Condition Assessment Manual

Appendix 1.01 – Guide for Trash Racks and Intakes Condition Assessment

HAP
HYDROPOWER
ADVANCEMENT PROJECT

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1.0 General

Unforeseen failure of the trash racks and intake structure can have a devastating impact on a plant. If one of these components failed, extensive outages and equipment repair would be required. Therefore, it is important to maintain a current assessment of the condition of the trash racks and intakes and plan accordingly. Condition assessments for the intakes and trash racks are essential to estimating the economic lifespan, potential risk of failure, and to evaluate the benefits and cost of necessary upgrades.

The following three step analyses are necessary to arrive at a condition indicator for the intakes and trash racks:

1) What parts/items should be included for an intake and trash rack condition assessment and which parts/items 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 intake and trash rack parts (rating criteria)?

This Appendix provides guides to answer the above questions, which can be applied to all intakes and trash racks. This condition assessment must be performed for each intake and trash rack. Even if the components appear to be identical, one may have experienced different Operation & Maintenance (O&M) and would arrive at different values for the condition indicators. The guide provided in this Appendix cannot quantify all factors that affect the condition of an individual trash rack or intake. Mitigating factors not included in this guide may trigger testing and further evaluation to determine the final score of the component condition.

This Appendix is not intended to define intake and trash rack maintenance practices or describe in detail inspections, tests, or measurements.

2.0 Constituent Parts Analysis

A typical trash rack consists of the trash rack structure, trash rake, trash conveyor, and monitoring system. Other common structural items in this location will be the intake structure, stoplogs/bulkhead gates, air vents, and hoisting machinery. These components are listed in Table 1 (references to HAP Taxonomy).

If any component does not exist, this part will be excluded from scoring mechanism by inputting "NA" into the Table. The effect of one component exclusion is usually insignificant to the entire system assessment and does not justify an adjustment of the weighting factors for the other components.

3.0 Metrics for Trash Rack and Intake Condition Assessments

Table 1 lists the following five parameters that are considered for condition assessment of trash racks and intakes:

- 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, historical O&M records, original design drawings, previous rehabilitation feasibility study reports (if conducted), interviews with plant staff and some inspections if possible.

The Data Quality Indicator, shown in Section 6.0 of this report, is an indicator used to determine the quality and confidence of available information and 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 condition assessment. The scores of data quality are determined by the on-site evaluators for each assessed component to indicate the data availability, 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 component condition to a greater or lesser degree than other parameters. Also some parts are more or less important to the overall plant generation than others. These weighting factors should be pre-determined by consensus among experienced hydropower engineers and plant O&M experts during the HAP process development. The range of absolute values of weighting factors will not affect the Condition Indicator of a trash rack or intake, which is calculated in Section 6.0 of this report.

Table 1: Typical Condition Assessment & Scoring

Trash Racks and Intakes 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
Trash Racks	3.1.1							2.0
Trash Rake	3.1.2							2.0
Trash Conveyor	3.1.3							1.5
Monitoring System	3.1.4							1.0
Intake Structures/Construction	3.2.1							3.0
Intake Gates	3.2.2							1.5
Bulkhead Gate/Stoplogs	3.2.3							1.0
Hoisting Machinery	3.2.4							1.0
Air Vent and Water Filling Valve	3.2.5							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 Trash Racks and Intakes

Physical Condition of the trash racks refer to those features that are observable or detected through measurement and testing. This includes surface roughness from corrosion, pitting, cracking damage, and hydraulic flow condition at the trash racks and intake. The surface condition of the trash rack is important because of its direct impact on efficiency and potential equipment damage. A wide range of surface deterioration is possible on trash racks. Uneven and restricted flow can be caused by minor surface deterioration and increase as the corrosion worsens. Significant corrosion can lead to substantial section loss and possible failure of trash racks, leaving generating equipment unprotected from reservoir debris. Therefore, the trash racks should have the surface conditions carefully evaluated with reference to the Trash Racks and Intakes Best Practice during the assessment.

For HAP site assessment, it is important to gather as much site specific information as possible regarding the trash rack and intake. This can include but is not limited to technical reports, design drawings, and maintenance history. Interview and discuss trash racks and intakes with the relevant plant personnel to assist in the physical condition scoring of these items. The results of all related information are analyzed and applied to Chart 1 to assign the condition scores.

Chart 1 Trash Rack and Intake Physical Condition Rating Criteria		
Physical Condition Description		Physical Condition Score
Excellent	Limited corrosion or cavitation of intake interiors, intake structures, and trash racks and components; limited concrete spalling or cracking of concrete intakes; no significant damage to trash racks and intakes due to debris; intake liner or coating is in good condition; Trash rake, conveyor, and monitoring systems and air valves are regularly tested and functioning properly; gates and hoisting equipment are in good condition and functioning properly; gate seals and slots are in good condition.	**8 – 10**
Good	Moderate corrosion or cavitation of intake interiors, intake structures, and trash racks and components; moderate concrete spalling or cracking of concrete intakes; minor damage to trash racks and intakes due to debris; intake liner or coating is in good condition; Trash rake, conveyor, and monitoring systems and air valves are tested and functioning; gates and hoisting equipment are adequate and functioning; gate seals and slots are adequate.	**5 – 7**
Fair	Large areas of corrosion or cavitation of intake interiors, intake structures, and trash racks and components; large areas of spalling and cracking of concrete intakes; moderate damage to trash racks and intakes due to debris; intake liner or coating is less than adequate; Trash rake, conveyor, and monitoring systems and air valves are not regularly tested but regularly exercised; gates and hoisting equipment are in fair condition; gate seals and slots are less than adequate.	**3 – 4**
Poor	Severe corrosion or cavitation of intake interiors, intake structures, and trash racks and components; severe spalling and cracking of concrete intakes; significant damage to trash racks and intakes due to debris; intake liner or coating is inadequate; Trash rake, conveyor, and monitoring systems and air valves are not regularly exercised; gates and hoisting equipment are in poor condition and are not functioning properly; gate seals and slots are in poor condition.	**0 – 2**

Age - Rating Criteria for Trash Rack and Intake Parts

Age is an important factor to consider when analyzing degradation and potential improvements for the trash racks. All components are subject to a finite life expectancy. The life can be extended and the decline limited in some instances by performing preventative and routine maintenance. However, as the age of the trash racks and intakes increases it will become more susceptible to failure and more likely to negatively affect plant efficiency.

Age scoring is relatively less objective than other condition parameters. The detailed scoring criteria developed in Chart 2 will allow the age score to be automatically generated in the HAP

Database by the actual years of the installed part. The trash racks, conveyors, rakes and hoisting machinery usually have an expected lifespan of approximately 30 years. Other parts such as gates and stoplogs have a life expectancy of 80 years. These life expectancies can vary, such as when innovative construction materials or technology is used. For example, the life expectancy for a steel trash rack is typically 15-35 years whereas a plastic or fiberglass trash rack can be expected to last 25-50 years. The age scoring criteria for various parts are shown in Chart 2.

Chart 2 Age Rating Criteria for Trash Rack and Intake Parts		
Age of Intake, Intake Structures, Intake Gates, and Stoplogs/Bulkhead Gates	**Age Score**	**Age of Trash Rack, Trash Rake, Trash Conveyor, Air Vents, and Hoisting Machinery**
< 30 Years	**8 – 10**	< 10 Years
30-60 Years	**5 – 7**	10 to 20 Years
60-80 Years	**3 – 4**	20 to 30 Years
> 80 years	**0 – 2**	> 30 years

Installed Technology Level – Rating Criteria for Trash Rack and Intake Parts

The Installed Technology Level indicates advancement levels of trash rack design, materials, and corrosion protection. Substantial improvements have been made in trash rack designs. The intake angle can be changed or a more hydrodynamic bar shape can be used to reduce head loss. These bars can also be designed such that cleaning is easier and more effective. Improvements in materials used for trash racks include grates constructed of stainless steel, fiber reinforced polymer (FRP), and high density polyethylene (HDPE) to improve corrosion resistance. Another effective method of reducing corrosion is to use cathodic protection systems on the trash rack structure.

Intake improvements are more difficult in most cases to implement because of the larger costs associated with the modifications. Common improvements include installation of turning vanes or splitter walls to improve intake flow and in extreme cases changes can be made to the intake geometry.

Scoring the Installed Technology Level requires historic knowledge of the intakes and trash racks. The material used for construction of the trash rack is a factor to consider for scoring the installed technology level. As discussed above, new innovations have been made using stainless steel, FRP, and HDPE to construct trash racks. See Chart 3 for technology rating criteria.

Chart 3 Trash Rack and Intake Technology Rating Criteria	
Technology Levels of Design and Construction	**Score for Installed Technology Level**
The technology has not been changed significantly since the component 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**

<u>Operating Restrictions - Rating Criteria for Trash Rack and Intake Parts</u>

The trash rack and intake Operating Restrictions refer to the current system limitations such as internal pressures, power capacity, and flow. 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) The trash rack and intake itself. To limit deterioration or to ensure structural safety, the operating ranges of maximum and minimum pressures and flows are constrained due to the limitations of the original design and/or the current deteriorated physical condition.
2) Environmental restrictions due to habitat maintenance, water quality issues (i.e., Dissolved Oxygen), recreational requirements, or fish passage. These restrictions can affect minimum required flows and thus affect the water flows available for power generation. Other environmental restrictions can stem from changes in flow conditions due to climate change.

The operational constraints of trash racks and intakes do not include the constraints from other components within the facility, although they can affect the unit and plant generations. For example, if the water level in the headwater reservoir is limited due to dam safety concerns, then the dam (not the trash rack and intake) will receive a lower score for operating restrictions.

Chart 4 describes the ratings of operating restrictions.

Chart 4 Trash Rack and Intake 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. Tested as Required; no known design and operational inefficiencies.	**8 – 10**
Minimal restraints: Operation range can be expanded with revised component selection and design. No known design and operational inefficiencies.	**5 – 7**
Moderate restraints: The operation range and performance can be significantly improved with revised component design.	**3 – 4**
Severe limitations: The component does not meet the operational criteria, not tested as required, or has a known design and operational deficiency.	**0 – 2**

<u>Maintenance Requirement – Rating Criteria for Parts</u>

The amount of corrective and preventative maintenance that has been or must be performed is usually an indication of the component condition. Typically the component condition will be better when more preventative maintenance has been performed. Conversely, when frequent corrective maintenance has been performed this will usually indicate a poorer component condition.

Other factors to consider for maintenance scoring include:

- The reoccurring need of maintenance or problems;
- Previous related failures of parts;

- Failures or problems of parts with similar design.

The results of maintenance history (including routine maintenance and corrective maintenance) are analyzed and applied to Chart 5 to score the intake and trash rack parts.

Chart 5 Trash Rack and Intake Maintenance Requirement Rating Criteria	
Amounts of Corrective Maintenance	**Maintenance Condition 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. 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 (e.g., corrosion caused leaks).	**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 Trash Rack and Intake Parts

The Data Quality scores reflect the quality of the inspection, test, and measurement results to evaluate the condition of trash rack and intake parts. The more current and complete the inspection, testing, 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 collect data (measurements, tests, operation logs, maintenance records, design drawings, previous assessment reports, etc.) to aid the current assessment. 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 trash rack and intake components are shown in Chart 6.

Chart 6 Trash Rack and Intake 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 is 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 the 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 the routine inspections, tests, and measurements were completed 24-36 months past the normal frequency, or some of the results are not available.	**3 – 4**
Very Low - One or more of the required inspections, tests, and measurements were completed >36 months past the normal frequency, or significant portion of the results are not available.	**0 – 2**

6.0 Trash Rack and Intake Condition and Data Quality Indicators

In Table 1, the final condition score called the Condition Indicator (CI) for the trash rack and intake 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 trash rack and intake 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 a trash rack or intake; *K* = the identification No. of trash rack or intake 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 trash rack or intake part.

7.0 Reference

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