ionomer resin.

Foam buoys generally require very little maintenance. A foam buoy hull can sustain considerable damage or loss of material without sinking, and still provide the proper signal to the mariner. Cuts, tears, gouges, shredding, or even missing chunks of foam will rarely be enough to affect the performance of the buoy. Foam buoys will lose their colour over time through fading, chalking, sunburn, and the accumulation of foreign materials (salt, dirt, guano, etc.). Usually, cleaning the surface of the buoy with high-pressure washing is enough to restore a proper colour. The metalwork of a foam buoy will deteriorate over time through corrosion and normal wear-and-tear, or there may be damage from collisions. The important considerations are whether the metalwork can continue to hold the buoy together, and whether the buoy remains safe to lift and handle.

To achieve the lowest life cycle cost for these buoys, they should be kept on station as long as possible, provided they remain serviceable and continue to present the required signal to the mariner. In other words, the steelwork should be intact, the buoy should be safe to handle, the colour should be recognizable; the daymark shape should be identifiable as a can or nun; and the buoy should have sufficient stability and freeboard to provide the required visual range for the aid. If the buoy fails to meet one or more of these requirements, it should be relieved and disposed of. Since these buoys are generally modular in construction, it is possible to salvage parts of these buoys that are still in good condition and reuse them to replace damaged parts and extend the life of other buoys. Other repair and recycling options may be available from the buoy manufacturer.

A 3. DISSIMILAR MATERIALS

Wherever possible, electrochemically compatible materials and fasteners should be used for the repair and refurbishment. Even subtle differences in electrical potential can lead to significant corrosion. For example, corrosion will occur even between cast iron and mild steel. If dissimilar materials must be used take care to isolate dissimilar materials from each other to prevent galvanic corrosion, by using plastic isolation such as plastic washers between the dissimilar materials, and also between the fasteners and the structure. Another alternative is plastic-coated fasteners. Where contact between dissimilar materials is unavoidable, it may be necessary to install a cathodic protection system to minimise galvanic corrosion.

A 4. CLEANING

Cleaning is generally required each time an aid is serviced. Cleaning covers those actions required to maintain the signal colour; to remove marine growth for reasons of colour retention or for reduction of drag or weight on floating AtoN; and to remove salt, dirt, or bird droppings from lanterns and solar panels. Modern pressure washing equipment is particularly suitable for these processes in the field, as all contaminants can be removed without introducing solvents or detergents into the environment. Care must be taken to ensure that correct pressures are used, as excessive pressure may result in the paint coating being removed, damage being caused to solar panels, mortar being removed from masonry structures, or other similar problems. Although manual scraping can also be used to remove marine growth from buoys, this can easily damage the coating system, and should be avoided if possible.

ANNEX B MOORINGS

B 1. INTRODUCTION

The life of a mooring (chain, rope, shackles, swivels, sinkers, anchors) will depend on local operating conditions; i.e. the sea state, water depth, type of sea bed, abrasive particles in the water, current speed, etc. The most rapid wear will be in the thrash (chafe) zone, where the chain meets the seabed. The Authority must plan to lift and replace worn components to keep the mooring in safe working order or to remove the entire mooring before it is worn to unsafe levels. Historic inspection information is extremely valuable in predicting mooring service life in specific locations.

B 2. CHAIN

A chain mooring consists of three parts: the riser (riding) chain, which hangs in the water column; the thrash (chafe) section, which moves against the sea floor as the buoy moves; and the ground (bottom) chain, which remains on the sea floor. Since the thrash section typically experiences the greatest wear, it is the most important area to inspect. Depending on the length of time between mooring inspections and the severity of the environment, it may be prudent to bring the entire mooring aboard for inspection. When inspecting chain, it is important to know its condition at the time of the last mooring inspection. Annual wear rates for a given buoy station can be estimated by keeping records of the chain measurements at each inspection. This information can be used to plan the frequency of mooring inspection visits that will be necessary for a given buoy station.

Inspect for chain wear by measuring the smallest parts of the most worn links, using a calliper. Replace the chain if it has worn down to the minimum useable diameter for the buoy type on station, or if any of the links are deformed, stretched, bent, or twisted.

When replacing sections of worn chain, enough chain should be removed on either side of the worn section to ensure that shackles do not ride in the thrash when the replacement chain is connected to the mooring. If a mooring has sufficient scope and only a short section of chain is worn, it may be possible to remove the worn section and join the riser and bottom sections without replacing any chain. If conditions permit, either the entire mooring or certain sections of the chain can be cut and ‘end-for-ended.’ This action will put ‘good’ chain in the thrash section and shift the worn chain to an area of less wear, such as in the riser or the bottom. This method can be utilized where chain is worn, but not to the extent that it needs to be replaced. Chain that is worn below the useable diameter for a given buoy type may be 'downgraded' and used on a buoy that requires a smaller chain size.

B 3. SYNTHETIC ROPE

Some Authorities use synthetic rope made from a wide variety of materials: nylon, polyester, polypropylene, and other advanced fibres. Regardless of the type of material used, there are a number of factors to consider with regard to the use and maintenance of these moorings. These include the need for proper material specifications, termination specifications, handling procedures and equipment, and mooring system design. Be aware that synthetic ropes can degrade from UV radiation, so consideration should be given to long-term storage in protected locations.

Personnel safety is a major concern when using synthetic moorings. The energy stored in the rope when under tension may be considerable, and suitable precautions must be taken to ensure that no personnel will be in any area that may be swept by the end of a broken rope.

Chafe and cutting are the greatest dangers to a rope mooring. It is easily demonstrated that a sharp knife will rapidly cut through a piece of rope, and any sharp edges presented by rocks, sea shells, or the servicing ship's own capstan can rapidly cause permanent damage to the surface of the rope. Allowing the rope to slip on the drum of a capstan or pulling it through an unsuitable fairlead may not only result in abrasive damage, but also in localised heating such that the surface fibres of the rope may melt, resulting in significant weakening. In addition, the rope can be weakened by ingress of sand or marine growth while on station.

When lifting a mooring for removal or inspection, two areas need special attention:

- Any fairlead that the rope runs over must be of sufficient diameter for the rope used, be of the roller type, and present no sharp edges.
- The winch or capstan must be designed for handling rope, and must not allow the rope to slip on the winch drum when under load.

Conventional capstans may be capable of recovering a rope mooring; however, their tendency to allow the rope to slip on the capstan drum will result in considerable heat being generated that can damage the rope. Successful techniques have been developed using spooling winches where the rope is wound onto a large rotating drum. However, this technique is limited by the length of rope, and hence the number of moorings that can be carried on the drum at any one time. If a large number of rope moorings are to be handled, the preferred method is to use a specialised rope hauling winch. These can be installed at the vessel's deck edge so that the rope can lead directly to the winch without a fairlead being required. The winch consists of an arrangement of large rubber wheels, which grip the rope without causing damage to the surface fibres. The rope usually only passes over a segment of hauling wheel rather than being wrapped around a drum, and can thus be placed in, or removed from, the hauling winch as may be necessary. This type of winch placed on the deck edge also has the advantage that there is no rope under load passing across the vessel's deck, which may present a serious hazard should the rope break.

Handling loops or shackles can be incorporated in the rope allowing the mooring to be hoisted in sections by the deck crane.

Consult the rope manufacturer for specific guidance on the installation, inspection, and maintenance of the rope and the rope terminations (i.e., thimbles and splices).

B 4. CONNECTING HARDWARE

Shackles and swivels that are excessively worn, deformed, stretched, bent, or twisted should be replaced. Swivels should be replaced if they have seized up and fail to rotate.

B 5. SINKERS

Sinkers are generally made from concrete, cast iron, or cast steel. Regardless of the type of material, the weak link would be the mooring eye. Mooring eyes should be repaired or replaced, or the entire sinker replaced, if the mooring eyes have worn to unsafe levels. It is most important that any material used to repair the mooring eye must be compatible and of similar hardness to the connecting shackle.

B 6. DISSIMILAR MATERIALS

Wherever possible, electrochemically compatible materials and fasteners should be used for the repair and refurbishment. Even subtle differences in electrical potential can lead to significant corrosion. For example, corrosion will occur even between cast iron and mild steel. If dissimilar materials must be used take care to isolate dissimilar materials from each other to prevent galvanic corrosion, by using plastic isolation such as plastic washers between the dissimilar materials, and also between the fasteners and the structure. Another alternative is plastic-coated fasteners. Where contact between dissimilar materials is unavoidable, it may be necessary to install a cathodic protection system to minimise galvanic corrosion.

B 7. CLEANING

Cleaning is generally required each time an aid is serviced. Cleaning covers those actions required to maintain the signal colour; to remove marine growth for reasons of colour retention or for reduction of drag or weight on floating AtoN; and to remove salt, dirt, or bird droppings from lanterns and solar panels. Modern pressure washing equipment is particularly suitable for these processes in the field, as all contaminants can be removed without introducing solvents or detergents into the environment. Care must be taken to ensure that correct pressures are used, as excessive pressure may result in the paint coating being removed, damage being caused to solar panels, mortar being removed from masonry structures, or other similar problems. Although manual scraping can also be used to remove marine growth from buoys, this can easily damage the coating system, and should be avoided if possible.

ANNEX C STRUCTURES

C 1 INTRODUCTION

This section provides guidance for assessing the physical condition of small AtoN structures (for lighthouse maintenance, reference IALA Guideline 1007, On Lighthouse Maintenance). The purpose is to evaluate the structural integrity of the aid to ensure the safety of servicing personnel who must climb it, and to identify what repairs might be needed. Be aware that structures may be located in areas where dangerous insects, animals, or poisonous plants may be located, so appropriate precautions must be employed when accessing these areas. The structures may also be located in fragile ecologic zones or areas with protected flora or fauna. Guidance in this regard is provided in IALA Guideline 1036, On Environmental Considerations in AtoN Engineering. Weather conditions should also be monitored to ensure the safety of the climbers. Note: Some Authorities may require training and certification of climbers, and/or certification that the tower itself is safe to climb (primarily for lattice towers).

C 2 OVERALL CONDITION ASSESSMENT

The following are the areas to be inspected to get an overall impression of the structure's condition, and to ensure the structure is safe to climb before proceeding with a more complete assessment.

Check horizontal and vertical alignment. Is the structure out of plumb? Do any of the vertical members appear bent or misaligned? Does the structure vibrate or move when the boat berths against it? Does the structure deflect from wind gusts or waves? Are there signs of damage caused by vessel impact, ice, logs, or other debris? Is the water under the structure deeper/shallower than originally designed, or deeper/shallower than reported at the previous inspection?

Check ladders for corrosion, broken, bent or missing rungs, loose or failed connections, and malfunctioning fall arrest systems. Is the ladder misaligned? Does the ladder vibrate or move from the current, waves, or when the boat berths against it? Check for bolt corrosion or loosening of bolts as indicated by wear marks from moving members, misalignment of mating surfaces, and by looseness or distortion of structural members. Loose bolts will typically move when hit with a hammer.

Check the extent of steel member corrosion in the splash zone. Hammer the surface corrosion to remove corrosion by-products and expose the steel below. Removal of the corrosion scale does not affect the structural integrity, and may expose severe corrosion defects.

Check continuity of the lighting protection system.

C 3 PILES

C 3.1. TIMBER

Timber members have traditionally been used for construction and maintenance of aid structures due to their availability, economy, and ease of handling relative to other construction materials. Timber damage is caused by fungal rot/decay, marine borer and insect attack, connector corrosion and bolt loosening, abrasion.

Check the tops of piles for physical damage, dry rot, and termite or pest infestation and determine the depth of deterioration. Check for cracked, rotted, loose, or worn piles or connecting braces. Visually examine piling in the tidal zone for marine borer damage. The tidal zone is the area between high and low tide and is likely to be the most damaged. Clear a section of the structure of all marine growth and visually inspect for surface deterioration. Sound the piles with a hammer and carefully probe with a thin-pointed tool such as an ice pick to look for internal decay and soft timber.

Check for member damage due to overload or impact. Check pile and mast alignment. If the aid is a multi-pile structure, are the piles angled toward each other evenly? Is the mast out of plumb?

Check for corrosion of steel fasteners, including bolts, drift pins, and wire rope. Steel fasteners embedded in wet timber usually corrode faster inside the timber, which may not be apparent from visual inspection. Strike the bolt ends with a hammer to check for internal corrosion failure. Wire rope is often used to wrap timber pile cluster structures to hold the pile heads together. This wire rope typically corrodes internally at a faster rate than externally and may be structurally compromised even when the exterior of the wire appears only lightly corroded.

C 3.2. STEEL

Steel is used in the construction of AtoN structures due to ease of connection, fabrication, and splicing, ductile behaviour, and the ability to drive steel piles through hard soil. There are six major types of steel structure deterioration to watch for in the marine environment: corrosion and coating loss; abrasion; loosening of structural connections, missing bolts; fatigue (broken or cracked welds); overloading; loss of foundation material.

Check for corrosion evidence: rust, scale, and holes, especially in the splash zone and at extreme low water level. Hammer the surface corrosion to expose the steel below for inspection. Steel member thickness can be easily measured with ultrasonic equipment. Inspect the condition of the cathodic protection system.

Check for deformation, distortion, or deflection. Check for abrasion as indicated by a worn, smooth, or polished appearance. Inspect welds for signs of corrosion, cracking, or breakage.

Inspect coating for any peeling, blistering, etc. Check for loss of foundation material and/or scour.

C 3.3. CONCRETE

Reinforced concrete is a construction material for ATON structures due to its relatively low cost and durability. The durability of concrete in the marine environment is highly dependent on the quality of concrete mix used. It is not unusual to find relatively new concrete structures in poor condition, while adjacent older structures are in better condition. Deterioration of concrete appears in the following forms: corroded steel reinforcing; abrasion wear, which is usually only significant in poor quality concrete; chemical deterioration accelerated by continuous exposure to saltwater, causing soft friable concrete (which can be pulled apart by hand or with hand tools); spalling and/or cracking with rust stains, which usually indicates the reinforcing steel is corroding; overloading damage as noted by cracking, spalling, or concrete breakage; shrinkage cracking.

Inspect for cracks, spalling, corrosion of reinforcing steel and visual signs of rust staining. Solid reinforcing bars are much more tolerant of corrosion than are prestressing strands (embedded high strength wire cable).

Check for evidence of chemical deterioration, abrasion wear, and overload damage. Sound the piling with a hammer to detect any loose layers of concrete or delaminating. A sharp ringing noise indicates sound concrete. A soft surface will be detected, not only by a sound change, but also by the change in rebound, or feel, of the hammer. A thud or hollow sound indicates a delaminated layer of concrete, most likely due to the corrosion expansion of internal reinforcing steel. Loose delaminated concrete may be removed to inspect the extent of reinforcing corrosion below.

C 4 OTHER CONSTRUCTION MATERIALS

C 4.1. MASONRY

Stone masonry structures can be built using many different types of stone block configurations and using irregular or rectangular cut stone blocks. Precast concrete block masonry is typically built using rectangular blocks which may or may not be reinforced. The blocks may be connected with iron or steel dowels or large 'staples,' and the corrosion of the connecting dowels may allow blocks to fall out of the structure. The joints between blocks may be left open (called dry masonry construction) or may be mortar filled (pointed joints).

Check for missing or displaced blocks, usually due to mortar deterioration, loss of wedging stones, or corrosion of iron/steel dowels between blocks. Check for wall movement, usually noted by a portion of the masonry structure having vertical and/or horizontal misalignment that varies from the design drawings or adjacent portions of the structure. Is a portion of the originally straight wall bowing outward? Has a portion of the structure settled?

Detailed guidance on the inspection and repair of masonry structures is available from the United States Parks Department at the following Internet address:

http://www.cr.nps.gov/maritime/handbook.htm

C 4.2. NON-FERROUS METALS

AtoN structures can be made entirely from marine-grade aluminium or stainless steel, or a combination of both. Also, these metals are used for the secondary portions of structures, such as platforms, marker masts, solar panel mountings, and guard railings.

With regard to aluminium, check for corrosion, particularly if the aluminium is in direct contact with steel, concrete, or mortar. Aluminium should be separated from these materials, typically using plastic spacers. Check for abrasion and wear. Aluminium is much softer than steel, and will wear if subject to rubbing with other objects. Check for cracked welds.

C 4.3. GRP

Many structural shapes, ladders, and gratings are available in glass reinforced plastic (fibreglass) composites that can be well suited to AtoN structures.

Check for broken members. GRP is prone to impact damage, particularly in extremes of hot and cold weather and with aging after prolonged UV exposure. Check for loose connections. GRP members are usually connected together using stainless steel bolts, which can loosen over time. Check for damage to the surface finish. Weathering and UV can degrade the surface finish, which can cause splinters to develop and present a hazard for servicing personnel.

Repair of fibreglass structures in remote locations may be undertaken using polyester, vinyl ester, or epoxy resin systems. Epoxy repairs are more robust and exothermic in nature, and epoxy repairs must be coated to prevent UV damage to the repaired area. Delamination of foam cores to the laminate can be repaired by pouring epoxy resin into the void between the core and skin laminate. Care should be taken in repair of mixed resin systems. Epoxy resins will bond over vinyl ester and polyester resins. Polyester and vinyl ester resins may not cure over epoxy repairs.

Structurally weak areas, such as the corners of door or hatch openings in GRP towers, should be repaired to the original thickness and strength. Any cracks in the laminate should be removed prior to repair with GRP matte and resin. Minor damage to the gelcoat can be repaired by grinding away the damaged area then recoating with gelcoat.

C 4.4. PLASTICS

Various grades of polyethylene plastics are used in AtoN structures. These may be in the form of sheets attached to the boat fendering of the structure, or polyethylene plastic piles and dimension 'lumber,' with or without internal reinforcing. The internal reinforcing is now mostly fibreglass rebar or fibres, though internal steel reinforcing has been used as well.

Check for broken or damaged members. Plastics are prone to impact damage, particularly in extremes of hot and cold weather and with aging after prolonged UV exposure. Check for cracking. This can result from the manufacturing process itself, or by corrosion of embedded reinforcing steel. Check for loose bolted connections.

C 4.5. RUBBER

There are several types of rubber that are often used in boat fendering on AtoN structures. The rubber will degrade over time after prolonged UV, ozone, and petroleum exposure. Ozone and UV will result in a hardened surface and rubber cracking with age. Petroleum exposure will swell and soften many types of rubber. The rubber deterioration should be monitored with each inspection, and the parts replaced when damaged. Check for rubber deterioration (i.e. hardening, cracking, swelling, softening).

C 5 STRUCTURE COMPONENTS

C 5.1. LADDERS

Check ladders for corroded, broken, bent, or missing rungs. Check horizontal and vertical alignment. Is the ladder misaligned? Does the ladder vibrate or move from the current or waves, or when the boat berths against it? Are there signs of damage caused by vessel impact, ice, logs, or other debris?

Check for corroded, loose, or failed connections. Loose bolts can be indicated by wear marks from moving members, misalignment of mating surfaces, and by looseness or distortion of the ladder. If bolt washers move, then there is no tension in the bolt to clamp the fastened members together. Inspect welds for signs of corrosion, cracking, or breakage. If the ladder has been deformed from an impact, then adjacent welds on rungs and mounting brackets may have been cracked. Also check the condition of ladder fenders.

If the ladder is equipped with a ladder safety device or fall arrest system, this must be inspected and maintained in accordance with the Authority's national health and safety requirements.

C 5.2. PLATFORM

Inspect the platform decking or grating for structural integrity and soundness. Check the railings for deterioration and parts that are broken, severely bent, or otherwise unsafe.

C 5.3. TOWER

Visually inspect all structural members and connections of the towers for evidence of corrosion, deformation, signs of fatigue, and cracks. Look for excess corrosion at the bolts and joints that are bolted together, and for missing, loose, or damaged bolts.

Check the plumb (straightness) of the tower. All towers must be plumb (straight up and down). A simple visual inspection is sufficient. If the tower looks crooked, use a straight edge as a sight and be sure it is not an optical illusion. You may even find towers that zig-zag. Improper construction or damage at specific section connections can cause one section of the tower to be out of plumb with the rest of the structure. Question any unexplained distortion. If the tower is leaning, something is wrong. Find out why it is leaning.

On hollow section structural members, rust damage on the interior surfaces might not be obvious. Each member of such a tower should have drain holes at the bottom to prevent water from collecting and causing damage. Check these drain holes to make sure they are not obstructed and are doing their job. Visible rust flakes or rust staining may be an indication of interior rust damage. Steel member thickness can be easily measured with ultrasonic equipment.

C 6 FOUNDATIONS

C 6.1. CONCRETE FOUNDATIONS

Check the wave zone protection; e.g., rock armour, gabions, ice protection (steel plates), and piling. Check for evidence of environmental erosion or storm events, which can cause loss of material around the structure and undermine the foundation. Inspect the concrete foundation above ground level for signs of cracking or spalling. If conditions of the concrete above ground level are poor, an area adjacent to the foundation should be excavated to check the condition of the concrete below ground level. Inspect the soil surrounding the structure foundation for evidence of settlement or upheaval. Inspect the anchor bolts connecting the concrete foundation to the steel tower for deformation, loose nuts, corrosion, or defects. Inspect for exposed reinforcing bars. For inspecting foundations which are underwater, divers or remote operated cameras can be used.

C 6.2. GUY ANCHORS AND HARDWARE

Look for any disturbance in the ground around the foundation of the guy. Inspect guy (wire rope) anchors, turnbuckles, thimbles, shackles, preformed dead end guy grips, shear pins, and cotter pins for signs of corrosion, deformation, and fatigue. Preformed guy grips should be checked to ensure there is no change in surface appearance of the guy strand immediately next to these grips. A change in surface appearance may indicate slippage. Ensure turnbuckles are properly moused with safety wire to prevent inadvertent turning of the turnbuckles. Also, turnbuckle threads should be coated with a light coat of petroleum-based grease to prevent corrosion and binding. Inspect structural guys for signs of strand separation, corrosion, fatigue, deformation, and broken strands. In weather conditions where there is no wind, a slack guy wire can be an indication that something is wrong. Verify that safety tie wires are installed on all turnbuckles, shackles, and pins. Inspect steel anchor hardware for corrosion, including steel surfaces in contact with the ground. Plastic-covered wire ropes are a possible solution to reduce corrosion and extend the life of wire ropes. Also, consider wrapping guy hardware with waterproofing tape (‘Denso’ tape).

C 7 DISSIMILAR MATERIALS

Wherever possible, electrochemically compatible materials and fasteners should be used for the repair and refurbishment. Even subtle differences in electrical potential can lead to significant corrosion. For example, corrosion will occur even between cast iron and mild steel. If dissimilar materials must be used take care to isolate dissimilar materials from each other to prevent galvanic corrosion, by using plastic isolation such as plastic washers between the dissimilar materials, and also between the fasteners and the structure. Another alternative is plastic-coated fasteners. Where contact between dissimilar materials is unavoidable, it may be necessary to install a cathodic protection system to minimise galvanic corrosion.

C 8 CLEANING

Cleaning is generally required each time an aid is serviced. Cleaning covers those actions required to maintain the signal colour; to remove marine growth for reasons of colour retention or for reduction of drag or weight on floating AtoN; and to remove salt, dirt, or bird droppings from lanterns and solar panels. Modern pressure washing equipment is particularly suitable for these processes in the field, as all contaminants can be removed without introducing solvents or detergents into the environment. Care must be taken to ensure that correct pressures are used, as excessive pressure may result in the paint coating being removed, damage being caused to solar panels, mortar being removed from masonry structures, or other similar problems. Although manual scraping can also be used to remove marine growth from buoys, this can easily damage the coating system, and should be avoided if possible.

ANNEX D SIGNAL EQUIPMENT

D 1 LANTERNS AND LAMPS

Visually inspect the lantern lens and base for cracks, crazing, holes, broken bird spikes, etc. Repair/replace if necessary. Check the level and focus of the lantern. Check operation of the daylight control, signal output, and flash character.

Filament lamps must be replaced before their working life is exceeded. Buoys and structures with lamp changers will need to have their lamps replaced before the last lamp is consumed. Replace all extinguished lamps and the operating lamp. Rotate remaining good lamps to the forward positions and use new lamps to fill the remainder of the lamp changer. Wipe lamps with a clean rag dampened with denatured alcohol. Rotate the turret to the first position. Those undertaking the replacement of lamps must appreciate the importance of correctly sealing the lantern after the new lamps have been installed and then functionally testing the light. Manufacturers will provide some guidance on lamp replacement intervals, but the local operating environment will affect lamp life. Feedback from inspection reports will enable practical lamp change periods to be established. Ensure that the correct lamp is used. Check for degradation of sector colours, and replace or adjust to the correct charted position as necessary.

LED (Light Emitting Diode) lanterns have the considerable advantage of requiring little or no maintenance over their service life. When LED lanterns are used, the need to visit the station to remove bird fouling or salt deposits may control the period of time between maintenance visits. Note the number of failed LEDs within the lantern, and replace as necessary in accordance with the Authority's guidelines.

D 2 ELECTRONIC SOUND SIGNALS

Turn off power to the sound signal. Visually inspect the mounting arrangement for structural integrity, and the housing for cracks, crazing, holes, etc. Repair or replace if necessary. Inspect the emitter openings for debris or dirt and clean if necessary. Apply power to the sound signal, command the fog detector to turn the horn on (if so equipped), and note if all emitters are operating, emitting a pure tone, and providing the correct sound character. Ensure drain holes in fog signal emitters are kept clear. Also, the fog detector calibration must be checked.

D 3 WAVE-ACTIVATED SOUND SIGNALS

Bells, gongs, and mounting hardware should be inspected for tone, wear, cracks, excessive rust, missing shock pads, and loose hardware. Bells and gongs that are excessively worn should be rotated or replaced. Bell and gong stands should be inspected for cracks, and repaired or replaced as necessary. Hammer hinges should be checked for wear and free movement. Hammer heads should be adjusted to properly impact the bell or gong, and replaced if necessary. Hammer heads that are worn should be rotated or replaced. Replace hammer bars if they are broken or severely bent.

Whistle balls should be replaced each time the buoy is overhauled. The ball valves on whistles should be checked for free operation and cleaned of salt and dirt. The air gap should be adjusted.

D 4 DAYBOARDS

Faded, damaged, or missing dayboards should be replaced.

D 5 RETROREFLECTIVE MATERIAL

Any retroreflective material which is peeling or faded should be replaced.

D 6 TOPMARKS

Repair or replace topmarks and mounting hardware as necessary.

D 7 DISSIMILAR MATERIALS

Wherever possible, electrochemically compatible materials and fasteners should be used for the repair and refurbishment. Even subtle differences in electrical potential can lead to significant corrosion. For example, corrosion will occur even between cast iron and mild steel. If dissimilar materials must be used take care to isolate dissimilar materials from each other to prevent galvanic corrosion, by using plastic isolation such as plastic washers between the dissimilar materials, and also between the fasteners and the structure. Another alternative is plastic-coated fasteners. Where contact between dissimilar materials is unavoidable, it may be necessary to install a cathodic protection system to minimise galvanic corrosion.

D 8 CLEANING

Cleaning is generally required each time an aid is serviced. Cleaning covers those actions required to maintain the signal colour; to remove marine growth for reasons of colour retention or for reduction of drag or weight on floating AtoN; and to remove salt, dirt, or bird droppings from lanterns and solar panels. Modern pressure washing equipment is particularly suitable for these processes in the field, as all contaminants can be removed without introducing solvents or detergents into the environment. Care must be taken to ensure that correct pressures are used, as excessive pressure may result in the paint coating being removed, damage being caused to solar panels, mortar being removed from masonry structures, or other similar problems. Although manual scraping can also be used to remove marine growth from buoys, this can easily damage the coating system, and should be avoided if possible.

ANNEX E POWER EQUIPMENT

E 1 SOLAR PANELS

Check to be sure that the tilt angle is properly set for the aid. Check the solar panel framework and mounting hardware for corrosion and tension. Check the solar panel for broken glass, and for evidence of water intrusion around the edges of the glass. Discolouration of the solar cells and potting material are typical signs of water intrusion. Inspect wiring for cuts, abrasion, and UV degradation. Where plugs and sockets are used, check for water ingress or corrosion. Clean the solar panel with fresh water. Test the power output, including the solar regulator. Replace the panel and/or solar regulator if necessary.

E 1.1 SECONDARY BATTERIES

Secondary batteries will need to be replaced before the end of their efficient working life. This is difficult to specify accurately as it will depend on the system used and the operating environment. Check the batteries for cracks, corroded terminals, and electrolyte level (as appropriate). Check the battery voltage in both on-load and off-load conditions.

Inspect battery boxes for damaged flanges, covers, gaskets, vent valves, and securing hardware. All accessible wiring and connections should be visually checked for cracking, deterioration, and corrosion. Wire retaining clips should be checked to ensure the wiring is secure. Stuffing tubes should be inspected.

E 2 PRIMARY BATTERIES

Check the batteries for cracks, corroded terminals, and electrolyte level (as appropriate). Check the battery voltage in both on-load and off-load conditions. Primary batteries will have to be changed before their capacity is exhausted by the electrical load (lantern, fog signal, racon etc.).

E 3 GAS CYLINDERS

Information may be found in the IALA Practical Notes for the Safe Handling of Gases, October 1993.

E 4 DISSIMILAR MATERIALS

Wherever possible, electrochemically compatible materials and fasteners should be used for the repair and refurbishment. Even subtle differences in electrical potential can lead to significant corrosion. For example, corrosion will occur even between cast iron and mild steel. If dissimilar materials must be used take care to isolate dissimilar materials from each other to prevent galvanic corrosion, by using plastic isolation such as plastic washers between the dissimilar materials, and also between the fasteners and the structure. Another alternative is plastic-coated fasteners. Where contact between dissimilar materials is unavoidable, it may be necessary to install a cathodic protection system to minimise galvanic corrosion.

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ANNEX F FAILURE PATTERNS

With the introduction in the 1960's of the first Boeing jumbo jets, questions were raised about the sense of continuing with maintenance requirements based on the traditional 'bath-tub' curve maintenance paradigm present at the time. Research found that most failures were not age-related, where the equipment failed because of length of use. It meant that time-based preventative maintenance was pointless in most cases. 'Age-related use' includes stress fatigue failures (e.g. shafts breaking, springs breaking, boiler tubes leaking), erosion/corrosion failures (e.g. material erosion, metal corrosion), wear-out failures (e.g. car tyre tread wear, packed gland leaks) and other such failures where the length of operating time contributes to the eventual failure.

Non-time related failures were unpredictable! Time in service had no influence on 77% to 89% of the failures. This is not the same as saying that there as no reason for the failure. There will definitely be reasons for a failure, but you cannot predict when there will be a failure based only on the age of the equipment. For the vast majority of equipment, you need to base maintenance on non-age related factors.

Most equipment assemblies and components eventually settle into a long period of chance failure. About 15% to 20% of maintenance will repeat based on age-related factors. This can be seen in work requests for the same repair again and again over a period of years.

It will be found that time-related failures by looking at your work orders on each item of equipment for as far back as you can and creating a Pareto Chart of its failure history. Good answers can be achieved by asking long-serving maintainers and operators 'what keeps failing on each piece of equipment?'

About 80% - 85% of repair work orders will happen randomly. The date cannot be predicted when they will occur. But it is possible to detect that they have started. It is possible to use the changed condition of the equipment to tell when a failure is due.

With around 80% of equipment failures being totally unpredictable based on the equipment's age, you must have a maintenance strategy to deal with them.

Around 20% of time-based repetitive failures are addressed by undertaking preventative maintenance and planned replacement maintenance. But non-time related failures cannot be addressed by renewal-based maintenance strategies, they require different solutions.

If renewal based maintenance strategies are applied to non-time related failures about 80% of money, time and effort will be wasted!

With time-random failures the simplest (but not the only) management strategy to use is to inspect your equipment and look for evidence of degraded conditions. A continuous means of monitoring condition by trending an equipment's performance graphically (e.g. power use verses throughput) can be used, or periodic inspections of equipment condition through observation and data measurement (e.g. lubrication sampling, temperature measurement, etc.) can be introduced.

If condition monitoring is based on timed inspections, the time periods must be set at a frequency that will permit the change to be spotted well before the impending failure. Figure 2 shows a frequency inspection period that will detect the degrading performance well before the failure.

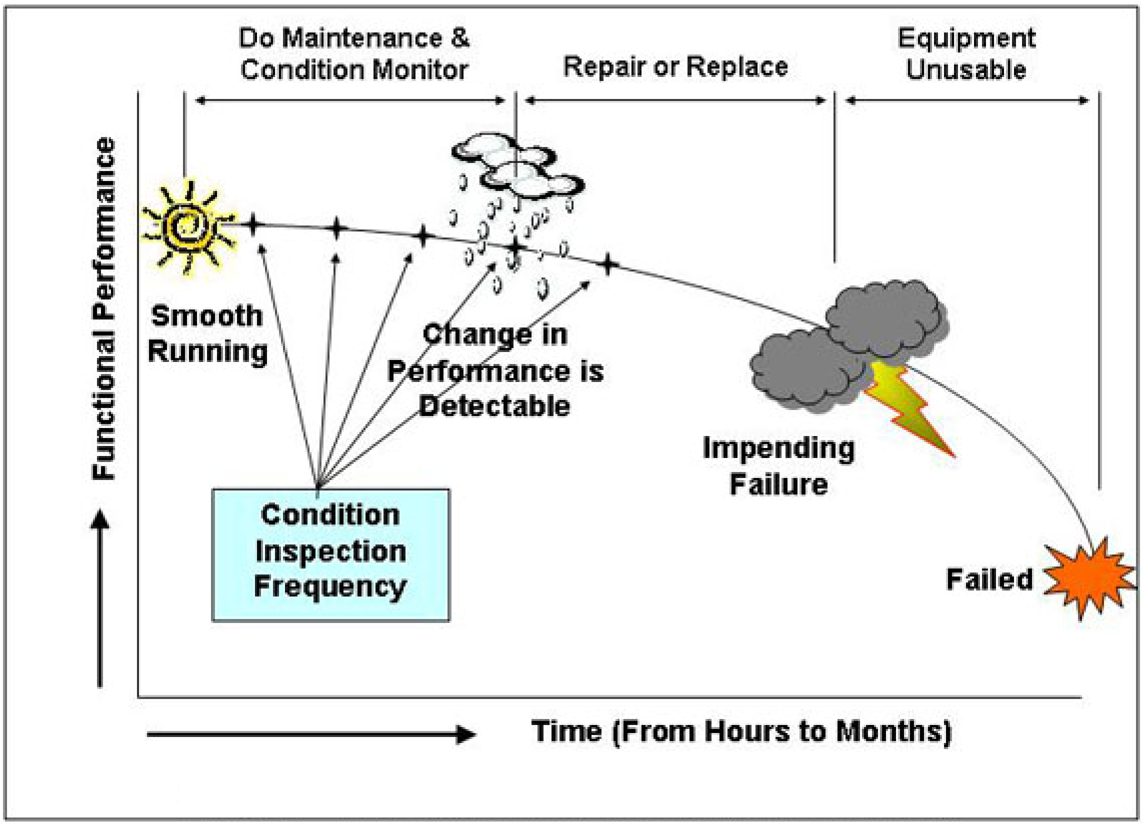

Figure 2 Setting the Condition Inspection Frequency

Having discovered the start of a failure its repair can be prepared for, or strategies be put in place and changes made in its use, to extend the time to failure.

But doing condition based maintenance will only marginally reduce your maintenance costs. The main thing condition monitoring does is to tell you that you have a problem in time to deal with it in a low cost way. It does not stop the problem!

There is one more step that must now be taken to drastically reduce maintenance costs. The failure mode must be removed. Having discovered a cause of failure through condition monitoring, it must be got rid of, or else it can randomly occur at anytime in the future after it is repaired. Only by removing failure modes will future maintenance be significantly reduced.

ANNEX G BENEFITS OF CONDITION BASED MONITORING

The following examples illustrate the benefits of Condition-Based Maintenance.

In order to demonstrate the difference between a conventional planned preventative maintenance and a condition based approach, consider how the approaches could be applied to a steel mill.

The steel mill consists of a series of rollers driven by electric motors working through gearboxes. The steel ingot is fed into the first roller and is partially flattened. It proceeds through successive rollers gradually being flattened into a thin sheet of steel at the final roller.

The traditional planned preventative maintenance system involves a full strip down during the annual factory shut down for summer holidays. During this shut down period gearboxes are opened, oil is changed, bearings are all changed and oil pumps are cleaned out and condition of the gear wheels is checked for damage. In the motors, bearings are replaced and brushes are replaced, commutators are cleaned and wiring and connections all checked. Bearings on the rollers are replaced.

During the following year, periodic bearing failures are encountered as the failure pattern for bearings is random. Gearbox oil leaks periodically occur when inspection plates or covers are not correctly replaced or replaced without seals. On one occasion a rag was accidentally left in the gearbox and found its way into the oil outlet. This resulted in blockage of the oil lubrication system with a consequent major failure of the gearbox. On another occasion a piece of wood was accidentally left in the gearbox and jammed in the gears again causing serious gearbox damage.

A further recurring cause of failure arose when two sheets of steel accidentally stuck together and went into one of the rollers causing it to jam. In this instance the roller would stall resulting in serious shaft or gearbox damage.

A condition based approach would take a rather different view.

As the failure pattern of bearings is random, temperature and vibration measurements were taken at weekly intervals to identify any bearings that were approaching failure. Bearings were not then replaced during annual shut down. This immediately removed the unnecessary cost of annual bearing replacement as well as avoiding replacing good bearings with new but weaker bearings.

Oil samples were taken at weekly intervals and tested for viscosity and grit content. Oil was only changed when these parameters were outside tolerance. This meant that oil was only changed at very infrequent intervals and was not changed at annual shut down. This removed the time required for oil change as well as the maintenance induced faults that traditionally occurred.

A shear pin system was installed in the drive system between each gearbox and the rollers so that if the rollers jammed the shear pin disconnected the roller from the gearbox resulting in no damage to any of the drive train. Once the jam was cleared a new shear pin was installed and the production line restored within a few minutes.

It is clear that the condition based approach not only reduced the amount of work required at annual shut down maintenance but also significantly improved the reliability of the production line.

ANNEX H PARAMETERS FOR AtoN CONDITION BASED MAINTENANCE

Applying this thinking to lighthouse and AtoN systems would clearly provide a more cost effective maintenance system. Since the basic concept is to measure critical parameters and only carry out maintenance dictated by out of tolerance parameters, the following list of measurable parameters has been drawn up.

1 Mooring chain wear.

2 Bearing vibration.

3 Bearing temperature.

4 Battery admittance/ conductance.

5 Battery water consumption.

6 Battery voltage, with temperature correction if necessary.

7 Battery charger condition – normal/fail.

8 Battery electrolyte specific gravity.

9 Floating aid position.

10 Position (e.g. DGPS integrity monitor).

11 Surface colour.

12 Paint thickness.

13 Structures metal thickness.

14 Building humidity – damp meter and wet/ dry bulb thermometer.

15 Building temperature.

16 Building IR camera.

17 Cathodic anode consumption.

18 Lamp service life/ spares consumption.

19 Degradation of luminous intensity of light source.

20 Electrical energy consumption.

21 Electrical current.

22 Electrical voltage.

23 Electrical frequency.

24 Check wind/ solar gen output against met weather conditions.

25 Dirt contamination.

26 Contact/ connection/ area temperature.

27 Oil consumption.

28 Oil temperature.

29 Oil pressure.

30 Oil quality – viscosity and dirt content.

31 Electronic systems:

  a Board visible corrosion.

b Temperature using IR camera.

c Output test to specification.

32 Software:

a Functional test;

b Self test/ watch dog.

33 Functional test, including redundant systems.

34 Insulation resistance.

35 Inductance.

36 Earth resistance.

37 Output power history.

38 Lattice tower verticality.

39 Daymark shape.

40 Light intensity.

41 Daylight switch functional test.

42 Monitor light on/ light off times using RCMS.

43 Ship tests:

a Obstruction for light.

b Sector check.

44 Visual inspection checks:

a Safety harness rails.

b Surface corrosion.

c Building condition.

d Access routes.

e Pointing of stone structures / walls.

f Obstruction growing around lights, antennae, solar modules etc.

g Bird fouling on solar modules, lantern glazing and sun switch glazing.

45 Security checks.

ANNEX I EXAMPLE OF MAINTENANCE OF BUOY SOLAR UNIT

I 1 SCOPE

This procedure covers the maintenance or refurbishment of the standard buoy solar units following 5 years' service on station to bring them fit for a further 5-year service period.

I 2 INSPECTION AND CLEANING FOLLOWING RETURN FROM VESSEL

The condition and function of the solar unit equipment should be thoroughly checked as soon as practicable after the solar unit is returned to the Depot.

The complete solar unit should be soaked with fresh water externally and cleaned of salt deposits and bird lime.

The condition of all electrical cables, glands and connections, including the battery connections, should be checked. If of doubtful condition the cable should be replaced, the Solar Modules and Regulator assemblies being returned to the supplier via stores, when the cable is part of these items.

The solar unit should be checked for compliance with the latest issued design drawings and specifications.

I 3 STRIP-DOWN OF SOLAR UNIT

The following items should be removed from the solar unit:

- Batteries;
- Lantern;
- Regulator, if this cannot be fully tested in-situ.

I 4 BATTERIES

Technical Procedure No. TP010 Buoy Solar Unit - Maintenance TP010 – Issue 2 – November 2004 Page 2 of 4

Follow the instructions from the battery suppliers. Technical Procedure No. TP010 Buoy Solar Unit - Maintenance TP010 – Issue 2 – November 2004 Page 3 of 4

ANNEX J MAINTENANCE OR REFURBISHMENT OF A MODULAR STRUCTURE

J 1 SCOPE

This procedure covers the maintenance or refurbishment of the Modular Superstructure following 10 years' service on station to bring them fit for a further 10-year service period.

The work is to be undertaken at Harwich and Swansea Depots under the direction of the Buoy Manager.

J 2 INSPECTION AND CLEANING FOLLOWING RETURN FROM VESSEL

The condition and function of the Modular Superstructure equipment should be thoroughly checked as soon as practicable after it is returned to the Depot.

The complete Modular Superstructure should be soaked with fresh water externally and cleaned of salt deposits and bird lime.

The condition of all electrical cables, glands and connections, including the battery terminals, should be checked. If of doubtful condition, the cable and/or assemblies should be replaced.

The Modular Superstructure should be checked for compliance with the latest issued design drawings and specifications.

J 3 STRIP-DOWN MODULAR SUPERSTRUCTURE

All electrical items should be stripped out of the Modular Superstructure, and inspected for degradation in its physical condition.

All cubicles, solar panels and lantern may be re-used for a whole service cycle once. After the second service cycle, these items must be disposed of in accordance with TH local environment regulations and procedures.

J 4 BATTERIES

Depending on types of battery, all batteries must be replaced to ensure that their condition is guaranteed. The old batteries must be disposed of in accordance with TH local environment regulations and procedures.

J 5 SOLAR MODULES

Check the glass face of the solar modules for cracks or signs of water ingress.

Replace all swell latches.

J 6 MECHANICAL PARTS

Visually check for cracks at welds, battery fixings and fixing down fasteners. If suspect, remove fittings from the damaged area, clean and inspect using an inspection light and magnifying glass. Undertake dye penetrant testing if necessary.

Check for excessive corrosion, especially at crevices and at contact surfaces with dissimilar metals. If excessive corrosion exists, remove fittings from the corroded area and clean away salt and corrosion deposits.

J 7 RE-BUILD

To ensure that a reliable Modular Superstructure is deployed after maintenance, the Buoy Build List should be followed from the pre-commissioning stage onwards. It is important that all checks and tests are carried out it to prevent on-station problems.

ANNEX K ESTATE MAINTENANCE DATABASE

This annex is an example for maintenance database structure.

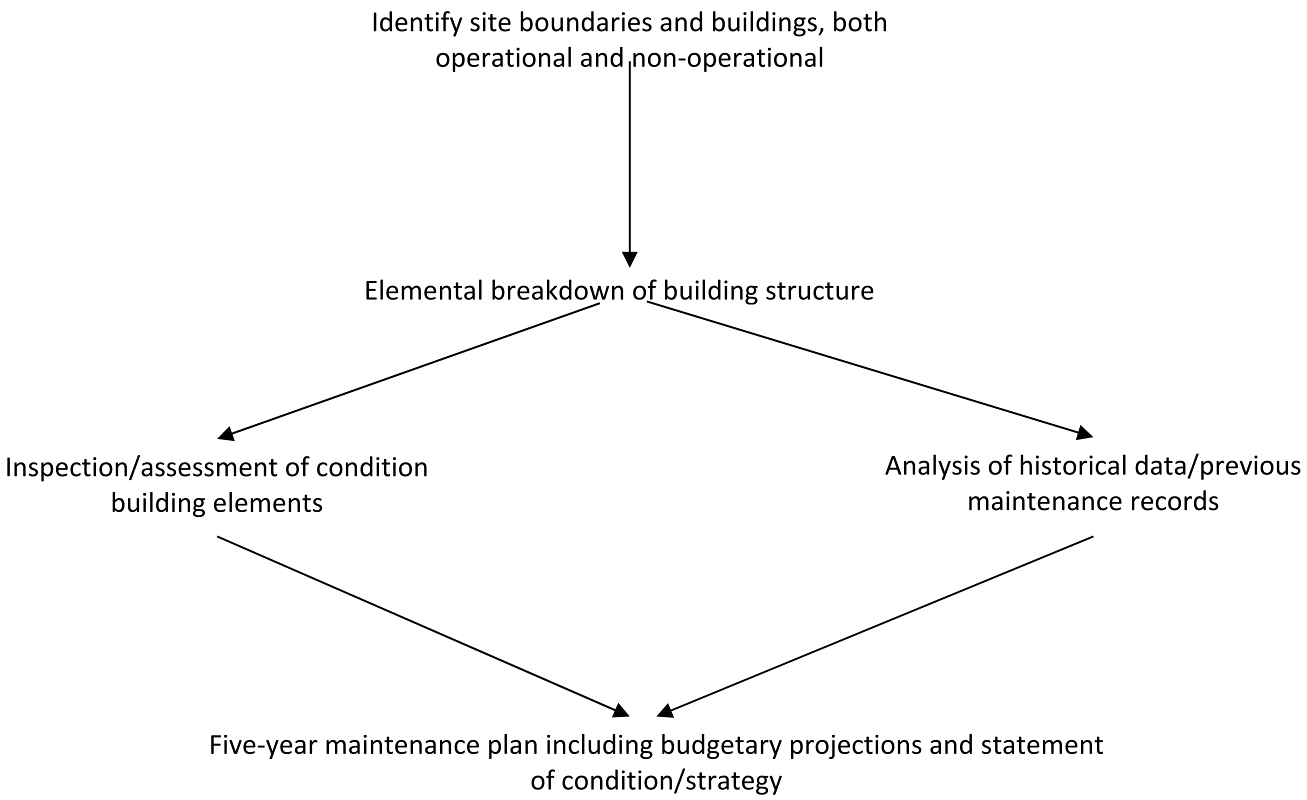

Figure 3 Steps in providing a maintenance database

The above flow chart shows the basic steps required in order to provide a maintenance database. However the database itself will be multifaceted and contain all information and data relevant to each station. It is proposed that information contained in it should include the following:

1 Asbestos register in order to comply with the Control of Asbestos at Work Regulations 2002.

2 Drawings.

3 Site services.

4 Painting program.

5 The Health and Safety File for the Construction (Design and Management) Regulations 1994.

6 Legal information regarding leases, boundaries, rights of way etc.

7 Contact details for all parties including attendants, contractors, utilities, local authorities etc.

8 Aids to Navigation information, equipment, specification, character etc.

9 Standard Maintenance Routines.

10 Work order requisition system.

ANNEX L EXAMPLE FIVE YEAR MAINTENANCE PLAN

This annex presents a five years' maintenance plan.

All the amounts in this table are shown in £ sterling.

Table 1 Five Year Maintenance Plan

Item	Location	Repair Works	Emergency Works	Year 1	Year 2	Year 3	Year 4	Year 5
6.1.00	Roofs	Periodic maintain/ monitor and ultimate replacement		32300	4050	1050	1050	243650
6.2.00	Abutments	Repair/ repoint/ overhaul						47700
6.3.00	Parapets	Repair/ repoint/ overhaul	750	16000				40450
6.4.00	Roof Construction	Check condition of roof timbers and decks in conjunction						4000
6.5.00	Roof Lights	Main replacements Included in works to roofs. Periodic check/overhaul			500		500	
6.6.00	Rainwater goods	Overhaul/replace		16000	9000		2000	37500
6.7.00	Roof Voids	Increase thickness of insulation during Mainworks to roofs. Periodic check/overhaul		-	-	-	-	11000
6.7.03	Roof Voids	Fit handrail & balustrade to access walkway, insulate small tank and pipework to rear roof void	5650					
6.8.00	Lift Motor rooms	Repair/ repoint/overhaul soffits, walls and steel access ladder.	1200	7650				

Item	Location	Repair Works	Emergency Works	Year 1	Year 2	Year 3	Year 4	Year 5
6.9.00	Frame	Check and fit fire protection required to exposed basement steelwork			3500			
6.10.00	External walls	overhaul/repoint		2400	3000			96000
6.11.00	Damp proof course	Repairs		3750		15000		
6.12.00	Windows and doors	Check standard of glazing to window room 121	350					
		Repairs Replacement		44050	1550	42050	1550	178750
6.13.00	External decorations	Redecorate to cyclical programme						59500
6.14.00	Sanitary accommodation & fittings	Periodic service and overhaul		1500	1500	1500	1500	1500
6.15.00	Floors	Periodic replacement of damaged and worn finishes		5000	5000	5000	5000	5000
6.16.00	Ceilings	Replace kitchen suspended ceiling and periodic replacement throughout building		5500	1500	1500	1500	1500
6.17.00	Internal doors	Periodic repair replacement		4500	4500	4500	4500	4500
6.18.00	Internal decorations	Redecorate on cyclical rolling programme		16000	16000	16000	16000	16000
6.19.00	Below ground drainage	Periodic check and flush			600			600
6.20.00	Deleterious materials	Test and remove as necessary	2000	3000				3000

Item	Location	Repair Works	Emergency Works	Year 1	Year 2	Year 3	Year 4	Year 5
6.21.00	Means of escape & Fire equipment	Maintain standard of escape routes and annual test/overhaul equipment		2250	2250	2250	2250	2250
6.22.00	Energy conservation	Replacement upgrade windows included previosly.6.12.01 Increase insulation in roof voids included previously 6.7.04						
6.23.00	Access	Periodic check and overhaul doors and all fittings as required		1750	1750	1750	1750	1750
6.24.00	Environment al	Deep clean kitchen floor tiles		1050				
6.25.00	Safety equipment	Test eye bolts to windows/ add eye bolts to remaining windows		6500	1500	1500	1500	1500
7.00.00	Electrical	Test/repairs/upgr ade		154750	271250	167750	15750	15750
8.00.00	Mechanical	Regular tests/repairs		17000	17000	17000	17000	17000
	TOTALS		9950	340950	344450	276850	71850	788900

ANNEX M AN APPROACH TO PLANNED PREVENTIVE MAINTENANCE OF LIGHTHOUSES

M 1 BACKGROUND

Trinity House (TH) has operated a computer based planned maintenance system for the past 15 years or so on a variety of software packages, currently the system is being operated on a ENGICA Q4 system.

The majority of TH lighthouses have been modernized in recent years; there are seven major lights to be completed by 2007. At the end of this program all stations will be fitted with modern control systems built to a standard either using dedicated electronics or PLC's, using standardized components. As far as practical standard cubicle and system build is used in order to minimize training and spares holding.

All of the stations have remote monitoring and control via telemetry from Harwich, including critical analogue system monitoring.

Mainland stations are typically battery powered floating charge from the mains, backup alternators are provided at DGPS stations. Offshore stations are either solar powered or solar/diesel hybrid or solar/wind/diesel hybrid. In the case of hybrid stations the solar pack is the primary power source, the alternatives being back up or supplemental power supplies.

All stations have comprehensive documentation including operating instructions, as fitted drawings of all systems, maintenance instructions, parts' lists and makers' manuals. This documentation is produced to an established procedure and a high standard. Prior to hand back of a re-engineering lighthouse from Engineering to Operations all appropriate training is completed.

The latest round of modernization has resulted in much improved reliability; the design critically designs out previously unreliable equipment. On completion of each modernization project a formal hand over procedure between Engineering and Operations ensures that the high standards are maintained.

M 2 THE ALTERNATIVE APPROACH TO MAINTENANCE BEING TAKEN BY TRINITY HOUSE

Trinity House takes the view that a combination of Planned and Conditioned Base Maintenance approach is more appropriate to maintenance systems, which are inherently more complex. A less rigorous approach has been taken in reviewing the maintenance need whilst retaining a structured review process. Using the approach taken Trinity House is able to quickly adapt its maintenance methodology to the changing technological demand.

Working from the basis that all stations have been engineered to a high level of reliability and that the current maintenance programs are maintaining the stations in a condition which enable Trinity House to exceed all IALA reliability and availability requirements a review of the maintenance need was carried out. All stations double or triple redundancy built in to the most critical processes, which makes them very resilient as demonstrated by the low level of casualties experienced.

As part of a five-year rolling program of maintenance performance the 'Maintenance Way Ahead 2002-2007' report was produced, this builds on the previous report covering the period 1995 – 2000.

The 2002-7 report identified that some changes were desirable in the way that maintenance was carried out on Trinity House Lighthouses to reflect the substantial improvements in reliability and maintainability, which was resulting from the latest lighthouse modernization program.

The existing maintenance program was based on contract attendants visiting each land or island station monthly (tower station attendants are usually TH operators) to carry out husbandry duties. Twice yearly a team of two or three technicians visit each station to carry out intrusive planned maintenance. This workload resulted in an average of 30 technician days for each station, which when taken with the management, support and planning overhead results in an average annual charge of £20,000 per station.

It was recognized that this level of maintenance on modernized stations was unnecessary and that intrusive maintenance on electronic systems was not capable of enhancing their reliability. It was decided that the maintenance could better be carried out in a three tiered system:

Level One	a none intrusive service primarily confirming the station functionality and key system checks, carried out during the monthly station visit by the attendant.
Level Two	an annual full station service carried out by a team of technicians, carrying out both Planned Preventative and Planned Maintenance tasks.
Level Three	an irregular maintenance routine to deal with major overhauls or repair work, for instance the overhaul of diesel engines (running hours driven), the mercury bath cleaning (five yearly), battery changes (condition driven) or glazing repairs (condition driven). Typically, this work will be planned a year in advance and form part of the Planned Preventative Maintenance for the station. Specialist technician teams typically will carry out this work, possibly as a separate visit to the routine PPM visit.

It is considered that the above maintenance strategy will reduce the maintenance technician effort by about 35%, resulting in both depot and manpower reviews.

At the same time, it was recognized that certain systems had less than optimal reliability, in particular Fog Signal systems, these issues are addressed via an established internal Defect Acquaint system with Operations requesting Engineering to review the system designs.

In order to determine the maintenance requirement of the modernized stations the following approach was taken.

The existing library of Standard Maintenance Routines was reviewed and updated to reflect the changing equipment levels on the stations. As an example as there are no longer any working pneumatic fog signals no references to these are carried over into the updated lists.

A review of spares holding was carried out against the standard station fit out and found to be well managed.

For each station:

1 Check that the station exceeds IALA availability requirements.

2 Desktop review of Planned Preventative Maintenance and Planned Maintenance of the station and the man-hours involved over the past two years.

3 Review that all documentation is up to date.

4 Review the casualty history of each station with particular regard to whether the level of maintenance had an impact on the cause of the casualty.

5 Identifying the major station systems:

- a General.
- b Batteries.
- c Engines;
- d Health and Safety.
- e Aid to Navigation.
- f Telemetry.
- g Premises.

6 Review current Planned Maintenance routines for station.

7 Station visit by a Mechanical/Electrical and Control/Communications line manager and two technicians to review each systems maintenance requirements in light of:

   a Station equipment fit out.

   b Station design.

   c Current Maintenance routines.

   d Station reliability.

8 Select from the revised library of standard maintenance routines the appropriate ones for the station being reviewed.

9 Produce the revised maintenance routine for the station together with agreed planned hours.

An example station is St Bees, located on the North West coast, this was reviewed according to the above methodology and revised maintenance routines determined based on monthly attendants visits and an annual technician visit. The outcome is a reduction in planned time on station by about 15% annually. This review was carried out in one day, with a further office half day for the two line managers.

Attached are station characteristics and the revised maintenance routines, for both the attendant and technician.

M 3 TRINITY HOUSE LIGHTHOUSE MAINTENANCE REVIEW WAY AHEAD

The revised routines are being piloted on fifteen stations during 2002-3 and further fifteen or twenty stations will be added during 2003-4. All the pilot stations in 2002-3 are mainland stations, battery powered, main’s float charge. Several of the stations in 2003-4 will be solar powered island stations and one will be a diesel cycle charge station.

By 2004-5 all modernized stations will be operating to the revised maintenance schedules.

In view of the forthcoming replacement Maintenance Planning System software it has been decided to run the pilot system in paper format until the new software is introduced during 2003-4.

This program has an impact on depots, manpower requirements both technician and supervisory, manpower deployment and support in areas of helicopter and ship usage.