Section

14

Maintenance, Improvement and Replacement Programs

14.1 Introduction

A key element for any successful operation is an effective maintenance, improvement and replacement program. The Panama Canal is not an exception to this concept. In fact, the Panama Canal has been able to succeed in a rapidly changing world because of its continuous aggressive programs directed to maintain and modernize the waterway in response to the demands imposed by new, different and bigger ships that arrive expecting to obtain a safe and expeditious transit. The Executive Vice Presidency for Operations has a significant responsibility on what is considered one of the major objectives of the Panama Canal Authority. This section provides guidance through all Operations units on the concepts that should be applied to succeed in all efforts required to operate with minimum downtime and disruption, while extending to the maximum the service life of Canal structures, facilities, and equipment at a reasonable cost.

14.2 Policy

The organization responsible for management of the Panama Canal is charged, by both the Organic Law of the Panama Canal Authority and the Treaty Concerning the Permanent Neutrality and Operation of the Panama Canal, with the efficient operation and proper maintenance of the Canal and its supporting or ancillary services. Accordingly, the Panama Canal organization shall maintain and improve or replace the structures, facilities, and equipment in its care consistent with sound business principles and applicable law and regulation in order to ensure the safe, efficient, and economical operation and management of the Panama Canal.

14.3 Background

Panama Canal operations and operations support are utterly dependent upon the interactive safe, reliable and efficient performance of a great variety of fixed and mobile structures, systems and equipment. Many of these artifacts are quite complex, specifically designed for Canal operations, exist in considerable numbers of alike or similar units, and are of high-replacement cost either singly or in aggregate. All must perform in a maritime tropical environment often under extreme conditions of load, duty cycle and exposure. Maintenance, improvement and, ultimately, replacement of these artifacts are critical to the cost-effective operation of the Panama Canal. To facilitate presentation, the measures implemented to maintain, improve and/or replace certain Canal structures, systems and equipment are categorized as follows:

a. Locks Maintenance, Improvement and Replacement Programs;

b. Locks Locomotive Maintenance, Improvement and Replacement Programs;

c. Floating Equipment Maintenance, Improvement and Replacement Programs;

d. Waterworks Maintenance, Improvement and Replacement Programs:

- Dam Safety Program
- Bank Stability Programs
- Channel Maintenance and Improvement Program
- Navigational Aids Maintenance, Improvement and Replacement Program
- Aquatic Vegetation Control Program

e. Buildings and Structures Inspection, Maintenance, and Improvement Program; and,

f. Motor Vehicle and Heavy Mobile Construction Equipment Maintenance and Replacement Programs.

14.4 Maintenance, Improvement and Replacement Program Elements

The following frame of reference is provided as a convenient means of relating the great variety of actions involved in the several maintenance, improvement, and replacement programs that are in effect. More comprehensive working definitions of commonly encountered terms are presented in Subsection 14.7.

a. *Maintenance:* The inclusive term for the actions necessary to keep the reliability of a unit or system.

b. *Repair:* The necessary actions to return a malfunctioned, damaged or failed unit or system to satisfactory operation.

c. *Overhaul:* A major repair effort to restore a unit or system to its full range of designed performance.

d. *Improvement:* Relatively small *conversions* or *alterations* of components or subsystems to enhance a unit's or system's performance.

e. *Modernization:* Defines major changes to a unit or system in order to achieve significant enhancement or expansion of its performance.

f. *Replacement:* Action taken to supplant a failed, damaged or inadequate unit or system with new equipment of similar or greater capability.

14.5 Criteria and Standards for Preventive Maintenance, Repair, and Overhaul

Hours of operating time or days/weeks/months/years of lapsed time are perhaps the most common criteria for maintenance, repair, overhaul and related actions. Chemical and physical analyses and a variety of nondestructive testing procedures are also available for some units and systems. Other criteria include inspections, fuel and lubricant consumption, measured clearances or misalignments, observed conditions or defects, component malfunctions or outright failures, accidental damage, performance outside established operating parameters, cost or frequency of minor repairs or adjustments, etc. Common failure modes; oil, vibration and thermal analysis; new requirements, warranty expirations, repair/replacement/resale cost analyses, book value and depreciation rates, safety or hazard reports, etc., are also considered. The sources of these criteria are commonly industrial standards, international standards and Government regulation, and local experience, either singly or in combination.

14.6 Implementation

Beyond the level of consumable items that are replaced or replenished, two or more of the elements defined in subsection 14.4 above are applicable to virtually every unit or system of ACP equipment, buildings, structures or facilities.

Relatively low-value, expendable, short life-span items that are readily available commercially or subject to frequent technological advances are usually maintained and appropriately repaired, then replaced on the basis of failure, deteriorating performance, obsolescence, or more demanding requirements.

More complex systems of higher value and longer life, along with more permanent products of more stable technology, are normally maintained, repaired, and overhauled/rehabilitated and may be reconditioned, converted/altered, or modernized according to the conditions, alternatives, and considerations defined above and in Subsection 14.7.

Six of these major programs, detailed in the attached topic papers, are summarized below:

a. *Locks Maintenance, Improvement and Replacement Programs*

The five locks complexes at Agua Clara, Cocoli, Gatun, Miraflores and Pedro Miguel are of fixed dimensions, permanently positioned, and not amenable to relocation or structural change. The basic locks structures are subject to continuous maintenance, limited improvements and component/subsystem replacements. Comprehensive programs of inspection, preventive maintenance, repair, overhaul/rehabilitation, component reconditioning, conversions/alterations, modernization, and unit/system replacement are conducted in the following locks subsystems: water transfer and control; electrical power and lighting distribution and control; ship movement and positioning; fire protection; buildings; physical security and access; utilities; communications; shops; support equipment. Techniques and procedures for these actions vary substantially depending on the permanent submersion, degree of exposure, or concurrent operational requirement for a particular unit or system.

b. *Locks Locomotive Maintenance, Improvement and Replacement Programs*

The locomotive fleet operating at Gatun, Miraflores and Pedro Miguel Locks totals one hundred (100) units. The differing physical and operating characteristics at each locks complex result in differing workload demands, and thus differing preventive maintenance, repair, and overhaul requirements. However, the criteria for locomotive component reconditioning, conversions/alterations, modernization, and replacement are essentially identical for all locomotives. The electric cranes mounted on locomotive chassis are treated similarly. Major locomotive mechanical components are often transferred to the Pedro Miguel Locomotive Component Repair Facility for extensive work. Locomotive rehabilitation is also performed there. Electrical components are transferred to the Energy Division's Armature Shop for repairs and reconditioning.

c. *Floating Equipment Maintenance, Improvement and Replacement Programs*

There are approximately 174 floating equipment units owned and operated by the Panama Canal Authority. The Executive Vice Presidency for Operations operates tugs, launches, small boats, special purpose barges and floats, locks caissons, cranes, dredges, dredge tenders, launches, small boats, barges, and special purpose craft. Replacement costs of these units range from $60M for a large dredge, to $4M for a tug or dredge tender; between $100K and $400K for a launch, to a few hundred dollars for some of the small boats. Inspection, preventive maintenance, and repair of floats, small boats, and special purpose craft and their propulsion units are normally conducted at the operator/user level and overhauls are seldom required. All other items of floating equipment are subject to inspection, preventive maintenance, repair, overhaul, component reconditioning, conversion/alteration, modernization, and replacement. All navigable floating equipment is subject to marine safety inspection and certification by the Maritime Safety Unit, Board of Inspectors.

d. *Waterworks Maintenance, Improvement, and Replacement Programs*

For purposes of this manual, *waterworks* are defined as those structures, facilities, and systems managed and maintained for the purpose of water management and control within the Panama Canal Authority. This includes Miraflores Spillway, with its day-to-day operation under the responsibility of the Executive Vice Presidency for Operations, but excludes the three locks complexes that are both the operational and maintenance responsibility of the Executive Vice Presidency for Operations. Hydroelectric generating systems and domestic water systems are also excluded from this group. Waterworks maintenance and improvement programs can be categorized by their application to dams (and associated spillways), Canal banks, navigation channels, navigational aids, and aquatic weed control.

(1) Dam Safety Program: The Panama Canal features three main dams with their associated spillways: Gatun, Miraflores, and Madden Dams. In addition, there are 41 saddle dams (25 natural, 16 man-made) in low places on the perimeters of Gatun and Madden reservoirs to achieve the designed reservoir levels. The water stored behind these dams is used for Canal operations to generate electric power and to provide potable water to the Canal area and the cities of Panama and Colon. The dams are also critical to flood control on the watershed. These dams are inspected, maintained and improved through a Dam Safety Program and the Authority conducts annual inspections. The Annual Dam Inspection Report is the basis for repairs and deficiency corrections to preserve the integrity and reliability of the Authority's dams and spillways. Pursuant to the original joint inspection, special instrumentation to evaluate dams' responses to earthquake forces was installed in FY 1990.

(2) Bank Stability Programs: The landslide activity that beset Canal builders still threatens navigation in Gaillard Cut and is, in fact, increases. This latter observation is corroborated by scientific literature indicating that such excavated slopes weaken with time. To counter this condition, the Authority actively pursues a Landslide Control

Program (LCP) along approximately 16.2 miles of a total of some 27 miles of Canal banks. These 16.2 miles of bank slopes are monitored on an instrumented surface control grid by means of surface instrumentation, exploratory boreholes, and borehole instrumentation. Readings are analyzed, mapped, and charted. Earthwork contractors stabilize incipient slides. Access roads and surface and subsurface drainage are constructed and maintained. Slopes are reforested. Emergency work to prevent, or recover from, slides is performed internally and/or on contract depending on magnitude and urgency. A permanent advisory board of eminent consultants reviews the Landslide Control Program. Preventive maintenance is the key to landslide control. Slope movements can be more readily halted before the movements further weaken the earth structure and before rains can accelerate the earth movement.

(3) Channel Maintenance and Improvement Program: The Dredging Division of the Executive Vice Presidency for Operations is responsible for execution of the Channel Maintenance and Improvement Program. Channel maintenance along 24 miles of channel exclusive of the deeper and less confined lake channel is a never-ending requirement driven by a large variety of shoaling conditions that prevail in Canal waters. Of a total of 25.2 square miles of anchorages, the 3.5-square-mile Atlantic Inner Anchorage is especially prone to shoaling. The need for channel and anchorage maintenance is determined by a continuous bottom sounding and survey effort, by projected sedimentation rates, and by observed shoals, bank slumps, and slides that intrude into the channel. Maintenance is accomplished by one or more of three dredges assigned to the Dredging Division. Needs for channel and anchorage improvements are normally identified by the Executive Vice Presidency for Operations. Maintenance and improvement dredging are combined into a ten-year Dredging Plan that is updated and extended annually. Emergency dredging requirements, such as those resulting from major landslides or suddenly emergent shoals, may be met by diverting effort from the Dredging Plan, by activating additional dredges or by contract.

(4) Navigational Aids Maintenance, Improvement and Replacement Programs: The Canal organization installs, maintains, improves and, as appropriate, replaces navigational aids in the Canal and its anchorages and approaches for the safety of Canal operations, and in back and branch channels for the safety of a variety of waterborne Canal support activities. A total of 1,778 units are maintained: 509 fixed and floating aids, 40 spare buoys, and 1,120 low pressure sodium bank lights for Canal operations; 109 small buoys for support activities. The Executive Vice President for Operations establishes operational and support requirements for navigational aids. Procurement, fabrication, construction, and installation is the responsibility of the Dredging Division. Scheduled maintenance and emergency repairs are the responsibility of that Division's Aids to Navigation Unit. Needs and means for improving or replacing navigational aids are determined by the Executive Vice Presidency for Operations.

(5) Aquatic Vegetation Control Programs: Aquatic vegetation and debris continuously threaten safe navigation, efficient operation, and proper maintenance of the Canal and its support facilities. The Protection and Emergency Response Division exercises the

responsibility for control of these growths. The control program employs approved herbicides to control and kill aquatic vegetation, and mechanical means to entrap, harvest and remove the vegetation. Growth and debris near certain critical areas and facilities in the Canal receive special attention. Existing techniques are continuously evaluated, and a constant search is conducted to find new and more effective means of combating this problem.

(6) Other Miscellaneous Programs: Four other collateral waterworks maintenance efforts are not addressed in detail in this section: The 4-mile Atlantic Breakwater; the 1.5-mile Amador Causeway; fire dredging spoil areas ashore; some 11 miles of Canal banks not subject to landslides that require some degree of erosion control or other maintenance by the Dredging Division.

e. *Buildings and Structures Inspection, Maintenance and Improvement Programs*

Maintenance and conservation of the buildings and structures in the ACP inventory is primarily the responsibility of the Executive Vice Presidency for Operations.

f. *Motor Vehicle and Heavy Mobile Construction Equipment Maintenance and Replacement Programs*

Passenger, cargo and special vehicles that operate on streets and highways, and off-road heavy mobile construction equipment, are under the responsibility of the Executive Vice Presidency for Operations, while assigned to different divisions.

(1) The Executive Vice Presidency for Operations operates a larger fleet of motor vehicles (passenger, non-passenger, special purpose) for the ACP. The passenger vehicles are grouped in five categories and the non-passenger vehicles consist of three categories of trucks. Operators are responsible for identifying and reporting deficiencies as occurring. A three-level preventive maintenance program is performed at the motor pool shops. Repairs are performed as indicated by operator reports and preventive maintenance inspections.

(2) Heavy mobile construction equipment is employed by the Executive Vice Presidency for Operations. Preventive maintenance, repairs, and overhauls are generally the responsibility of the operating division. Large diesel engines from this equipment are usually overhauled in the Fleet and Equipment Maintenance Division. Replacement decisions are based on nominal service life, estimates of cost of repairs, breakdown/repair history, and parts availability.

14.7 Definitions

For the purposes of this document, the following working definitions are offered:

a. *Inspection*: Action taken to identify necessary measures performed to preserve, restore or improve the operational capability of a unit or system. Inspections are an integral part of preventive maintenance programs and also may be recurrently or specifically scheduled to identify required and desired items for repair, overhaul/rehabilitation, reconditioning, conversion/alteration, modernization, or replacement. Inspections are also critical to any decision to advance or defer work upon, or replacement of, a unit or system.

b. *Maintenance*: Inclusive term for the full range of actions taken to preserve, restore, or improve the operational capability of a unit or system.

c. *Preventive Maintenance*: Actions taken by operators/users and, in some cases, by mobile, station, or pool technicians or craftsmen to keep units in reliable operating condition, reduce downtime, extend service life, and thus minimize costs and maximize efficiency. This includes measures such as adjustment, cleaning, lubrication, and replacement or replenishment of consumable items that can be performed on running units or on operable units during scheduled or opportune periods of disablement that do not preclude performance of assigned tasks. Preventive maintenance actions normally take place before a unit or system malfunctions or fails.

d. *Planned Maintenance Programs*: Detailed, structured maintenance management programs of varying complexities and scope that have been developed for many complex or high-value units and systems. Some of these programs concentrate on preventive maintenance, but others cover the full scope of maintenance. Manufacturers' recommendations and engineering standards coupled with records of historical performance are blended together with feedback from reliable operators and input from experienced craftsman to form the basis on which planned maintenance programs are developed. Commitment to proper execution of the programs is obtained by providing realistically attainable schedules that can be monitored to see how well the program functions. Through the use of micro-computer technology, large amounts of data can be input, and other desired information can be extracted, to assist in determining the need for additional maintenance actions, parts replacement, overhaul, etc.

e. *Repair:* Maintenance actions taken to replace or mend failed or deteriorated components that impair or preclude a unit's or system's operational performance. Depending on their magnitude and complexity, repairs may be performed by operators/users or technicians/craftsmen on site, in field shops, or in major shops or industrial facilities. Repairs normally require that the unit or system be placed out of service for the duration of the repair action.

f. *Overhaul or Rehabilitation*: Comprehensive repair actions taken by technicians/craftsmen to restore a unit or system to full capability within specified

ranges of performance criteria. Normally, it entails placing the unit or system out of service for an extended period and removal from the operating site or environment. It may include conversions, alterations, or modernization.

g. *Alternative Actions:* Certain actions may be taken in conjunction with or in lieu of repair actions to enhance or extend the serviceability of a unit or system:

(1) *Reconditioning*: Actions taken to restore failed or worn major components to like-new condition for subsequent reincorporation or reinstallation in a unit or system. Normally accomplished by technicians/craftsmen in shop or industrial facilities away from the operating site or environment.

(2) *Conversions or Alterations*: Actions taken to improve, enhance, or modify the performance/reliability/maintainability, or to ameliorate obsolescence, expense, or deficiencies of major components of a unit or system. Most often performed in conjunction with unit/system overhaul or rehabilitation, but some lesser actions may be undertaken independently.

(3) *Modernization*: Major actions taken to enhance or extend the capability, efficiency, performance, or serviceability of a unit or system. Normally, are performed in conjunction with or in lieu of overhaul or rehabilitation and incorporating outstanding alterations or conversions.

h. *Unit or System Replacement*: Actions taken to supplant failed, worn, or inadequate equipment normally with equipment of similar or greater capability, or of more advanced technology. Replacement decisions may be based upon inspections, major or catastrophic failure, obsolescence, lack of reliability, possibilities of repairing, new requirements, cost benefit, etc.