HALLIDAYS HYDROPOWER
REVENUE FROM YOUR RIVER

Stringers Weir

Turbine Operation Parameters

Site Name	Stringers Weir
Site Address	Pear Mill Industrial Estate, Stockport, SK6 2BP
Installed System	75kW Archimedes Screw and Fish-pass
Site Parameters	Head 1.7m, Q_{mean} 5.25 m^3/s

Introduction

The purpose of this document is to:

1. Outline the operation parameters of the variable speed Archimedes Screw Hydro Turbine (ASHT) installed at Stringers Weir
2. Highlight where the parameters differ from the those stated in the Abstraction Licence
3. Demonstrate that these remain within the Environment Agency (EA) guidelines and legalisation for ASHT installations
4. Demonstrate there is no additional risk to fish

Operational Parameters

The abstraction licence for Stringers Weir issued to Hallidays Hydropower on 30th January 2015 states as follows; *''Hydro-electric power generation by means of a three-bladed Achimedean screw turbine of 3.6m diameter''* [1]
However a 4 bladed 3.5m diameter ASHT (see *Table 1*) has been installed as it better suited the flow regime on site.

The above changes were brought about through the normal design process, and were not deliberately hidden from the EA. The deviations from the issued abstraction licence came to light after an EA site inspection and a thorough comparison by Hallidays Hydropower of the Abstraction Licence and the as-built-drawings.

Turbine Parameters	Value
Diameter (m)	3.5
Number of blades	4
Max turbine speed (rpm)	24
Normal turbine speed (rpm)	22.6
Max tip speed (m/s)	4.40
Normal tip speed (m/s)	4.14
Max abstraction (m^3/s)	5.9

Table 1- Stringers Weir as-built AHST parameters

The tip speeds were calculated using the following equation;

$$Tip\ Speed = \frac{\pi \times (Turbine\ Diameter) \times rpm}{60}$$

Environment Agency Guidelines

EA guidelines for run-of-river hydropower schemes were issued in December 2013, this document was subsequently withdrawn on 11th February 2016.

The EA guidelines outline the minimum diameter and a maximum rotational speed for a 3, 4, and 5 bladed turbines, as seen in *Table 2*.

Number of blades	Minimum diameter (m) of turbine	Maximum rotational speed of turbine
5	3.0	24
4	2.2	30
3	1.4	32

Table 2- Turbine diameter and rotational speed [2]

By comparing Table 1 and Table 2, it is evident that the 4 bladed ASHT installed at Stringers weir falls within the EA guidelines as it does not exceed the maximum rotational speed and is wider than the minimum turbine diameter.

''We will normally approve the use of ASHTs according to the table below. (Table 2) Schemes designed within these parameters are likely to require only trash screens. Protection of the leading edge of the blade will be necessary'' – EA guidelines for run-of-river hydropower schemes [2]

Fish Risk

Turbine Diameter

The installed ASHT has a reduced diameter (3.5m) compared to the turbine diameter (3.6m) detailed in the Abstraction Licence [1], a smaller diameter turbine running at the same rpm will have a reduced tip speed, hence this change does not increase the risk to fish, **in fact it reduces the risk to fish.**

Number of Blades

The installed ASHT has 4 blades not 3 blades, as stated in the Abstraction Licence. It might be assumed that an increase in blade number would increase the risk of a leading edge contact occurring. However date gathered in the FishTek AHST Risk Assessment report demonstrates that there is no increased chance of a leading edge collision with a higher number of turbine blades (see *Figure 1*)

"The empirically corrected probabilities of leading edge contact occurring for fish of a range of sizes is presented in figure 1 for 3, 4 and 5-bladed systems. This shows clearly that for a given rotational speed, an increase in the number of blades does not equate to an increase in the probability of a fish being struck. This is due to the previously discussed influence of screw flow rates and hence approach velocity." [3]

By comparing the probability of leading edge contact at 24 rpm with 0.2-0.4m fish for a 3 bladed screw in Figure 1 (0.035) with the probability of leading edge contact at 24 rpm with 0.2-0.4m fish for a 4 bladed screw in Figure 2 (0.025) it is clear that there is no increased risk of leading edge contact with a 4 bladed ASHT.

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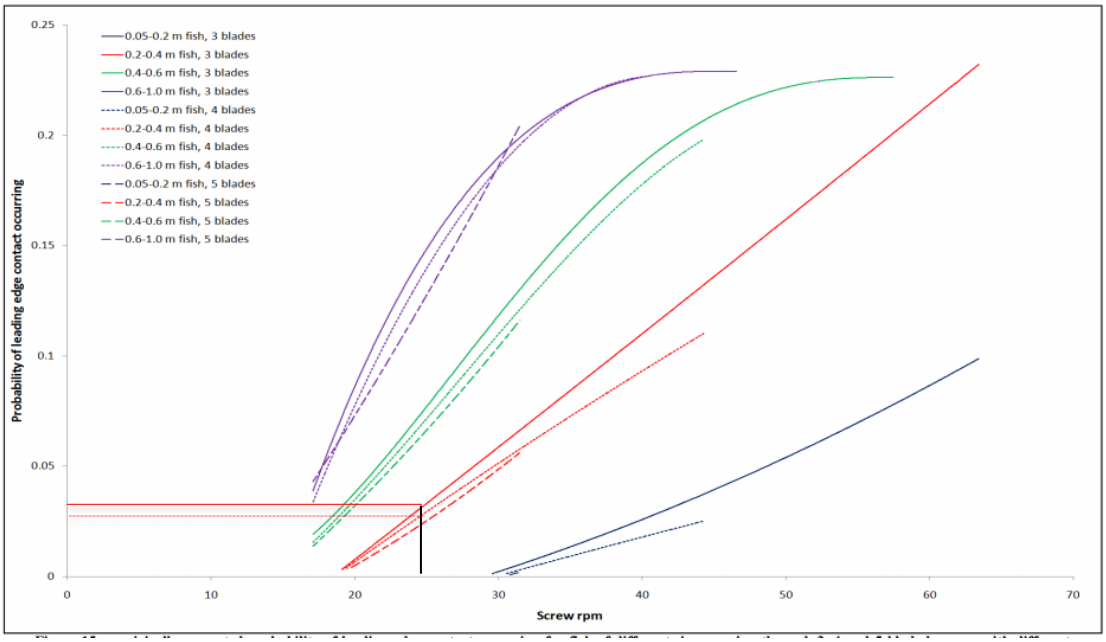

Figure 1 – empirically corrected probability of leading edge contact occurring for fish of different sizes passing through 3, 4 and 5-bladed screws with different rotational speeds. Lines are second order polynomial best fit lines to the raw data of 201 commercially available screw systems. Solid lines correspond to systems with 3 blades, thin- bashed lines to systems with 4 blades and think-dashed lines to systems with 5 blades [3]

Variable Speed Drive

The turbine system installed at Stringers Weir is fitted with a Variable Speed Drive (VSD), so compared to other ASTH installations it does not run at a fixed speed. As stated in the Fish-Tek ASHT risk assessment- *''This has the effect of reducing the average rpm at which the variable system is turning, although the maximum rpm for the two machines are the same''. [3]*

The relationship between the RPM and flow for VSD controlled AHST and fixed speed controlled AHST can be seen in *figure 2.* The relationship between the gap between blades (time between blade passes) and exceedance for VSD controlled AHST and fixed speed controlled AHST can be seen in *figure 3*.

The primary benefits for fisheries of VSD screws therefore are the maintenance of water depths within the screws by variable turbines that does not occur with fixed speed screws and the average increase in the gaps between blades. The increased depth in variable speed screws will be particularly marked at lower river flows and hence screw takes. This offers a significant advantage as it is likely that fish stand a higher probability of delaying at fixed screw speeds with shallow water depths in the screw itself, shorter time intervals between the helix leading edges and lower water depths in the forebay area. This is represented in *figure 2* and *3.*

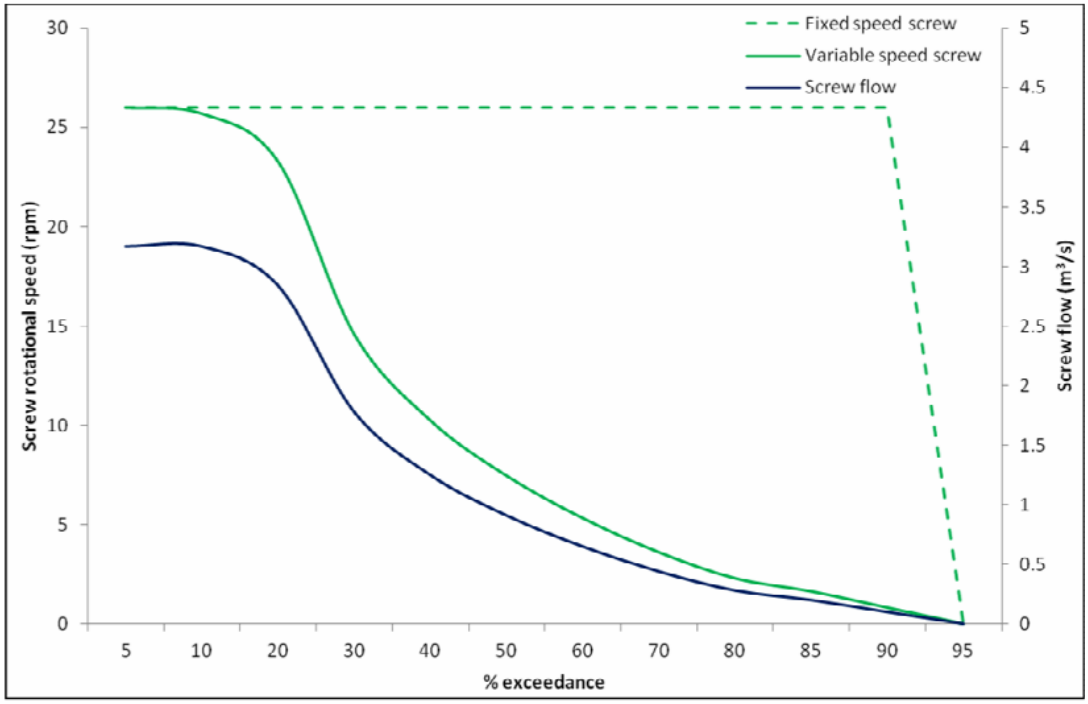

Figure 2 - Hypothetical relationship between screw flow across the FDC for a fixed speed and variable speed in a high base-floe river, taking up to a maximum of Qmean with a maximum rpm of 26 [3]

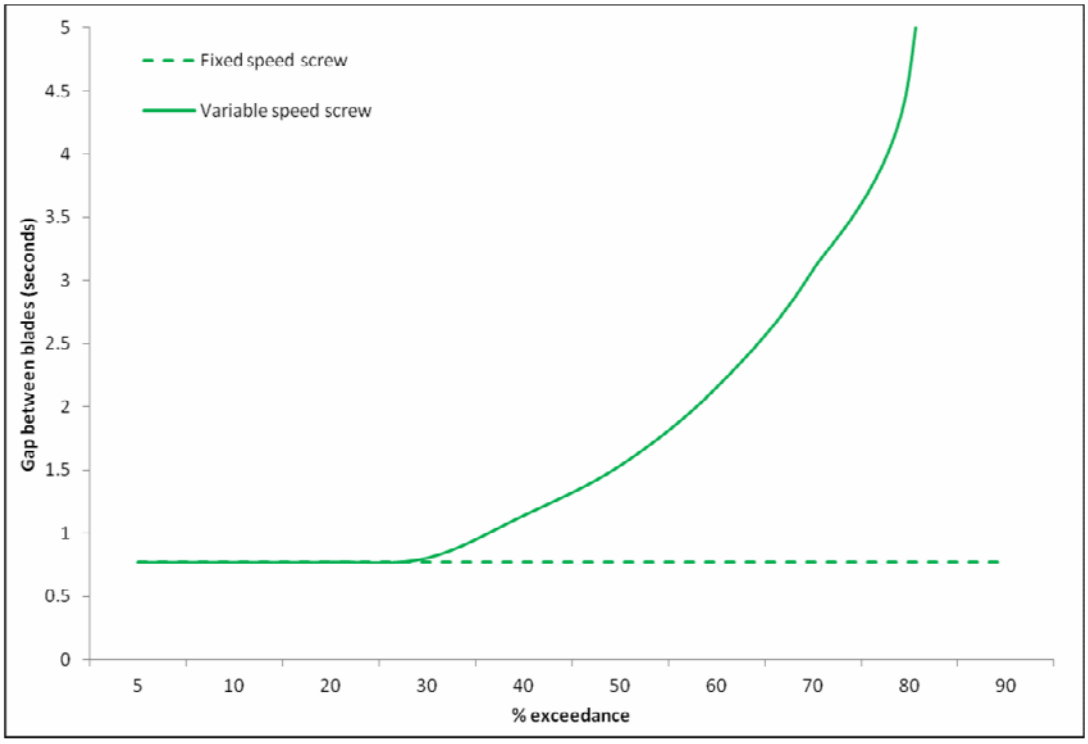

Figure 3- graph showing the gap between blades for fixed and variable speed 3-bladed screws in a hypothetical low base-flow river with a maximum screw rpm of 26 [3]

Conclusion

Whilst the parameters of the as-built AHST installation at Stringers Weir differ from those discussed in the issued licences, the evidence shows that there is no perceived increased risk to aquatic life in the river and the net benefit of improved generation output has a wider benefit in the reduction of greenhouse gasses.

Works Cited

[1] Enviroment Agency, *Full Licence To Abstract Water,* Date of Issue 30 January 2015.

[2] "Guidance for run-of-river hydropower," Environment Agency, December 2013. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/499589/LIT_7511.pdf. [Accessed 20 04 17].

[3] T. P.Kibel, "Achimedean Screw Risk Assessment," Fish Tek, September 2011. [Online]. Available: http://www.fishtek.co.uk/downloads/Fishtek-screw-risk-assessment-example-report.pdf.