Condition Assessment Manual

Appendix 1.06 – Guide for Leakage and Releases Condition Assessment

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1.0 General

Unregulated or excessive leakage and releases can negatively impact power generation at a hydropower facility since any significant water loss is a loss in potential generation. This condition assessment addresses leakage and releases issues as they relate to spillways, sluiceways, and dam structure. The two primary sources of leakage considered within this assessment are seepage at foundations or dam abutments and inadequate sealing at spillway and sluiceway gate seals. Releases are the excess spillage of water from spillways and sluiceways due to either excess storage (i.e. regulate reservoir level) or maintenance of minimum downstream flow requirements (i.e. dissolved oxygen).

For leakage and releases, the three following steps are necessary to establish a condition indicator:

1) What parts/items are to be included in the condition assessment and what is their level of importance (parts and their weighting factors)?

2) What metrics/parameters are to be investigated for the quantitative condition assessment and what is their level of importance (condition parameters and their weighting factors)?

3) How to assign numerical scores to the parts/items (rating criteria)?

This Appendix provides guides to help answer the questions above, which can be applied to the leakage and releases through spillways, sluiceways, and dams. The condition assessment of leakage and releases is not as tangible as other facility parts/items such as penstocks or turbines. Table 1 includes three systems (spillways, sluiceways, and dam structure) which are often sources of leakage or used to regulate releases. Due to the variation in sources of leakage and basis for releases, the guides provided in this Appendix cannot quantify all contributing factors. Mitigating factors not included in this Guide may trigger testing and further evaluation to determine the final condition score and determine the feasibility of replacement or repair.

This Appendix is not intended to define maintenance practices associated with leakage or releases 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

For the scoped leakage and releases assessment, the constituent parts/items are analyzed and listed in Table 1 (references to HAP Taxonomy).

If any part (e.g., flashboard) does not exist in a particular system, this part will be excluded from scoring mechanism by inputting “NA” into the Table. The effect of one part exclusion is usually

insignificant to the entire system assessment and does not justify an adjustment of the weighting factors for the other parts.

3.0 Metrics for Condition Assessment

As listed in Table 1, the following five condition parameters are considered for the condition assessment of leakage and releases:

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

These five condition parameters are scored based on previous testing and measurements (i.e. flow measurements), historical Operation and Maintenance (O&M) records, original design drawings, previous rehabilitation feasibility study reports if available, interviews with plant personnel, and inspections where available.

It can be noted that there is a certain level of relevance between the age and physical condition, maintenance needs, or some operating restrictions. However, as a benchmark condition assessment (without specific testing and measurements conducted on site) the five parameters are regarded as providing the basis for assessing the condition of leakage and releases.

In addition, the Data Quality Indicator, as an independent metric, is intended to reflect the quality of the available information and the confidence of the information used for the condition assessment. In some cases, data may be missing, out-of-date, or of questionable integrity. Any of these situations could affect the results of the condition assessment. The scores of data quality are determined by the on-site evaluators for each assessed part/item to indicate the data availability, integrity, and accuracy; and the confidence of 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 condition to a greater degree than others. Also, some parts are more or less important than other parts to the system. These weighting factors should be pre-

determined by consensus among experienced hydropower engineers and plant O&M experts. Once they are determined for each part/item, they should be largely fixed from plant to plant for similar arrangements. In some plants the weighting factors will have to be adjusted for specific arrangements. 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 will not affect the Condition Indicator, which is the weighted summation of all scores assigned to the parts/items and five condition parameters.

Table 1: Typical Spillways/Sluiceways/Dams Condition Assessment & Scoring for Leakage and Releases

Leakage & Releases through Spillways/Sluiceways/ Dams	Taxonomy ID	Physical Condition Score	Age Score	Installed Technology Score	Operating Restrictions Score	Maintenance Requirement Score	Data Quality Score	Weighting Factors for Parts
Concrete Structure	2.1.1							5.0
Spillway Gates	2.1.2							3.0
Spillway Gates Hoisting Machinery	2.1.3							2.0
Flashboard	2.1.4							2.0
Bulkhead Gates/Stoplogs	2.1.5							2.0
Spillway Caisson	2.1.6							3.0
Sluiceway Gates	2.2.1							3.0
Sluiceway Gate Operating Equipment	2.2.2							2.0
Sluiceway Trash Racks	2.2.3							2.0
Sluiceway Inlet Structure	2.2.4							3.0
Sluiceway Outlet Structure	2.2.5							3.0
Main Dam	2.3.1							5.0
Embankment	2.3.2							3.0
Retaining Walls	2.3.3							3.0
Drainage Galleries	2.3.4							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 Leakage and Releases

Physical Condition refers to those features that are observable or detected through measurement and testing. It includes leakage at gate seals, gate seal deterioration, seepage, structural deterioration (i.e. concrete cracking), functionality of operating equipment, excess release, etc. In addition to efficiency related issues, severe leakage or seepage may be an indication of compromised structural integrity or safety issues. Therefore, leakage and releases should be carefully evaluated. The Best Practices for Leakage and Releases can assist in evaluating the physical condition. For HAP site assessment, it is important to interview and discuss with plant personnel to help score the physical condition. The results of all related information are analyzed and applied to Chart 1.

Chart 1 Leakage and Releases Physical Condition Rating Criteria		
Physical Condition Rating Scale		Physical Condition Score
Excellent	Limited leakage from gate seals; no sign of gate seal deterioration; tailwater flows are clean; limited or no downstream leakage or seepage at dam abutments; spillway and sluiceway gates are working properly and have been recently calibrated; limited concrete deterioration of structures. Parts/items are functioning properly and there are no significant water losses due to leakage and releases.	8 – 10
Good	Moderate leakage from gate seals; minimal gate seal deterioration; tailwater flows fairly are clean and free of debris; minimal downstream leakage or seepage at dam abutments; spillway and sluiceway gates are functioning but have not been recently calibrated; minimal concrete deterioration of structures. Parts/items are functioning and there are only minimal water losses due to leakage and releases. Minor repairs may be necessary.	5 – 7
Fair	Significant leakage from gate seals; moderate gate seal deterioration; muddy tailwater flows are common; significant downstream leakage or seepage at dam abutments; spillway and sluiceway gates are working but are rarely calibrated or monitored; moderate concrete deterioration structures. Parts/items are functioning however there are significant water losses due to leakage and releases. Moderate repairs may be necessary.	3 – 4
Poor	Severe leakage from gate seals; severe gate seal deterioration or failure of seals; tailwater flows are muddy; severe downstream leakage or seepage at dam abutments; spillway and sluiceways gates are not functioning; severe concrete deterioration of structures. Parts/items are not functioning and there is excessive water losses due to leakage and releases. Replacement or repairs are necessary.	0 – 2

Age - Rating Criteria for Leakage and Releases

Age is an important factor when considering part or system upgrade as it can be an indication of performance degradation. As structures age, they become more susceptible to deterioration due to turbulent flow and severe weather. Also gate systems become less reliable with age due to infrequent calibration, poor equipment maintenance, and seal deterioration. Not only does increased wear result in operational problems (i.e. water loss) and loss of efficiency, it can also increase the safety concerns.

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

Chart 2 Age Rating Criteria for Leakage and Releases			
Age of Structures and Gates	Age Score	Age of Gate Seals	Age of Operating Equipment
<30 years	**8 - 10**	<10 years	<15 years
30-60 years	**5 - 7**	10-15 years	15-25 years
60-80 years	**3 - 4**	15-20 years	25-35 years
>80 years	**0 - 2**	>20 years	>35 years

Installed Technology Level – Rating Criteria for Leakage and Releases

The Installed Technology indicates advancement in design, installation/construction techniques, gate calibration, instrumentation, and gate seal technology which may affect performance. Outdated technology may cause difficulties for supplying replacement parts or performing routine maintenance which can result in prolonged outages.

Scoring the Installed Technology requires historic knowledge of spillway and sluiceway technology advancement and familiarity with industry standards and materials. For example, historically wood and steel were used for gate seals; however, most modern facilities use rubber

seals which significantly reduce leakage. Therefore, spillway and sluiceway gates utilizing rubber seals will receive a higher score than those using other materials. With advances in instrumentation and software analysis, releases can be better regulated and losses due to leakage more easily quantified. Systems utilizing state of the art instrumentation and analysis software will also receive a higher score than plant utilizing antiquated calibration techniques.

The competence, professionalism, and reputation of the original suppliers could also impact the Installed Technology. As compared to highly reputable manufacturers with a good service record, the parts supplied or installed by unknown or disreputable companies would get lower scores. The Installed Technology scoring criteria for various parts are shown in Chart 3.

Chart 3 Leakage and Releases Technology Rating Criteria	
Technology Levels of the Parts/Items	**Score for Installed Technology Level**
The technology has not been changed significantly since the part/item was installed; and the installed technology was supplied by brand name companies with a 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 Leakage and Releases

The Operating Restrictions refers to the current limitations on the operating ranges including flow and power capacity. Either under-sized or under-utilized capacity may reduce the overall operational performance and accelerate the deterioration of the physical condition. Operational

limitations play a role in determining the serviceability of the unit: the greater the limitations, the greater the generation loss.

Operating restrictions can be caused by to two sources:

1) Excessive water loss due to unregulated release from spillways and sluiceways (poor gate calibration), or loss of generation due to required minimum release amounts which in some cases can be avoided. For example, minimum releases are sometimes required to improve dissolved oxygen levels which can also be met with the installation of aeration weirs or aerating turbines. Also, some plants have installed generating equipment to utilize previously unused generation potential from environmental releases.
2) Increase outages due to deterioration or reliability of gate systems.

Chart 4 describes the ratings of Operating Restrictions.

Chart 4 Leakage and Releases 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.	**8 – 10**
Minimal restraints: Operation range can be expanded with revised equipment selection or design.	**5 – 7**
Moderate restraints: The operation range and performance can be significantly improved with revised system design.	**3 – 4**
Severe limitations: The part/item does not meet the operational criteria, performance and reliability are significantly limited if it operates under current environment/requirement.	**0 – 2**

Maintenance Requirement – Rating Criteria for Leakage and Releases

The amount of corrective maintenance that either has been or must be performed is an indication of the part/item condition. If the part/item has required limited or no maintenance, then that is an indication that the system is in good condition. If it has required extreme

corrective maintenance resulting in unscheduled or forced outages, then the part/item is considered to be in poor condition.

Other factors to consider for maintenance scoring include:

- Maintenance needs are increasing with time or problems are re-occurring
- Previous failures or issues related to parts/items
- Failures or problems with parts/items of similar design and material

The results of the maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5.

Chart 5 Leakage and Releases Maintenance Requirement Rating Criteria	
Amounts of Corrective Maintenance	**Maintenance Requirement Score**
Minimum level (normal condition): A small amount of routine preventive maintenance is required. No corrective maintenance.	**9 – 10**
Low level: Small amounts of corrective maintenance (e.g., less than 3 staff days per component 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.	**5 – 6**
Significant/Extensive level: Significant additional and corrective maintenance is required; forced outage occurs and outages are extended due to maintenance problems.	**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**

<u>Data Quality – Rating Criteria for Leakage and Releases</u>

The Data Quality score reflects the quality of the inspection, test, and measurement results used to evaluate leakage and releases. The more current and complete the inspection, tests, and measurement results are, the higher the Data Quality scores. The frequency of normal

testing is as recommended by the HAP assessment team in conjunction with industry standards.

Reasonable efforts should be made to perform visual inspections and data collection (measurements, tests, operation logs, maintenance records, design drawings, previous assessment reports, 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 of the Data Quality scores, considering as many factors as possible. The suggested criteria for scoring the Data Quality are developed in Chart 6.

Chart 6 Leakage and Releases Data Quality Rating Criteria	
Data Availability, Integrity and Accuracy	**Data Quality Score**
High – The maintenance policies and procedures were followed by the plant and the routine inspections, tests, and measurements 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 measurements 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 measurements 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 measurements were completed >36 months past the normal frequency, or significant portion of results are not available.	**0 – 2**

6.0 Condition and Data Quality Indicator

In Table 1, the final condition score for flumes and open channels, 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 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 associated with leakage and releases; K = the identification No. of 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 a 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 a part.

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 testing would more directly reveal the condition of the pressurized water conveyance.

7.0 References

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