SECTION 01 81 13 – FILLING AND EMPTYING SYSTEMS

1.01 SUMMARY: [A16]This Section identifies the hydraulic requirements for the design and construction of a filling and emptying (F-E) system for the third set of locks, consisting of one lock complex on the Atlantic end and another one on the Pacific end of the Panama Canal. Each of the new structures shall be triple-lift locks with contiguous chambers to raise and lower vessels transiting from ocean- to lake-level and vice versa.[A16] Each lock chamber shall have Water-Saving Basins (WSBs). WSBs' arrangement constraints shall be according to Section 01 10 00 (*General Project Requirements*), Subparagraph 1.04 A.1.a.3) (*Water-Saving Basins (WSBs)*).

A. **Scope of Work**: [A16]The work required by the Contractor under this Section includes, but shall not be limited to, the design, construction, and testing of the F-E system:[A16] [A17](Subparagraph 1.02 C. explains the culverts, conduits, and WSBs in greater detail.)[A17]

1. **Main Culverts**: [A17]The F-E system shall have one main longitudinal culvert along each side of the lock chambers to laterally feed and empty the Chambers through the side ports. Water for filling shall be obtained from the Gatun Lake, from upper levels of lock chambers, and from WSBs. Water shall be discharged to ocean, lower levels of lock chambers and WSBs.[A17]

2. [A16](Reserved)[A16]

3. [A17]**Water-Saving Basins**: The WSBs shall temporarily store part of water released from the lock chambers so that it can be reused to raise water levels in the chambers.[A17]

4. **Conduits**: [A17]The conduits shall transport water between the lock chambers [A17] and the WSBs.

5. **Main Culvert Valves**: [A17]These valves shall control water flow between contiguous lock chambers, from Gatun Lake, and to ocean level.[A17] Specifications of valves are provided in Section 01 81 23 (*Culvert and Conduit Valves*).

6. **Conduit Valves**: [A17]These valves shall [A17] control water flow between the WSBs and the main culverts. Specifications of valves are provided in Section 01 81 23 (*Culvert and Conduit Valves*).

7. **Ports**: [A17]The ports shall both feed water from the culvert into the lock chamber and draw it back from the chamber into the culvert.[A17]

B. **Main Objectives**: The main objectives of the F-E system are to achieve the functional and operational objectives of Section 01 10 00 (*General Project Requirements*), specifically the four main objectives of the [A17]lock F-E[A17] systems are to: 1) minimize the F-E times to increase the vessel-throughput capacity of the system, 2) minimize [A7]water slopes and[A7] hawser forces to achieve a balanced and safe process, 3) minimize the overall use of fresh lake water, and 4) maintain the vessel positioned in the center of the chamber longitudinally and transversally during the F-E process. [A16]The Contractor shall

design and construct an F-E system that is as symmetrical as possible and achieves these objectives.[A16]

C. **Lock Operations**: F-E systems shall be designed for all operating scenarios of vessels transiting in both directions [A17]— Up Lockages (from ocean to lake level) and Down Lockages (from lake to ocean level) — [A17] and for different vessel sizes and types, including multiple vessel lockages. See Section 01 92 00 (*Facility Operation*) for an operational description.

D. **Operations with or without the use of WSBs**: [A17]Under standard operating conditions (see 1.03 B), the Contractor's hydraulic design shall provide daily average water savings of at least 59% using the WSBs, as compared with not using them, [A17] [A16]for all combinations of mean high and mean low levels of Gatun Lake and oceans.[A16] The locks shall also meet the Employer's performance criteria with and without the use of WSBs, by means of gravity-fed systems, without the use of pumps.

E. **Hawser Forces**: During the F-E process for the lock chamber, water surface turbulence and hawser forces will be generated due to system asymmetry (for example, the mode for operating the inner gates is different between the [A17]Up-Lockage and Down-Lockage [A17] processes). These [A7]water slopes and[A7] hawser forces shall be kept at a minimum in order to reduce mooring forces.

F. **Throughput Capacity**: Lock-throughput capacity is determined by the amount of time needed for vessels to enter and exit the chamber, for the gates to open and close, for the hydraulic F-E process, for the movement of vessels through the lock chambers, and for mooring / unmooring [A7] Section 01 92 00 (*Facilities Operation*).[A7]

G. **Preliminary Hydraulic Design**: [A17]The Employer, after conducting a multi-criteria analysis, has selected the initial configurations and features that meet the needs of the system, including a three-level lock with WSBs; an F-E system that provides for high system reliability, redundancy, and symmetry and that is comprised of two longitudinal culverts, side ports to the lock chambers, conduits at each chamber with the corresponding conduit valves, and a minimum of four sets of valves at each main culvert location (lake intake, between chambers, and at ocean discharge); rolling gates; a vessel-positioning system using tugboats, mooring lines, and bitts on lock walls; and other features. The Employer has selected the main design options and design characteristics for the hydraulic F-E system, while detailed final design considerations and performance shall be the responsibility of the Contractor. The Employer has provided the Contractor in Volume VI (*Reference Documents*) results of the numerical models already developed and any available information from the models that might be of assistance to the Contractor for information purposes only, and subject to the provisions of Sub-Clause 5.1 (*General Design Obligations*) of the Conditions of Contract. [A17]

H. **Design Criteria**:

1. [A16]The Employer's conceptual design of the F-E system for the new locks of the Panama Canal has involved a series of tests, model studies, scenarios, selection and decision-making that the Employer has conducted with the assistance of his design engineers (see Volume VI (*Reference Documents*) [A17]subject to the

provisions of Sub-Clause 5.1 (*General Design Obligations*) of the Conditions of Contract). [A17]

2. The developed design criteria included in this Section are critical for the optimum performance of the system, with minimum operating times, at its maximum capacity, minimum water usage, and maximizing vessel safety throughout Transits.[A16]

I. **Further Modeling**: The [A15]Employer contracted the services of a recognized hydraulic laboratory to carry out [A15] the physical modeling studies for the new locks' hydraulic design. [A17]The results of these studies have been provided to the Contractor for information purposes only, and subject to the provisions of Sub-Clause 5.1 (*General Design Obligations*) of the Conditions of Contract, and [A17] comprise the following:

1. A scale physical model to verify, refine, and validate the configuration, geometry, and conceptual design of the F-E system for the new locks. Study reports CPP TO5-Task5.1-CNR-R001 Interim model results (26-march-2008), TO5-Task5.1-CNR-R002 Optimization tests report (18-april-2008) and TO5-Task5.1-CNR-R003 Final report (14-October-2008).

2. A 3-D numerical model analyzing in detail the lock outlet flows as well as the density currents in the lower chamber and the navigational channel for the Pacific sea entrance. [A16]Study report CPP TO4-Task4.2-TEC-R002 Numerical model of density currents Pacific side [A16] [A17](18-april-2008). [A17]

3. A navigation-tank model that simulates the horizontal movements of vessels entering and exiting lock chambers with different approach wall configurations, arriving maneuver options, chamber-to-chamber vessel movements, for different vessel types, sizes and water level conditions. [A16]Study reports CPP TO3-Task3.1-FHR-R015 Model tests 12000 TEU (26-march-2008), TO3-TASK3.1-FHR-R018 MODEL 8000 TEU AND TO3-TASK3.1-FHR-R021 BULK CARRIER [A16] [A17] (18-april-2008). [A17]

J. [A16]The Contractor shall prepare the hydraulic designs, including numerical modeling.

1. The Contractor shall validate its F-E design using its own modeler for 2-D and 3-D designs and its own numerical model as included in the Contractor's Technical Proposal and shall provide a complete and detailed report to the Employer's Representative.

2. The Contractor shall also validate its F-E design with its own selected laboratory or may contract directly the Employer's selected laboratory.[A16] All physical models and tests shall be photographed, and digital copies shall be included in a report. Time events shall be recorded; a digital video shall be made for the records and reports. Complete and detailed reports shall be submitted to the Employer's Representative for approval. [A16]The Contractor's physical model to validate his F-E system design and performance is only required after the [A17]Commencement Date.[A17] See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

3. The Contractor's hydraulic design information shall be submitted in accordance with Section 01 33 00 (*Submittal Procedures*).[A16]

4. The Contractor shall provide the Employer's hydraulic experts and other Employer's Personnel with information for reviewing the design, models, results, and reports as they are developed and produced. The Employer's hydraulic experts and other Employer's Personnel shall be granted access to Contractor's facilities to meet with the Contractor's hydraulic designer, modeler, and other Contractor's Personnel in order to comment, discuss and review the design, models, results and reports as they are developed and produced. Full responsibility for the F-E system design and performance shall remain with the Contractor. See Section 01 40 00 (*Quality Requirements*).

1.02 [A15]REFERENCES:[A15]

A. **Standards**: The Contractor shall use the following reference standards for design.

1. **Permanent International Association of Navigation Congresses (PIANC)**:

   Final report of the international commission for the study of locks (1986).

2. **U.S. Army Corps of Engineers (USACE)**:

   EM 1110-2-1604 Hydraulic Design of Navigation Locks (1995).

   EM 1110-2-2602 Planning and Design of Navigation Locks (1995).

3. **Recommandations pour le calcul aux états-limites des ouvrages en site aquatique (ROSA)**:

   ROSA 2000 Recommandations pour le calcul aux états-limites des ouvrages en site aquatique (2000). The regulations of ROSA 2000 are based on Eurocodes and completed with specific requirements for maritime structures.

4. **British Standard Institute (BSI)**:

   BSI 6349 British Standard Code of Practice for Maritime Structures.

5. **Deutsches Institut für Normung (DIN)**:

   ISO 7545 Shipbuilding and marine structures - Inland navigation - Single-lock automatic couplings for push tows (1983).

6. **Empfehlungen des Arbeitsausschusses Ufereinfassungen (EAU)**:

   Recommendations of the Committee for Waterfront Structures - Harbors and Waterways (2004), 8th edition.

7. **American Society for Testing and Materials (ASTM) International Standards**:

ASTM E29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

B. **Units**: Reference units are included in Section 01 42 23 (*Units of Measurement*).

C. [A17]**Explanation of Terminology**: Refer also to Section 01 42 16 (*Definitions*). [A17]

1. **Culverts and Conduits**:

a. **Main Culverts.** [A17]These are the longitudinal channels moving water by gravity from lake to lock, chamber to chamber, and lock to ocean level. [A17] The near main culvert at each lock complex is the one closest to the WSBs, while the far main culvert is the one on the opposite side of the chamber.

b. **Conduits.** [A17]These [A17] are the transversal sections joining lock main culverts with the WSBs.

c. **Secondary culverts.** [A17]These are [A17] manifold-like hydraulic structure connecting the main culverts with the lock chambers through side ports. [A16]See Subparagraph 1.03 A.3.b.[A16]

2. **Lock Chambers**:

a. The upper chamber is the highest lock chamber connecting to Gatun Lake.

b. The middle chamber is the chamber between the upper and lower lock chambers.\

c. The lower chamber is the lock chamber connecting to the sea.

3. **WSBs**: [A16]The nomenclature for the different WSB levels based on the Employer's conceptual design was chosen to avoid confusion with the nomenclature for the different chamber levels, any changes by the Contractor to the number of basins shall be adjusted to obtain the same intent.[A16]

a. The top WSB is the highest basin of the three basins in each lock level.

b. The intermediate WSB is the one between the top and bottom basin.

c. The bottom WSB is the lowest basin.

4. **Levels**: The following water levels shall be used for all computations.

a. **Gatun Lake** Water Levels:

1) **Maximum Operating Level**: +27.13 m (+89 ft)[1] PLD.

2) **Mean Operating Level**: +25.9 m (+85 ft) PLD.

3) **Minimum Operating Level**: +24.70 m (+81 ft) PLD.

4) **Extreme Low Level**: +23.8 m (+78 ft) PLD[2].

b. **Atlantic Ocean** Water Levels:

1) **Highest High Water**: +0.57 m (+1.86 ft) PLD.

2) **Mean High Water**: +0.30 m (+0.97 ft) PLD.

3) **Mean Sea Level**: +0.11 m (+0.36 ft) PLD.

4) **Mean Low Water**: -0.12m (-0.384 ft) PLD

5) **Lowest Low Water**: -0.39 m (-1.29 ft) PLD.

c. **Pacific Ocean** Water Levels:

1) **Highest High Water**: +3.66 m (+12.0 ft) PLD.

2) **Mean High Water**: +2.14 m (+7.02 ft) PLD.

3) **Mean Sea Level**: +0.31 m (+1.01 ft) PLD.

4) **Mean Low Water Springs**: -2.32 m (-7.62 ft) PLD.

5) **Lowest Low Water**: -3.44 m (-11.30 ft) PLD.

D. **Related Publications** as background information:

1. PIANC 26th International Navigation Congress in Brussels (June 1985).

2. Hydraulic design experiences and practices of navigation locks in China (PIANC newsletter 69 – 1990).

3. Hydraulic design of a longitudinal culvert for a lock filling and emptying system. Journal of Hydraulic Engineering, John E. Hite (2004).

[1] Metric values shall govern; English units are included for reference and illustrative purposes and are rounded. (deleted text)
[2] Extreme lake level may be implemented during severe dry-season events such as seen during El Niño in 1997-98.

4. Filling and Emptying Systems for High-Lift Navigation Locks, G.A. Pickering (PIANC 26th Navigation Congress, June 1985).

5. Locks on the wide-gauge Rhone waterway, R. Pinatel (Compagnie National du Rhône – La Houille Blanche bulletin 2, March 1981).

6. Irregular operation of saving-basin navigation locks, F. Mosony (University of Karlsruhe, Germany – PIANC bulletin 64, 1989).

7. Navigation locks of Tucurui, C.E. Almeida (Universidad de Sao Paulo, Brasil – PIANC 26th International Navigation Congress, June 1985).

8. The filling of a high lift lock and its problems, D. Pinto da Silva (PIANC bulletin 52 – 1986).

9. Internal Flow Systems, D.S. Miller (British Hydromechanics Research Association, UK, 1996).

[A7](Deleted text)[A7]

E. **Drawings**: See the list of drawings in Section 00 01 15.06 01 (*List of Drawings*).

F. **Study Reports**: [A16]included in Volume VI (*Reference Documents*):[A16]

1. Conceptual Design of the Post-Panamax Locks - Update of Pacific Locks Conceptual Design and Harmonization of Atlantic Locks Conceptual Design, Revision A, Consorcio Post-Panamax (CPP), April 2005.
2. Alternative Conceptual Design of Pacific and Atlantic Post-Panamax Locks-3x2 WSB, CPP, July 2005.
3. Diseño Conceptual de las Esclusas Post-Panamax, CPP, March 2002.
4. Panama Canal concept design - Atlantic lock structures - Third lane Project (Gate Selection Study), USACE, 2003.
5. TO1-Task 1.2.5-CNR-R012 Numerical model of variations for the selected F-E system, CPP, September 2007.
6. TO1-Task 1.2.5-CNR-FHR-R013 Specification on hawser force criteria, CPP, September 2007.

[A7]7. TO3-Task 3.1-FHR-R015 Model tests 12000 TEU, CPP, March 2008.

8. TO3-Task 3.1-FHR-R018 Model tests 8000 TEU, CPP, April 2008.
9. TO3-TASK3.1-FHR-R021 MODEL TEST BULKER, CPP, APRIL 2008
10. TO4-Task 4.2-TEC-R002 Numerical model of density currents Pacific side, CPP, April-2008.
11. TO5-Task 5.1-CNR-R001 Interim report validation tests, CPP, March 2008.
12. TO5-Task 5.1-CNR-R002 Optimization tests report, CPP, April 2008.[A7]
13. TO5-Task 5.1-CNR-R003 Final report, CPP, October 2008.

1.03 REQUIREMENTS:

A. **Functional Requirements**:

1. The F-E system shall be gravity-based, without use of pumps.

2. [A8]Each lock chamber shall have Water-Saving Basins (WSBs).[A8]

3. The F-E system shall consist of the following elements:

   a. Two main culverts connecting Gatun Lake with the secondary culverts [A17]and with the lock chambers and then [A17] draining to the ocean.

   b. Two secondary culverts (for each lock chamber) with ports to [A17]the chamber and connections [A17] to the main culverts. [A15]The Employer's conceptual design included a secondary culvert to improve the symmetry of the F-E system in the lock chamber; the Contractor may propose an alternate solution as long as F-E symmetry is achieved. [A15]

   c. [A8]Water-Saving Basins (WSBs)[A8] [A16]sufficient in number and size to achieve required water savings, see Subparagraph 1.01 D.[A16]

   d. [A17]Sufficient conduits, connecting each WSB to the main culverts to ensure high F-E system reliability, redundancy and symmetry for each lock chamber. [A17]

   e. Valves: 1) main culvert valves between Gatun Lake and the upper chamber, between consecutive chambers, and between the lower chamber and the ocean [A17]and [A17] 2) conduit valves between WSBs and the main culverts.

   f. [A16]Means of Equalization to compensate differences in water level in the lock chambers and the space in-between adjacent gates in the same lock head. See [A16] [A17]Section 01 81 19 (*Lock Gates*). [A17]

   g. [A15](Reserved)[A15]

4. [A16]The control system (opening and closing times, triggers and conditions for opening and closing) of the valves shall be designed and optimized based on the results of the Contractor's modeling as described in this Section.[A16] Maximum flexibility, safety and reliability of controls and operators shall be incorporated for all operating, maintenance and accidental conditions. The control system shall be able to use water level data and calculate water levels taking into account available lock chamber sizes, ocean water levels, use of WSBs, [A15]traffic direction,[A15] among other variables and provide operator with optimum and safe sequence of operation.

5. The F-E system shall allow independent equalizing of lock chambers.

6. The F-E system shall allow independent equalizing the water level between a chamber and the space between redundant gates, when both are used. See Section 01 81 19 (*Lock Gates*). The means of Equalization shall not induce vibration on the lock gates or cause water turbulence that will result in additional maneuvering requirements of the transiting vessel, or in additional Lockage [A16]Time.

7. The F-E system shall provide symmetrical water movement in both the longitudinal and transversal directions within each lock chamber under [A17]standard [A17] operating conditions. The F-E system must be designed to maintain vessels safely centered both laterally and longitudinally in the chamber.

8. To reduce forces on vessels, F-E system side ports shall be located as close as possible to the chamber floor.

9. The flow of water between the adjacent chambers of the locks, and between the chambers and WSBs shall be controlled by means of culvert and conduit valves. Specifications of valves are provided in Section 01 81 23 (*Culvert and Conduit Valves*).

10. The design of F-E system shall allow for the dewatering of separate parts of the system (culverts, conduits, ports, WSBs, valves areas, intakes, discharges, lock chambers and gate Recesses) for maintenance while keeping the lock chamber in operation. The Contractor shall design and provide procedures for each dewatering and refilling scenario. [A7]Section 01 92 00.13 (*Dry Outages*).[A7]

11. The materials used for the F-E system shall be chosen to be durable and to require low maintenance, taking into account high flow velocities occurring during operation. Wherever appropriate, materials with low resistance to the flow shall be used to minimize hydraulic losses of the system. The materials shall be chosen to minimize sea-life growth and corrosion from seawater. The tribological properties of materials shall be taken into account to limit wear off of moving parts.

12. [A16]The Contractor's design of WSB shall be such as to:[A16]

    a. Avoid formation of vortex at the WSB intake when the WSB is emptied into the lock chamber;

    b. Avoid high turbulence and waves into WSB when the WSB is filled from the lock chamber;

    c. Avoid sediment deposition problems on the WSB bottom floor;

    d. For fast dewatering of WSB, a minimum bottom slope of 2% shall be applied;

    e. A minimum water depth at conduit intake shall be 1.50 m;

    f. Have trash-rack system at conduit intake to avoid entry of large objects into F-E system.

13. The F-E system shall be able to operate with and without the use of WSBs and shall have the ability to switch from operating scenarios with the use of WSB to operating scenarios without the use of WSB at any time, in a short period of time. For example, after the last Up Lockage (turn-around-time) and then after the last Down Lockage or when required.

14. The water discharge from the locks and intake of fresh water from the Gatun Lake shall minimize interference with the navigation channel and approaching vessels, and avoid as far as possible any increase of maneuvering time for vessels due to disturbing currents from lock water discharge or water intake.

15. Allow for minimum silt and debris accumulation and for a quick cleaning of system with minimum impact to lock operations.

16. [A10]The system shall also allow for removal of any entrapped air during system refilling after either a culvert or a chamber dry outage. [A10]

B. **Performance Requirements**:

1. **Optimum Lockage and Cycle Times**: [A16]The Contractor's design of the F-E system shall minimize both Lockage Time and Cycle Time. These times shall not exceed the maximums specified[3] for the conditions indicated in this Section, Section 01 10 00 (*General Project Requirements*), Section 01 81 13.13 (*Physical Model for Filling and Emptying System*), Section 01 91 00 [A16] [A17] *(Tests on Completion and Tests after Completion)* and Section 01 92 00 (*Facilities Operation*) [A17].

2. **Vessel movements**: During F-E processes, asymmetrical flow in the lock chamber may induce vessel movements causing vessel hitting the wall, gates, tugs or other vessels inside the chamber, or introducing excessive [A7]water slopes or[A7] hawser forces. [A16]The Contractor's design of the F-E system shall prevent occurrence of such circumstances by providing as smooth water flow in the lock chamber as possible. The maximum vessel displacements, water slopes and maximum hawser forces shall not exceed the criteria established in this Section.[A16]

3. **Lock Operations**: [A17]The hydraulic F-E system shall ensure safe Transits in all operating conditions, as well as complying with water-slope and hawser-load criteria and the required Lockage Times and Cycle Times. The requirements of this Section shall also apply for the following types operating conditions. See Section 01 42 16 (*Definitions*) for definitions of Lockage Time, Cycle Time, and Design Vessel.

   a. The standard operating condition covers the full range of combinations of lockages in which the Design Vessel is handled with no other vessels in the lock chambers, with all gates, culverts and valves operational.

[3] As the time to move ship in or out of chamber is largely dependent on the actual operation, the default time of 17 minutes shall be taken into account in all calculations.

b. A non-standard lockage involves other vessel types and sizes, multiple vessels in the chamber, or one or more gates, culverts, or valves out-of-service). Only minimum modifications to operating procedures or to resource utilization shall be necessary to meet the above-mentioned requirements in these conditions. The Contractor shall provide data on the operating procedures, target times, water slopes, and hawser forces expected for each such condition. [A17]

4. **Water Slopes and Hawser Forces**: The surface water slopes shall not exceed an end-to-end value of 0.14 ‰[4] for longitudinal (0.008 degrees along the vessel length) and 0.10 ‰ for transversal[5] [A7] and hawser forces shall not exceed available mooring system strength using a safety factor [A7]of 5[6].[A7]

5. **Water Savings**: [A17]WSBs shall reduce water consumption by at least the amounts indicated for the conditions described in Subparagraph 1.01 D. [A17]

6. **Maximum Flow Velocity**: The [A17]cross-sectional [A17] average water velocities at any point in culverts, conduits, and ports [A10]and at any time during the F-E [A10] shall not exceed [A17]8 m/s, [A17] to avoid risk of quick erosion of the culverts, conduits, and ports. This shall be shown for [A12]99% of combinations of maximum and minimum water levels between Gatun Lake, the oceans and the lock. In the areas where this velocity is exceeded, the Contractor shall provide special surface treatment or linings to [A12] [A17]ensure durability and avoid quick erosion of culvert/conduit surfaces. [A17]

[A10]7. **Availability**: For availability of [A12]F-E system as a critical element for [A12] the whole lock complex, please refer to Section 01 10 00 (*General Project Requirements*). [A10]

8. **Cavitation and Air** [A10]**Entrapment**: [A10]The Contractor shall design so that neither cavitation, nor air entrapment, nor water hammer, occurs in the F-E system. Spreading of cavitation and air entrapment shall be examined in the operating mode with the use of WSBs, and without the use of WSBs. [A16]Testing in the Contractor's physical scale model shall be executed [A16] [A17]under simulated standard and non-standard operating conditions to ensure that these phenomena do not occur during any type of lockage. [A17]

9. **Density Currents**: The F-E system shall maintain symmetrical distribution of density currents at sea entrances, in order to minimize their adverse effect on vessel approaching lock and entering lower chamber.

10. **Water Density Differences**: The F-E system shall take into account the differences in salinity concentration of water and density in culverts, conduits, valves, and gates.

[4] Measurement of surface water slope in parts per mil: tons force per thousand ton of vessel displacement.
[5] [A7]Measurement of surface water slope in parts per mil: tons force per thousand ton of vessel displacement.
[6] For reference see Employer model studies limit the longitudinal hawser forces to 51 tons and transversal hawser forces to 19 tons. Reference report CPP TO5-CNR-R001 (March 2008) [A7] [A16]in Volume VI (*Reference Documents).*[A16]

11. **Water Intake and Discharge**: [A17]To minimize interference with the maneuvering and navigation of vessels and to minimize the possibility that disturbances in currents necessitate increases in vessel-maneuvering times, water shall enter the locks at the culvert intakes and be discharged from the locks so that surface velocities in the approach areas, measured 200 m along the lock centerline away from the lock Knuckle, do not exceed 1.25 m/s,[7]. [A17]

12. **Approach Structures**[8]: At the sea entrances, the approach structures shall not divert density currents nor navigation currents in a manner that could adversely affect vessels maneuvering and mooring in the area. Lake approaches, [A7]if required,[A7] shall also allow for smooth and unaffected entry, exit and mooring of vessels. [A16]The Contractor's numerical models shall be used to help ascertain the impact of the approach structures on currents and vessels. Refer to Section 01 42 16 (*Definitions*) for definition of approach structures.[A16]

13. **Sizes/Dimensions**: Minimum water depth over gate sills and chamber floors, and chamber dimensions used for the design shall be as defined in Section 01 10 00 (*General Project Requirements*).

1.04 DESIGN CRITERIA [A15]AND PERFORMANCE [A15]:

A. **Design Criteria for the F-E System**:

1. The extreme high limits of water levels of Gatun Lake and the Pacific and Atlantic Oceans shall be used to determine top of walls for [A17]lock chambers operating with and without the use of WSB, using static water level differential calculations. [A17] Sufficient freeboard shall be chosen to prevent overtopping by wind waves and unforeseen water level fluctuations [A7](deleted footnote reference)[A7]

   a. [A16]Top-of-lock wall with minimum 1.50 m freeboard.[A16]

   b. [A16]Top-of-WSB wall with minimum 0.80 m freeboard.[A16]

2. The extreme low water level of Atlantic Ocean, minimum operating level of Gatun Lake and mean low water [A17]spring of the Pacific Ocean shall be used to determine lock chamber and WSB floor or bottom levels, using static water level differential calculations. [A17]

   [A10]a. For minimum water depth to be used in the chambers refer [A12]Section 01 10 00 (*General Project Requirements*). [A12]

[7] [A16]Refer to study TO3-Task 3.1-FHR-R015 Model tests 12000 TEU, CPP, March 2008 included in Volume VI (*Reference Documents*).[A16]

[8] Approach structures are structures designed and built for vessel maneuvering at lock entrances as well as for mooring and queuing.

b. A minimum water depth [A12]as established in Subparagraph 1.03 A.12.e.[A12] shall be used in the WSBs. [A10]

3. [A16]The Contractor's design of the F-E system shall be supported by the Contractor's own numerical and physical modeling.[A16] [A7]See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).[A7]

4. The F-E times shall be calculated for lockages with and without the use of WSBs. These times shall be according to scenarios defined in this Section and shall take into account the varying water heads between the Lake and Oceans and the lock chambers and between Water-Saving Basins and the [A17]lock chambers, both during F-E phases. The Contractor shall simulate Up-Lockage and Down-Lockage vessel Transits. [A17]

5. **Water Head Frequency**: [A16]The Contractor's F-E system design shall meet all performance criteria for the complete range of lake and ocean water levels values with an incidence of 99% of a simulated operation time of 365 days, according to the scenarios defined in this Section.[A16]

6. [A16]All combinations of high and low levels of Gatun Lake and ocean and the lock, and of WSBs and the lock, shall be considered to ensure that the water velocities in culverts and ports do not exceed limits established in Subparagraph 1.03 B.6. for all F-E operating scenarios.[A16]

7. [A8]Each lock complex shall provide water savings of at least [A12]the limits established in Subparagraph 1.01 D. so that [A12] when Water-Saving Basins (WSBs) are used for lockages, as compared with lockages without WSBs.[A8] The water saving criterion shall be achieved for all scenarios defined in this Section.

8. **Valve Opening and Closure Operations and Schedules**:

   a. [A16]The valve opening and closure schedules given in this Section 01 81 13 and Employer's conceptual study included in Volume VI (*Reference Documents*) is for information (refer to Sub-Clause 5.1 (*General Design Obligations*) of the Conditions of Contract).[A16] The operation times of separate parts of the F-E system shall be optimized to meet the [A15]maximum times specified in Section 01 10 00 (*General Project Requirements*). [A15]

   b. [A17]In both standard and non-standard operating conditions, [A17] [A16]valve opening and closing schedules shall be calculated and verified by the Contractor by means of his own detailed physical model to validate and optimize design to ensure smooth, efficient and safe operation. The Contractor's recommended valve schedules for each operating scenario shall be provided to the Employer's Representative for review.[A16]

   c. The ageing effect of the culverts and conduits shall be considered to ascertain that the F-E times obtained with the future higher roughness of the walls will still be in accordance with the time requirements in this Section.

9. **Hydraulic Time Requirements**: [A16]To test the overall performance of the system, the total hydraulic time is to be calculated for the set of operations corresponding to the lockage for Design Vessels in sequence transiting between the lake and the ocean and vice versa.[A16] The operating time criteria shall be achieved for [A10]all [A10] of the water-level combinations [A10]for lake [A10] and ocean levels. The cases to be studied are as provided below for [A10]maximum[A10] times in minutes, as actual F-E times vary with lake and ocean levels, see Paragraph 1.06. See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*), Section 01 91 00 (*Tests on Completion and Tests after Completion*) and Section 01 92 00 (*Facilities Operations*).

   a. Reference per-chamber F-E time without the use of WSB: 10 minutes.

   b. Reference per chamber F-E time with the use of WSB: 17 minutes.[A7]

10. **Hawser Forces and Vessel Mooring**:

   a. The Contractor shall design an optimum mooring system and shall determine hawser forces occurring during the F-E operation.

   b. [A16]The Contractor shall prove that the forces induced by the Design Vessel's movements due to F-E process do not exceed the maximum permissible loading of the required force to moor the vessel, see Subparagraph 1.03 B.4. and Section 01 92 00 (*Facility Operation*).[A16] This shall be shown by means of maximum [A7]water[A7] slope in the chambers (with and without the vessel), and the maximum hawser forces.

   c. All hawser force calculations shall be done for operation with and without the use of WSBs, for scenarios defined in this Section, and for the Design Vessel, Capesize bulk carrier and Suezmax tanker, and for multiple vessel lockages. [A7]Section 01 92 00 (*Facility Operation*).[A7]

   d. [A16]The Contractor shall calculate water slopes and forces with his own numerical models and empirical formulas and compare them with past studies and models. Prior to final design, the forces shall be validated with his own physical modeling[9]. The design and test reports shall include the mooring system proposed, the strength required and safety factor for each operating scenario described in this Section.[A16]

B. **Methods of Calculation**:

1. [A16]The following design elements of the F-E system shall be evaluated through Contractor's numerical modeling and validated with his own physical modeling, see Section 01 81 13.13 (*Physical Model F-E System*): All design, model and test reports shall be provided to the Employer's Representative for review.[A16]

[9] [A7]See Section 01 81 13.13 [A7] (*Physical Model for Filling and Emptying System*).

a. [A17]F-E times for vessels transiting in Up Lockages and Down Lockages. Cumulative hydraulic times shall be calculated for through or complete lockage (Lockage Time) and for Relay Lockages (Cycle Time), during changes in vessel direction or "turnaround", and with and without the use of WSBs.

b. Water levels in lock chambers and WSBs and volume of water used with and without the use of WSBs.

c. Water velocities, pressure, and head losses in culverts, conduits, ports, elbows, junctions, transitions; around culvert and conduits valves; at lock intake manifolds, intake screens and discharges; and at WSB intakes and outlets. [A17]

d. Optimization of port to culvert relationship, component size, location, geometry configuration in the complete hydraulic network. All culvert, conduit, [A17]and [A17] port size selections shall be fully supported, documented and reported;

e. Minimization of cavitation risk, air entrapment, water hammer, [A17]and[A17] erosion in metal and concrete.

f. Selection of culvert and conduit valves and sizes.

g. The vessel movement throughout the F-E cycle and estimation of the effects of longitudinal and transversal forces.

h. The maximum water slopes and hawser forces for all operating conditions, including maximum heads.

i. The culvert and conduit valve operating opening and closure schedules.

j. Providing a hydraulic profile and system network for the complete F-E system including hydraulic characteristic values of each node and element shown.

k. Providing flexibility to handle different vessel [A17]mixes and [A17] gate and valve maintenance conditions.

l. Reducing density currents.

2. The scenarios to be examined for the preliminary design (to be submitted with the [A7]Tender[A7]) shall include, but shall not be limited to:

a. **Water Levels**:

1) Maximum level of the Gatun Lake and extreme low water level for the Atlantic Ocean and mean low water [A17]spring [A17] for the Pacific Ocean;

2) Minimum operating level of the Gatun Lake and extreme high water level for the Atlantic Ocean and the mean [A15]high[A15] water level for the Pacific Ocean;

b. [A16]All lock chambers with its corresponding WSBs;[A16]

c. [A16]Design Vessel in [A16 A17]Up Lockage and Down Lockage.[A17]

3. [A16]The scenarios to be examined for the Contractor's detailed design shall include, but shall not be limited to the preliminary design scenarios and additional scenarios:[A16]

a. **Water Levels**: For the calculation of times for F-E, bottom levels of WSBs duration of lockage cycle, throughput and water consumption, ocean water levels shall be represented by means of harmonic constants, derived from the measured water levels.

b. **Rolling Gate Operations**:

1) **Normal Operating Mode**: 2 gates closed ahead of vessel and one astern

2) **Other Cases Requiring Special Procedures**: one gate ahead and one astern

C. **Hydraulic Design of the Filling and Emptying (F-E) System**:

1. The F-E system to be studied will be a lateral double culvert system with ports along the chamber similar to the conceptual design shown on the reference drawings.

2. If the Contractor identifies a F-E system that improves overall lock performance, without significantly raising costs, and operational and maintenance requirements, then such a system should be studied and submitted to the Employer Representative for review and approval.

3. The system shall maintain the vessel positioned/moored in the center of the chamber, providing for a smooth vertical movement of vessels, minimizing longitudinal and transversal movement of vessels.

4. The system shall maintain symmetrical distribution of density currents at sea entrances, in order to minimize their adverse effect on vessel approaching lock and entering lower chamber.

5. **Software and Method Requirements**: The three main types of software that the Contractor shall use with the hydraulic study are:

a. A one dimensional (1-D) numerical model (Flowmaster, Locksim, etc.) shall be used for the simulation of the lock F-E system and the calculation of hydraulic times.

b. A two dimensional (2-D) numerical model (Delft 2D, Fluent, etc.) for the lock shall be used in the calculation of hawser forces. The presence of the vessel in the lock shall be simulated. A time series for water elevation shall be available at each point of the computational grid. The hydrostatic forces upon the vessel's hull and particularly the longitudinal component of the hawser forces shall be calculated for the whole F-E cycle. An estimate of the transversal component for the hydrostatic force shall also be calculated. This procedure may be validated by applying the numerical model to a case previously studied with a physical model and comparing the [A7]results[10].[A7]

c. A combination of three dimensional (3-D) numerical models (Delft 3D, Fluent Software, etc.) shall be used for the design of particular hydraulic shapes such as ports, connections between the primary and secondary culverts, connections between WSB conduits and the main culvert, intakes and outlets in the lake and ocean, also to validate [A7]water slopes and[A7] hawser forces. To calibrate the 3-D models, some experiments with physical models shall be conducted to validate the numerical [A7]approach[11].[A7] The 3-D numerical model shall be used to precisely establish the flow distribution and the head losses for the port system of the F-E lateral system. The same applies to the connection between the main and secondary culverts. The different loss equations obtained with the 3-D numerical model shall be integrated to the lock 1-D and 2-D software programs to obtain accurate F-E times and hawser forces for all operating scenarios.

d. All hydraulic analysis software shall be state-of-the-art commercial packages with previous similar applications. The Contractor shall submit all formulas and equations used for hydraulic calculations indicating data sources used and assumed descriptions of variables and coefficients, calculation and simulation results, analysis, discussion, conclusions and recommendations.

e. [A16]The Contractor shall compare the hydraulic model results with those achieved on his own physical modeling, and report a comparative analysis showing similarities and differences found with an explanation and actions taken to homologate differences.[12A16] See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

7. **Hydraulic Design Considerations**:

[A8]a. The lateral F-E system optimized in the detailed Employer's conceptual design studies[13] [A12]is provided for information only (refer to Sub-Clause 5.1 (*General Design Obligations*) of the Conditions of Contract) shall be used as a reference.[A8] See Subparagraph 1.02 F.[A12]

[10] [A7]See Section 01 81 13.13 [A7] *(Physical Model for Filling and Emptying System).*
[11] [A7]See Section 01 81 13.13 [A7] (*Physical Model for Filling and Emptying System*).
[12] See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).
[13] See 1.02 (*References*), Paragraph F., study reports by CPP.

b. [A16]The Employer's reference or base design consists of feeding the lock chambers by means of longitudinal main culverts and side ports, so as to obtain a symmetrical longitudinal distribution of the flows.[A16] In addition, this system allows the same discharge distribution, whether the flow comes from the WSBs or from an upstream chamber or Gatun Lake.

8. **Numerical 3-D Modeling shall be used**:

a. To accurately establish the flow distribution, head losses and hydraulic characteristics for critical hydraulic elements such as:

1) Entrance and exit of side ports;

2) Connections between culverts;

3) Entry or intake of main culvert;

4) Exit or outlet of main culvert;

5) Approach walls – effect of approach structures on vessel movement, taking into account density currents when applicable;

6) Entrance and discharge to WSBs;

7) Connections between WSB conduits and main culvert;

8) Split or bifurcation of valves in culvert and conduits;

9) Bends in culverts and conduits;

10) Water slopes and hawser forces;

11) Valves opening and closing schedules;

12) Density currents and density differentials in culverts, conduits, valves, chambers and proximity areas.

13) Dry culvert isolation from the chambers of one wall of the lock complex.

b. To establish assumed values for turbulent flow, laminar flow, Reynolds values, Froude Number, flow length characteristics, and other pertinent hydraulic values and parameters. [A16]The Contractor's numerical 3-D model will aid in designing his own physical model and, in turn, the results of physical model should validate the numerical models[14].[A16]

c. To calculate and provide values for:

[14] See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

1) **Static and Total Pressure**: including kinetic energy or dynamic pressure, potential energy;

2) Head loss curves between two points and coefficients of head loss for each required element of the F-E system;

d. Provide manuals for software used showing equations for multi-scale and non-linear equations for turbulent flows.

9. **Determining Requirements for Culverts, Conduits, and Ports**:

a. [A16](Reserved)[A16]

b. The number and size of the ports shall lead to a ratio between the total area of the ports and the manifold area, σ, close to 1, where the manifold to be considered shall be the secondary culvert. The maximum velocity for port jets shall not exceed [A12]limits established in Subparagraph 1.03 B.6. [A12]

c. The ports along the lock chamber shall be aligned around the hydraulic center of the lock chamber. [A17]The hydraulic center of the lock chamber (which is the geometric center of the total wet area in the lock chamber) shall be determined taking into account the gate Recesses, gate volumes, and space between gates and shall be validated simulation runs and modeling by the Contractor using different hydraulic centers for all operating scenarios. [A17]

10. **Hawser Forces Design Criteria**:

a. [A4]The vertical rate of change of water level shall not exceed 3 meters per minute. [A4]

b. Longitudinal and transversal movements of vessels caused by the F-E operation shall be reduced to a minimum, and shall not cause unacceptable hawser forces.

c. [A16]Vessels shall be safely moored (see Section 01 92 00 (*Facilities Operations*) for a description for the mooring system); this shall be tested with the Contractor's numerical models for the Design Vessel, Capesize bulk carrier and Suezmax tanker, and for multiple vessel lockages (tandem) [15], and for the Design Vessel in the Contractor's physical model[16].[A16]

d. The maximum loading shall be [A12]in compliance with limits established in Subparagraph 1.03 B.4. [A12]

e. [A16]The Design Vessel shall be safely held in place in the center of the lock chamber by means of a mooring system.[A16] For the mooring

[15] Tandem Lockage: see Section 01 42 16.
[16] See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

strength calculation as required in this Section, the Contractor shall use Samson Proton-8 strand lines with 57 mm (2.25 inch) diameters, ultimate tensile [A7]strength[A7] of 140 tons, safety factors of 5 [A7](deleted text). [A7]

11. **Physical Model**: See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

D. **Maintenance Data**: Special operation procedures in case of maintenance of the F-E system shall be clearly described in the Maintenance Plan. Refer to Section 01 78 23 [A17] (*Operations Data*) and Section 01 93 00 (*Maintenance Services)*. [A17] This shall include the procedures for special cases for partly functioning F-E system (e.g., longer valve opening times, use of additional mooring lines), and for cleaning/flushing debris and silt accumulation.

[A15]**1.05 SUBMITTALS**: Submittal procedures shall be in accordance with Section 01 33 00 (*Submittal Procedures*).

A. **Hydraulic Performance of F-E System**: [A16]Resulting from the Contractor's numerical and physical models and all F-E system performance tests outlined in Paragraph 1.06[A16] and Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

1. Water levels in lock chambers and WSB for each scenario studied.
2. F-E times for each scenario studied.
3. Water slopes in lock chambers and corresponding forces on ship and mooring lines.
4. Water usage with and without use of WSBs.
5. Water velocities in culverts, conduits, ports, intake and discharge.
6. Valve opening schedule for each scenario studied.
7. Pressures in culverts and calculations to [A17]ensure there is no [A17] cavitation nor air entrapment.
8. Description of hydraulic network, dimensions, geometry, head losses, etc.

1.06 [A16]**TESTS ON COMPLETION - F-E SYSTEM PERFORMANCE TESTS**: The Contractor shall demonstrate during the performance testing that the F-E system conform to the criteria and requirements outlined in this Section. See Section 01 81 13.13 (*Physical Model for Filling and Emptying System*) and Section 01 91 00 [A16] [A17] (*Tests on Completion and Tests after Completion*) for commissioning and testing procedures and additional requirements.[A17]

A. [A16]**Tests on Completion - General Testing Requirements for Performance of F-E System**:[A16]

1. [A16]This Paragraph 1.06 describes the criteria that the Contractor must meet during the Tests on Completion - F-E system performance tests. The not-to-exceed F-E times for maximum, mean and minimum lifts are set out in Paragraph 1.06 of Section 01 81 13.13 (*Physical Model for Filling and Emptying System*) for 8 different cases. As can be seen, the applicable not-to exceed-times (NTET's) vary since they are based on the varying total lift which is itself dependent upon the varying Atlantic and Pacific Ocean tides and varying Gatun Lake levels.[A16] Where the total lift for a given performance test (calculated as provided below)

falls in between values provided in Paragraph 1.06 of Section 01 81 13.13 (*Physical Model for Filling and Emptying System*), the required NTET shall be derived by lineal interpolation as applicable between the NTET's provided.

2. The F-E system performance tests shall be conducted both with and without the use of WSB's. The standard operating mode shall be [A17]used; see 1.03 B.3.[A17]

3. Before performing the F-E system performance tests, the Contractor shall install and calibrate water level gauges at each lock complex near the entrance of the locks from Gatun Lake and near the entrance of the locks from the Atlantic and Pacific Oceans, in lock chambers and WSBs. The Contractor shall also install instrumentation to measure water slopes, velocities, pressures, and valve position as requested in this Section 01 81 13. This information shall be provided to the Employer's Representative prior to conducting tests. All elevations shall be in meters PLD.

4. Prior to starting each F-E system performance test at each lock, the Contractor shall submit to the Employer's Representative the NTET to be used for that particular chamber test, based on the Gatun Lake and Atlantic or Pacific Ocean water surface elevations during which tests will be conducted.

5. Also prior to each series of F-E tests, the Contractor shall provide the estimated beginning and ending water surface elevations for each chamber and each WSB to be used for that particular test sequence. The initial water surface elevations shall be set to match those to be used during routine operation of the locks in a way that satisfies the Employer's Requirements.

6. The F-E times shall be measured from the moment the valves start to open to let water in or out of the chamber, until the water level in the chamber is fully equalized between two adjacent lock water bodies, the valve is closed, so that the next valve in sequence can be opened.

7. During and at the end of the F-E system performance tests, the Contractor shall record the following data: Gatun Lake and ocean water surface elevations (meters PLD), water surface elevations in all lock chambers, and water surface elevations in all WSBs, water slopes in lock chambers, velocities in culverts and conduits, pressures in culvert and conduits, calculation of water saved with use of WSB, and valve open/close schedule. This data shall be provided to the Employer's Representative by the end of the day of the test.

8. (Reserved)

9. (Reserved)

10. (Reserved)

11. The required NTET for each F-E performance test shall be the average of the required NTET for each of the three runs which comprise each F-E performance test, calculated as set out in this Subparagraph 1.06 A.11., refer also to Subparagraph 1.06 A.1. and Subparagraph 1.06 D.3. Since the Tests on

Completion for the F-E system will be conducted with varying ocean tides, the required NTET's for each of the three runs that comprise a single performance test will be the arithmetic average of the NTET for the starting total lift corresponding to each run. For example:

a. For the case 1 test which comprise the test for an Up Lockage in the Pacific locks with the use of WSBs, if for the first of the three runs begins with a given Gatun Lake level of 26.22 m PLD and a Pacific Ocean level of minus 0.65 m PLD, the total lift is 26.87 m and the corresponding NTET is 50.95 minutes, this is calculated by linearly interpolating mean and high lifts in Pacific lock values from Table 1 – 01 81 13.13 in Subparagraph 1.02 A.5., Section 01 81 13.13 (*Physical Model for Filling and Emptying System*), and for the NTET by linear interpolation from corresponding times for mean and high lifts under case 1 in Subparagraph 1.06 E.1., Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

b. If, at the start of the second run, the tide is at +0.47 m PLD, the corresponding total lift is now 25.75 m, we calculate the corresponding NTET in a similar way by linear interpolation to be 50.31 minutes.

c. Finally, if at the start of the third run the tide is at +1.62 m PLD, the total lift is then 24.60 m, the calculated NTET is 49.64 minutes.

d. The three NTETs will then be averaged to give the required NTET for that performance test. In our example, the NTET for this first of the three runs will be (50.95 + 50.31 + 49.64)/3 = 50.3 minutes.

12. Time-measurement tolerance shall be no more than ±0.1% of the stated values.[A17]

13. Lock chamber equalization is achieved when the water pressure is equal on the upstream and downstream sides of the lock gate and gate is ready to be opened. Sensors shall be placed on both sides of all lock gates during Tests on Completion.

14. A minimum of six water level sensors shall be placed in each lock chamber to measure water slopes: a minimum of three sensors in each lock chamber wall, placed one at each end and one in the middle of the lock chamber, to allow measurement of longitudinal and transversal water slopes for the Tests on Completion.

B. **Not-to-**[A17]**Exceed**[A17] **Filling and Emptying Times with Use of Water-Saving Basins**: [A16]The NTETs are for the hydraulic times for filling or emptying all lock chambers and corresponding WSBs in the full sequence of operation.[A16]

1. [A17]**Case 1**:[A17] The NTETs (in minutes) for an Up Lockage (Northbound) in the Pacific locks for combinations of Gatun Lake and Pacific Ocean levels (in meters PLD) with the use of WSBs are defined under Case 1, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

2. [A17]**Case 2**:[A17] The NTETs (in minutes) for a Down Lockage (Southbound) in the Pacific locks for combinations of Gatun Lake and Pacific Ocean levels (in meters PLD) with the use of WSBs are defined under Case 2, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

3. [A17]**Case 3**:[A17] The NTETs (in minutes) for an Up Lockage (Southbound) in the Atlantic locks for combinations of Gatun Lake and Atlantic Ocean levels (in meters PLD) with the use of WSBs are defined under Case 3, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

4. [A17]**Case 4**: [A17] The NTETs (in minutes) for a Down Lockage (Northbound) in the Atlantic locks for combinations of Gatun Lake and Atlantic Ocean levels (in meters PLD) with the use of WSBs are defined under Case 4, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

C. **Not-to-Exceed Filling and Emptying Times Without Use of Water-Saving Basins**: [A16]The not-to-exceed times are for the hydraulic times for filling or emptying all lock chambers in the corresponding sequence of operations.[A16]

1. [A17]**Case 5**:[A17] The NTETs (in minutes) for an Up Lockage (Northbound) in the Pacific locks for combinations of Gatun Lake and Pacific Ocean levels (in meters PLD) without the use of WSBs are defined under Case 5, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

2. [A17]**Case 6**: [A17] The NTETs (in minutes) for a Down Lockage (Southbound) in the Pacific locks for combinations of Gatun Lake and Pacific Ocean levels (in meters PLD) without the use of WSBs are defined under Case 6, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

3. [A17]**Case 7**:[A17] The NTETs (in minutes) for an Up Lockage (Southbound) in the Atlantic locks for combinations of Gatun Lake and Atlantic Ocean levels (in meters PLD) without the use of WSBs are defined under Case 7, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

4. [A17]**Case 8**:[A17] The NTETs (in minutes) for a Down Lockage (Northbound) in the Atlantic locks for combinations of Gatun Lake and Atlantic Ocean levels (in meters PLD) without the use of WSBs are defined under Case 8, Paragraph 1.06, Section 01 81 13.13 (*Physical Model for Filling and Emptying System*).

D. **F-E Time Performance Test Procedures**:

1. Atlantic and Pacific locks shall be tested independently.

2. Each performance test shall consist of three consecutive runs. There shall be 8 separate performance tests, being one for each of the eight test cases as set out in Subparagraph 1.06 B. and 1.06 C. Each of the three runs in each performance test shall fill or empty all three lock chambers and where applicable WSB's simulating a full lockage.

3. For each performance test for each of the 8 test cases, the measured time shall be the average of the three runs.

4. For each of the 8 test cases, a performance test shall be deemed to have failed if the measured time (calculated as set out in the preceding Subparagraph 1.06 D.3.) exceeds the applicable NTET (calculated as set out in Subparagraph 1.06 A.10.) and/or if other relevant criteria outlined in this Section are not met.

5. For the consequences of test failure, the Contractor is referred to Sub-Clause 9.3 (Retesting) and Sub-Clause 9.4 (Failure to Pass Tests on Completion) of the Conditions of Contract and Paragraph 1.06 of Section 01 91 00 (*Tests on Completion and Tests after Completion*). In particular, the Parties acknowledge Sub-Clause 9.4(b) of the Conditions of Contract having regard to the failure of certain performance tests required in this Section 01 81 13, as stated in Subparagraph 1.06 of Section 01 91 00 (*Tests on Completion and Tests After Completion*).

E. **Calculation of F-E Time Performance Damages**: See Paragraphs 1.06 and 1.07, Section 01 91 00 (*Test on Completion and Tests after Completion*).

F. **Measurement Tolerances**:

1. **Maximum Allowable Water Slopes and Hawser Forces**: The F-E system performance tests shall demonstrate that the requirements stated in Subparagraph 1.03 B.4. have been met regarding the maximum allowable longitudinal and transverse water slopes and the not-to-exceed hawser forces in all three chambers during the entire F-E cycle with and without the use of WSBs. [A16]Water slopes and forces measurement tolerance shall be no more than ±1%[A16] [A17]of the stated value. [A17]

2. **Maximum Allowable Flow Velocities in Culverts, Conduits and Ports**: The F-E system performance tests shall demonstrate that the requirements stated in Subparagraph 1.03 B.6. have been met regarding the maximum flow velocities at any point in the culverts, conduits, or ports. [A16]Velocities measurement tolerance shall be no more than ±1%[A16] [A17]of the stated value.[A17]

3. **Air Entrapment and Cavitation**: The F-E system performance tests shall demonstrate that in accordance with the requirements of Subparagraph 1.03 B.8. during the F-E process the system does not exhibit cavitation, water hammer and entrapped air does not affect operation, reliability, nor durability of valves, conduits, culverts or other portions of the F-E system.

4. **Maximum Allowable Surface Velocities Lock Approaches and Discharges**: The F-E system performance tests shall demonstrate that the water surface velocities in the lock approach and discharge areas are met in accordance with the requirements of Subparagraph 1.03 B.11. [A16]Velocities measurement tolerance shall be no more than ±1%[A16] [A17]of the stated value.[A17]

5. **Volume of Water Saved Using Water-Saving Basins**: Water level measurements made during the F-E system performance tests shall be the basis of calculations to demonstrate that the requirements stated in Subparagraph 1.01.D. have been met. The volume of water saved with the use of WSBs as compared to without the use of WSBs for a given lake and ocean level shall be calculated by the Contractor and submitted to the Employer's Representative to demonstrate compliance with the requirements of this Subparagraph 1.01.D. The measurements shall be based on water level measurements taken from the WSB and lock chambers during the F-E system performance tests. [A16]Water volume measurement tolerance shall be no more than ±1%[A16 A17]of the stated value.[A17]

1.07 QUALITY ASSURANCE: The Contractor's quality management system shall comply with Section 01 40 00 (*Quality Requirements*).

END OF SECTION

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