Quest Integrity

CAPABILITIES STATEMENT
HYDRO POWER

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CHALLENGE CONVENTION

TABLE OF CONTENTS

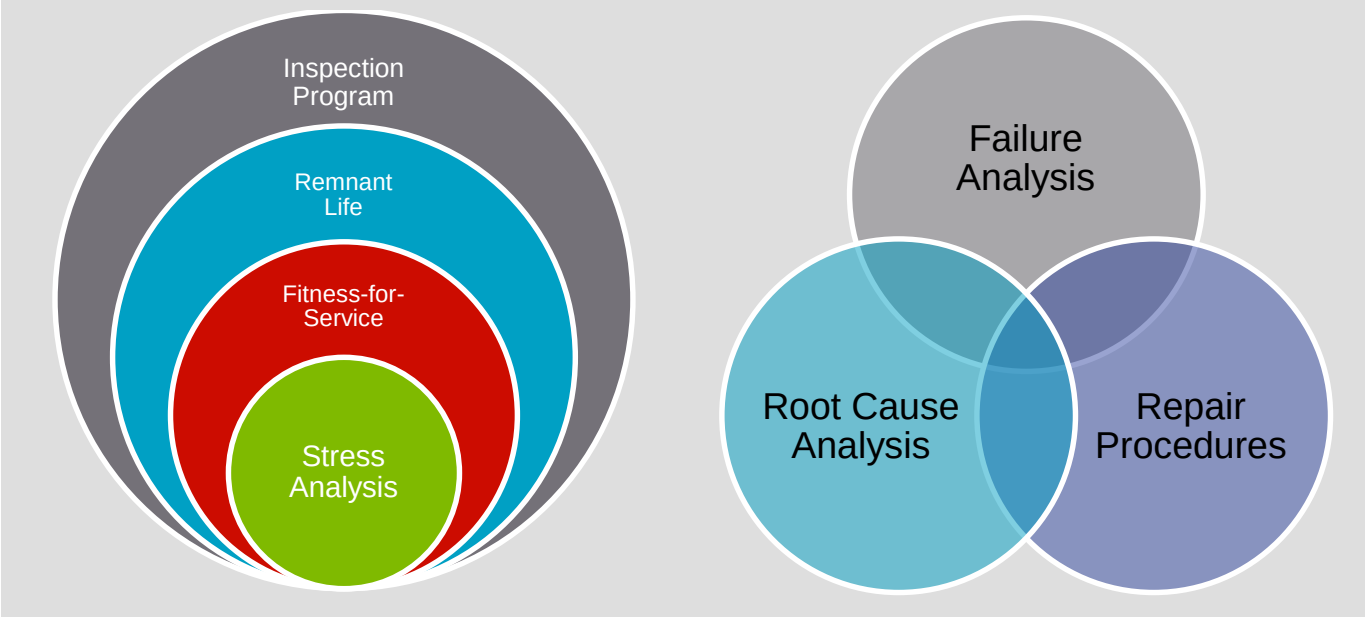
1 INTRODUCTION

Quest Integrity, a Team Industrial Services company, is a global leader in the development and delivery of asset integrity and reliability management services and solutions for its clients. Solutions consist of technology-enabled, advanced inspection and engineering assessment services and products that help companies in the refining and chemical, pipeline, syngas and power industries reduce operational and safety risk, improve operational planning and increase profitability. Quest Integrity is headquartered in Seattle and has offices in Houston, Denver, Canada, The Netherlands, United Arab Emirates, Saudi Arabia, Australia and New Zealand.

2 KEY SERVICES TO HYDRO POWER

Quest Integrity has improved operations and maintenance and supported rehabilitation and modernization programs for numerous power plants. This independent and expert service is provided through advanced inspection and engineering capabilities on fixed and rotating equipment found in and outside of the powerhouse. The accuracy, coverage and repeatability of these inspection and assessment services have led to documented improvements in the safety and sustainability of client operating assets. Several major power companies have adopted Quest Integrity solutions as part of their best practice procedures.

Things That Might Keep You Up At Night	**Solution Service**[1]
"*We discovered cracking in our turbine shaft, can we make it safely to the next outage? If so, what is the best repair procedure?"*	Remnant life assessment / Materials consulting
"How do we optimize our inspection dollars, where do we look, what inspection method do we use, and how frequent?"	Development of focused inspection programs
"Our radial arm gate has sections with significant pitting and corrosion. Is there a codifed approach to assessing this damage?"	Fitness-for-Service
"Our Kaplan blades developed cracks which we have repaired. The cracks have reappeared near the repair site. What is the root cause of the cracking and how long can we safely continue to operate this unit?"	Materials consulting / Fitness-for-Service / Remnant life



Remnant Life and Inspection **Materials Consulting**

[1] The solution service often involves a multi-disciplinary engineering approach (e.g. civil, mechanical, metallurgical, NDT)

2.1 DEVELOPMENT OF INSPECTION PLANS BASED ON RISK BASED INSPECTION STRATEGY

Quest Integrity provides expert risk-based inspection (RBI), involving identification of high-risk assets, assessment of equipment condition, evaluation of maintenance and inspection programs, study of operating protocols and estimated life consumption of critical assets. This process takes into account the likelihood and consequences of mechanical failure. The information is then used to modify and optimize inspection and maintenance programs, audit procedures, operating limits and safety protocols.

2.2 REMNANT LIFE ASSESSMENT

Provides expert recommendation on “how long” it will take identified damage mechanisms to reach a critical condition on stationary and rotating components. The most common damage mechanisms assessed are fatigue crack growth and metal loss. Remnant life assessments are typically used for life cycle planning, and provide valuable information for defining asset management strategies.

2.3 CRACK LIKE FLAWS, METAL LOSS AND PITTING FITNESS-FOR-SERVICE ASSESSMENTS

Provides expertise on the practical management of crack like flaws, metal loss and pitting conditions using guidelines outlined in the ASME FFS-1 and British Standard BS7910. The results of the Fitness-for-Service assessment provide plant operators with a clear understanding of the criticality of the damage and “go-no-go” criteria for continued operation.

2.4 STRESS ANALYSIS

Provides expert recommendations on critical stresses found in a component, or an assembly of components, due to operating or severe loading. Stresses due to fluctuating loading can also be determined for fatigue assessments. Typically, stress analyses are conducted using finite element analysis (FEA). The results are used for subsequent Fitness-for-Service, remnant life and other assessments.

2.5 FAILURE ANALYSIS

A multidisciplinary approach is used to investigate the cause of failure in static and rotating plant equipment. Defects in design and operational processes are determined to prevent the occurrence of similar future failures.

2.6 ROOT CAUSE ANALYSIS (RCA)

Provides expert analysis to identify primary failure or fault mechanisms. Failure analysis and structural integrity investigations are often key part of RCA.

2.7 REPAIR / REPLACEMENT PROCEDURES

Provides expert repair and/or replacement strategies for components where known damage processes are expected to occur or have been known to occur, to minimize future risks. This often requires more detail than in the original manufacture.

3 AUXILIARY SERVICES TO HYDRO POWER

In conjunction with key services described in Section 2 above, Quest Integrity has demonstrated expertise in the following services:

3.1 COMPUTATIONAL FLUID DYNAMICS

Expert capabilities to perform Computational Fluid Dynamics (CFD) including: flow analyses that accurately predict pressures along the fluid-structure boundaries to be used in subsequent stress analyses; modeling of flow induced vibration and other fluid-structure phenomena such as cavitation. This CFD expertise, coupled with fracture mechanics and stress analysis expertise, provides unique advanced capabilities applicable to the hydropower industry.

3.2 SPECIALISED NDT INSPECTION

Provides expert and leading edge automated and manual inspection. Integration of NDT methods with structural integrity consulting provides Fitness-for-Service evaluations that allow clients to quickly determine if the component can continue in service, or if repair is required. A wide variety of ultrasonic techniques include fully automated and distance encoded: phased array methods (annular and linear), Time of Flight diffraction, through transmission, and Pitch and Catch.

3.3 DESIGN REVIEW

Provides third party assessment of key design parameters. This may include vibration modal modeling, fluid flow modeling, finite element stress analysis to determine the physical response of the component and material selection.

3.4 THIRD PARTY AUDIT OF MANUFACTURING / FABRICATION

Provides expert recommendation and review of inspection procedures and testing methods for critical manufactured/ fabricated components to ensure fitness-for-duty.

3.5 DEVELOPMENT OF RISK BASED SPARE PART SPECIFICATION

Provides management strategies for critical spares to improve availability and safety, minimize capital expenditure and ensure business continuity. Additional consideration is placed on critical tooling, storage and maintenance of spares to ensure optimized long-term availability.

3.6 ON-SITE STRAIN GAUGING

Provides expert onsite measurement of stresses using strain gauges and associated equipment. This is typically used for calibration of finite element models and defining transient loading.

3.7 VIBRATION ANALYSIS

Provides expert recommendation on modeling of vibration and related effects of vibratory fatigue. Typically, a modal analysis is undertaken to determine the natural frequencies of the assessed components for comparison against operating frequencies. If available, displacements or data from accelerometers gathered during operation is used to complement and validate the analysis.

4 PREVIOUS EXPERIENCE – REPRESENTATIVE PROJECTS

The table below represents some of Quest Integrity's typical hydropower projects[2].

Description	Client
The Raccoon Mountain Pumped Storage Facility (RPS) in Chattanooga, Tennessee is among the world's largest pumped storage hydroelectric power stations. Tennessee Valley Authority (TVA) operates RPS with four 415 MW reversible Francis units, providing 1600 MW of generating capacity. TVA wanted to develop a long-term inspection program for critical equipment associated with pressure boundaries along the waterway at RPS. The scope of this project encompassed components along the waterway beginning with the **Penstock Tube Liner including the Spherical Ball Valve, Spiral Case, Wicket Gates, Headcover, Mechanical Shaft Seal, Wheel-pit piping, Draft Tube,** and associated **Manways**. The project consisted of multiple analyses including computational fluid dynamics (CFD), finite element analysis (FEA), and Fitness-for-Service assessments.	Tennessee Valley Authority (TVA)
Fitness-for-Service (FFS) evaluation of a vertical generator shaft under daily start-stop conditions. The project included detailed analyses to determine if the generator shaft could continue to operate until a scheduled refurbishment in 2017, and if so, could the generator remain in-service with a power uprate, and for how long.	Tennessee Valley Authority (TVA)
Fitness-for-Service (FFS) evaluation of three families of 1940's era wicket gates.	Tennessee Valley Authority (TVA)
Critical technical review of USBR analysis for Hoover Dam project.	U.S. Bureau of Reclamation (USBR)
Finite element analysis and fracture mechanics assessment of main Inlet valve on a 34MW Francis vertical turbine.	Snowy Hydro
3D laser scanning used to capture the complex sweep of the runner blade was conducted to create a 3D CAD model of a section of the runner. This was used as the basis for a computational fluid dynamics analysis to calculate the pressure distribution on all fluid-contacting surfaces of the blade. In turn, this was mapped onto a finite element model to carry out an analysis to determine the stresses in the critical area. Using these stresses, a critical defect assessment was conducted to determine the maximum allowable safe crack size that could exist in the trailing edge of the crown to blade weld.	Mighty River Power

[2] Client references can be made available.

Description	Client
A finite element analysis and local thinning analysis was carried out on a head cover suffering from erosion damage.	Mighty River Power
A structural integrity program was carried out on a number of head covers. This included analysis of uneven bolt tension, fracture mechanics and fatigue analysis of fasteners, and a vibration analysis using measured data.	Hydro Tasmania
Stress analysis of penstock where the support had undergone severe movements and visual cracking was seen in the concrete support blocks.	Genesis Energy
Defect assessment of welds cracking in penstock including material toughness testing residual stress measurements, critical crack size and fatigue calculations.	Genesis Energy
Fatigue analysis of horizontal rotor shaft with Pelton buckets, including critical crack size calculations and calculations of safe inspection periods.	Hydro Tasmania
Erosion analysis of wicket gates. Twenty-four (24) wicket gates were found to be suffering from severe erosion. The maximum allowable wall loss for avoidance of failure was calculated in accordance with accepted Fitness-for-Service codes.	Mighty River Power
Assistance with weld repair on the body of a main inlet valve. The purpose of the analysis was to minimize the heat input and associated distortion by optimizing the amount of welding required to repair cracking found in the main inlet valve body.	Hydro Tasmania

QUEST INTEGRITY

Quest Integrity, a Team Industrial Services company, is a global leader in the development and delivery of asset integrity and reliability management services. The company's integrated solutions consist of technology-enabled, advanced inspection and engineering assessment services and products that help organizations improve operational planning, increase profitability, and reduce operational and safety risks. Quest Integrity is built on a foundation of leading edge science and technology that has innovated and influenced industry best practices since 1971.

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