Condition Assessment Manual

Appendix 1.13 – Guide for Raw Water System Condition Assessment

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1.0 General

Unforeseen failure of the raw water system can have a substantial impact on power generation and revenues due to overheating damage to critical plant system leading to forced outage. Therefore, it is important to maintain an updated condition assessment of the raw water system and plan accordingly. A raw water system condition assessment is essential to estimate the economic lifespan and potential risk of failure, and to evaluate the benefits and cost of raw water system upgrading.

For any type of raw water system, the following three-step analyses are necessary to arrive at a raw water system condition indicator:

1) What parts should be included for raw water system condition assessment and which parts are more important than others (parts and their weighting factors)?

2) What metrics/parameters should be investigated for quantitative condition assessment and which ones are more important than others (condition parameters and their weighting factors)?

3) How to assign numerical scores to the raw water system (rating criteria)?

This Appendix provides guides to answer the above questions, which can be applied to all raw waters systems. The condition assessment is performed on individual raw water system in a plant, because even the originally identical raw water system may have experienced different Operation & Maintenance (O&M) histories and would arrive at different values of condition indicators. Due to the uniqueness of each individual raw water system, the guides provided in this Appendix cannot quantify all factors that affect individual raw water system condition. Mitigating factors not included in this guide may trigger testing and further evaluation to determine the final score of the raw water system condition and to make the decision of raw water system replacement or rehabilitation.

This Appendix is not intended to define raw water system maintenance practices or describe in detail inspections, tests, or measurements. Utility-specific maintenance policies and procedures must be consulted for such information.

2.0 Constituent Parts Analysis

The raw water system includes the supply intake, strainers, pumps, valves, generator air coolers, piping and instrumentation/monitoring. If any part does not exist in particular raw water system (i.e. pumps on a high head plant), this part will be excluded from scoring mechanism by inputting "NA" into the Table. The effect of one part exclusion is usually insignificant to justify any adjustment for the weighting factors of other raw water parts.

3.0 Metrics for Raw Water Condition Assessment

As listed in Table 1, the following five condition parameters are considered for condition assessment of raw water system parts:

- The Physical Condition
- The Age
- The Installed Technology Level
- The Operating Restrictions
- The Maintenance Requirement

These five condition parameters are scored based on the previous testing and measurements, historical O&M records, original design drawings, previous rehabilitation feasibility study reports if conducted, interviews with plant staff and some limited inspections. It is noticed that there is a certain level of relevance between the age and physical condition, maintenance needs, or some operating restrictions. However, as a benchmarking condition assessment without specific testing and measurements conducted on site, these five parameters are regarded as providing the basis for assessing the condition of raw water system parts.

In addition, the Data Quality Indicator, as an independent metric, is to reflect the quality of available information and the confidence on the information used for the condition assessment. In some cases, data may be missing, out-of-date, or of questionable integrity, and any of these situations could affect the results of condition assessment. The scores of data quality are determined by the on-site evaluators for each assessed part/item to indicate the information and data availability, integrity and accuracy and the confidence on the given condition ratings (MWH 2010).

4.0 Weighting Factors

There are two categories of weighting factors in Table 1. It is recognized that some condition parameters affect the raw water system condition to a greater or lesser degree than other parameters; also some parts are more or less important than other parts to an entire raw water system. These weighting factors should be pre-determined by consensus among experienced hydropower mechanical engineers and plant O&M experts. Once they are determined for each type of raw water system, they should be largely fixed from plant to plant for the same type of raw water system, except for special designs found in a raw water system where the weighting factors have to be adjusted. In this case, the adjustment of weighting factors must be conducted by HAP core process development team. The range of absolute values of weighting factors won't affect the Condition Indicator of a raw water system, which is the weighted summation of all scores that assigned to the raw water system parts and five condition parameters.

Table 1: Typical Raw Water System Condition Assessment & Scoring - XXX Hydropower Plant (Unit #)

Raw Water System for Unit ___	Taxonomy ID	Physical Condition Score	Age Score	Installed Technology Score	Operating Restrictions Score	Maintenance Requirement Score	Data Quality Score	Weighting Factors for Parts
Supply Intake	4.2.4.1							1.0
Stainers	4.2.4.2							1.0
Pumps	4.2.4.3							2.0
Valves	4.2.4.4							1.0
Generator Coolers	4.2.4.5							1.5
Piping	4.2.4.6							2.0
Instrumentation/Monitoring	4.2.4.7							1.0
Weighting Factors for Condition Parameters		2.0	1.0	1.0	1.0	1.5	Data Quality -->	*0.00*
							Condition Indicator -->	*0.00*

5.0 Rating Criteria

Physical Condition - Rating Criteria for Raw Water System Parts

Physical Condition of raw water system refers to those features that are observable or detected through measurement and testing, including some observed performance. It includes the observation of pump vibration and noise, pipeline leaks and sticking of valves, as well as the analysis result from pipe and valve internal inspections. The Best Practices of Raw Water System Condition Assessment can assist in evaluating the raw water system condition. For HAP site assessment, it is important to conduct interviews and discussions with plant personnel in order to score the physical condition of raw water parts. The results of all related information are analyzed and applied to Chart 1 to assign the condition scores of raw water parts.

Chart 1 Raw Water System Physical Condition Rating Criteria		
Physical Condition Rating Scale		Physical Condition Score
Excellent	No noticeable defects. Some aging or wear may be noticeable. No evidence of pump vibration and noise or pipeline leaks.	7– 10
Good	Some deterioration or defects are evident, but function is not significantly affected. Observable evidence of pump vibration and noise and/or pipeline leaks.	4 – 6
Poor	Serious deterioration in at least some portions, function is inadequate, unit efficiency or availability significantly affected.	1 - 3
Failed	No longer functions, may cause failure of a major component.	0

Age - Rating Criteria for Raw Water System Parts

Age scoring is relatively more objective than other condition parameters. The detailed scoring criteria developed in Chart 2 allows the age score be automatically generated in the HAP Database by the actual years of the installed part.

Chart 2 Age Rating Criteria for Raw Water System Parts	
Age of the Raw Water System Major Parts/Items	**Age Score**
0 - 10 years	**10**
11 - 15 years	**9**
16 - 20 years	**8**
21 - 25 years	**7**
26 - 30 years	**6**
31 - 35 years	**5**
36 - 40 years	**4**
41 - 50 years	**3**
51 - 70 years	**2**
71 - 99 years	**1**
> 100 years	**0**

Installed Technology Level – Rating Criteria for Raw Water System Parts

The Installed Technology Level indicates advancement levels of designing, machining, installation and materials, which may effect on the unit and plant performance. The outdated technology may bring difficulties for spare parts supply and become a prolonged outage when it fails.

Scoring the Installed Technology Level requires historic knowledge of raw water system technology advancement and familiarity with the current piping construction standards (ASME B31.3). The basic design concepts for raw water systems at hydro plants have not changed substantially. However, there are a number of component design improvements for raw water systems that have become state of the art. Most of these changes have been driven by technical improvements in materials of construction and the cost of materials such as stainless steel and copper/copper alloys.

Materials of construction selection for raw water piping systems and components is based on the specific characteristics of the system including water quality of the raw water supply (suspended solids, tendencies to scale, potential bio-fouling, potential for corrosion, etc.) .

Exposed larger bore piping (> Ø4”) can be flanged or butt welded carbon steel or stainless steel (Flanged piping allows disassembly of the piping system for internal build-up cleaning out). Small bore piping is non-corrosive material such as stainless steel. Embedded piping is stainless steel or cement lined ductile iron (for larger bore piping) with flanged joints for external piping connections.

Valves larger than 6” are normally gate valves. Isolation valves Ø2½” to Ø6” are normally butterfly valves. Stainless steel ball valves are normally used for Ø2” and smaller valves. Valves are manually operated or remotely actuated based on process requirements, staffing levels, etc. Closed cell foam piping insulation systems for eliminating external piping condensation have replaced asbestos containing systems. Raw cooling water pump design has changed very little over time. However, mechanical seals have replaced packing glands. Advances in pump materials of construction, impeller design and manufacturing, as well as more efficient motor design provide improvements in pump reliability and operating and maintenance costs.

Current raw water system designs include stainless steel duplex automatic backwash strainers. Subsystems such as turbine seal water and fire protection can be equipped with finer mesh automatic backwash strainers for additional performance reliability for these systems. These features are labor saving methods, especially suitable for the facilities that are not continually staffed.

In addition, the competence, professionalism and reputation of the original suppliers could also imply the installed technology levels. Compared to those from large and well-known manufacturers, the raw water parts supplied by small and unnamed companies would get lower scores. A review of installed technologies in use is compared to Chart 3 to determine the score for the raw water system.

Chart 3 Raw Water System Technology Rating Criteria	
Technology Levels of the Parts/Items	**Score for Installed Technology Level**
The technology has not been changed significantly since the part was installed; and the installed technology was supplied by brand name companies with great reputation.	**8 – 10**
The technology has been more or less advanced but no problem to supply the matching parts in next 5-10 years, or the technology change has little effect on the efficiency and reliability of power generation (but may reduce the cost of replacement). The installed technology was supplied by medium companies with good reputation.	**4 – 7**
The installed technology has been phased out, it is a problem to supply parts in reasonable order time, or the technology change has significantly improved the efficiency and reliability of power generation. The installed technology was supplied by small companies with bad reputation.	**0 – 3**

Operating Restrictions - Rating Criteria for Raw Water System Parts

The raw water system operating restrictions refer to the limitations on normal operation range of water pressure and flow rate, based on the original design and current condition of raw water parts. Operational limitations play a role in determining the serviceability of raw water system pumps: the greater the limitations, the greater the loss of cooling efficiency throughout the system.

The operating restrictions may be sourced from the system itself. The operating ranges of maximum/minimum water flows and pressures are constrained due to the original design and/or currently deteriorated raw water physical condition (e.g., hot bearings and severe vibrations).

Chart 4 describes the ratings of raw water system operating restrictions.

Chart 4 Raw Water System Operating Restrictions Rating Criteria	
Operating Restrictions or Off-Design Conditions	**Score for Operating Restrictions**
The design standard has no changes, and the original design has no constraints on the required operation. No known design and operational deficiencies.	**8 – 10**
Minimal restraints: Special operational requirements are needed to avoid minor maintenance issues. The operation range can be expanded with revised equipment selection and design. No known design and operational deficiencies.	**5 – 7**
Moderate restraints: Special operational requirements are needed to avoid major maintenance issues. The operation range and performance can be significantly improved with revised equipment selection and design.	**3 – 4**
Severe limitations: The equipment do not meet the operational criteria or not tested as required or has a known design and operational deficiency.	**0 – 2**

Maintenance Requirement – Rating Criteria for Raw Water system Parts

Maintenance of a raw water system is directly connected to the quality of the amount of corrective maintenance that either has been or must be performed is an indication of the raw water system condition. No corrective maintenance is an indication that the raw water system is in good shape. Severe corrective maintenance requires scheduled or forced outages to perform.

Other factors to consider for maintenance scoring include:

- The need of maintenance is increasing with time or problems are reoccurring;
- Previous failures related to the raw water system parts;
- Failures and problems of raw water system parts with similar design.

The results of raw water system maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5 to score the raw water system parts.

Chart 5 Raw Water System Maintenance Requirement Rating Criteria	
Amounts of Corrective Maintenance	**Maintenance Requirement Score**
Minimum level (normal condition): A small amount of routine preventive maintenance is required (e.g., Flow Charting). No corrective maintenance.	**9 – 10**
Low level: Small amounts of corrective maintenance (e.g., less than 3 staff days per unit per year). Repairs that could be completed during a unit preventive maintenance outage that is scheduled on a periodic basis.	**7 – 8**
Moderate level: Some corrective maintenance that causes extensions of unit preventative maintenance outages (e.g., Pump Replacement).	**5 – 6**
Significant/Extensive level: Significant additional and corrective maintenance is required; forced outage occurs and outages are extended due to maintenance problems (e.g., Cooler Rebuild/Replacement).	**3 – 4**
Severe level: Severe corrective maintenance that requires scheduled or forced outages. Repeated forced outages, frequent repairs, abnormal wear to components, and/or labor-intensive maintenance is required.	**0 – 2**

Data Quality – Rating Criteria for Raw Water Parts

The Data quality scores reflect the quality of the inspection, test, and measurement results to evaluate the condition of raw water system parts. The more current and complete the inspection, testing and measurement results, the higher the Data Quality scores. The frequency of normal testing is as recommended by the organization. Reasonable efforts should be made to perform visual inspections and data collection (measurements, tests, operation logs, maintenance records, design drawings, previous assessment reports and etc.). However, when data is unavailable to score a condition parameter properly, it may be assumed that the condition is “Good” or numerically equal to some mid-range number 3-7. Meanwhile, the Data Quality score is graded low to recognize the poor or missing data.

Qualified personnel should make a subjective determination for the Data Quality scores, considering as many factors as possible. The suggested criteria for scoring the Data Quality of raw water system parts are developed in Chart 6.

Chart 6 Raw Water System Data Quality Rating Criteria	
Data Availability, Integrity and Accuracy	**Data Quality Score**
High – The Raw Water System maintenance policies and procedures were followed by the plant and the routine inspections, tests and measurement were performed within normal frequency in the plant. The required data and information are available to the assessment team through all means of site visits, possible visual inspections and interviews with experienced plant staff.	**8 – 10**
Medium – One or more of routine inspections, tests and measurement were completed 6-24 months past the normal frequency, or small portion of required data, information and documents are not available to the assessment team.	**5 – 7**
Low – One or more of routine inspections, tests and measurement were completed 24-36 months past the normal frequency, or some of results are not available.	**3 – 4**
Very Low – One or more of required inspections, tests and measurement were completed >36 months past the normal frequency, or significant portion of results are not available.	**0 – 2**

In Table 1, the final condition score of the raw water system, i.e., the Condition Indicator, *CI*, can be calculated as follows:

$$CI = \frac{\sum_{K=1,M}^{J=1,5} S_C(K,J) \times F(K) \times F(J)}{\sum_{K=1,M}^{J=1,5} F(K) \times F(J)} \qquad (1)$$

The raw water system Data Quality Indicator, *DI*, will be the weighted summation of all Data Quality scores received for its associated parts/items:

$$DI = \frac{\sum_{K=1,M} S_D(K) \times F(K)}{\sum_{K=1,M} F(K)} \qquad (2)$$

Here M = the total number of parts/items associated with the raw water system; K = the identification No. of raw water system parts (from 1 to M); J = the identification No. of condition parameters (from 1 to 5, respectively for physical condition, age,…); $S_C(K, J)$ = the condition score of the raw waters part for one of 5 condition parameters; $S_D(K)$ = the data quality score for a part; $F(J)$ = the weighting factor for a condition parameter; $F(K)$ = the weighting factor for raw water system.

The calculated Condition Indicator from equation (1) may be adjusted by the results of internal inspections and specific testing results that would be performed, since the specific raw water system testing would more directly reveal the condition of the raw water system.

6.0 Reference

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