The Amjet Turbine Systems ATS-63 Low Head Hydro Turbine/Generator

March 2015

Basic Concept

The Amjet ATS-63 is new and innovative single turbine-generator unit technology which utilizes conventional Kaplan propeller turbine technology within an axial flow compact composite design. The turbine-generator unit is lighter and able to be fully submerged. Because of its modular design and manufacturing advantages, the Amjet ATS-63 can be produced at lower cost and in much less time than conventional technology. It doesn't require a powerhouse, which also lowers installation cost significantly. The technology has been configured for low head sites throughout North America. Its combination of reduced turbine-generator cost and civil costs permits power installation at existing dams or repowering sites that otherwise would be deemed not economical. The installation simplicity and ease of maintenance are also significant advantages. This white paper explains low head opportunity and application of the Amjet ATS 63 units.

The low head hydro opportunity, as established in large part by the US Department of Energy research, comprises a wide range of small hydro applications including replacement of aging existing turbines, adding power at non-powered low head dams, run-of-the-river new applications, irrigation canal drops, city water pipeline inline turbine-generators where pressure reduction is needed, and other municipal water works and industrial power recovery. The common denominator is an operating range with net heads from 5 to 42ft (1.5 to 12.8m) with flows of 310 to 925CFS (9-26m3/s) and power outputs of 100 to 2,500kW for the majority of potential applications. Estimates for the US are 6.7GW[1] in available capacity and the world is estimated at 5x that of the US. This equates to 56,000 turbine/generators at an average 600kW rating. At an installed cost of $1 million per unit the market is $56 billion. Levelized cost of energy in these applications is estimated below 5cents/kWh.

Amjet is also developing its next generation ATS-32 single turbine-generator unit technology that will serve the same head range but smaller available flows of 50 to 300cfs (1.4 – 8.5m3/sec) and 25 – 625kW output, while maintaining the LCOE of 5cents/kWh.

The conventional hydro industry's approach to this opportunity, as in the past, is a smaller version of expensive metallic traditional custom designs, which would make it difficult to produce an economically feasible solution to this market. These smaller versions still require considerable civil costs as well as basically the civil structures are also just smaller versions of the custom designed larger structures. Amjet's approach is a paradigm change in terms of traditional low head hydro.

ATS set out to develop a design that has the following parameters:

- Operating range of 5 to 42ft (1.5-12.8m) head and 310 to 925CFS (9-26m3/sec) flow producing 100kW to 2.5MW capacity
- Low cost unit and low cost installation to allow profitable operation without subsidy
- Compact, low weight design: Integrate turbine and generator in one housing
- Eliminate wicket gates and pitch controls (electronic variable speed control instead)

[1] Based on comprehensive market study done by Knight Piésold & Co. for Amjet Turbine Systems, LLC.

- Low weight composite construction to achieve lower cost, reliable operation and avoiding corrosion
- Design that reliably operates under water.
- Modular design for mass production and power selection in 50kW steps
- Universal installation without need for a powerhouse and overhead crane
- Designs for single, small multiple (2-10) and large multiple (50 to 200 units) installations
- Design lifting hardware for maintenance, overhaul or replacement in one day
- Transportable in commercial truck or container (no special transport vehicles)

The result is the ATS-63 hydro turbine/generator shown in Fig. 1 that satisfies these parameters. It is an in-line turbine-generator with integrated rim generator and specialized electronic design producing a compact variable speed generator, keeping the over-all dimensions to a container-shippable device. The unit weighs one fifth of a conventional turbine-generator of the same rating and its compact design has a one fifth footprint. The in-line construction and low weight make the unit versatile and allows installations not possible with conventional designs.

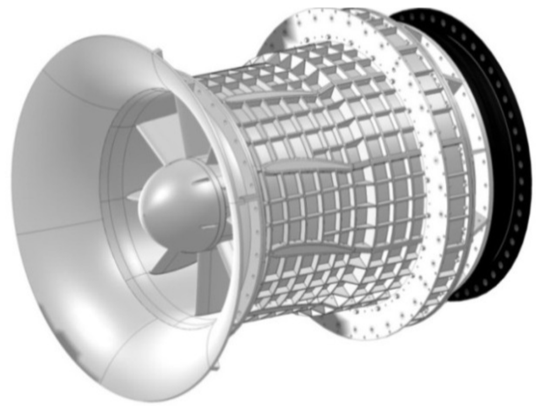


Fig. 1 ATS-63 turbine/generator

Amjet has followed a stringent technical development process in meeting the parameters. It has some additional features, namely (1) a variable speed operation that covers a wide range of outputs with identical hydrodynamic shape at near constant high efficiency and (2) Proprietary electronic circuitry design which is compact and efficiently controls variable rotational speed. Amjet constructed a one eights scale model (See Figure 2) and it was tested at the University of Iowa's IIHR Hydroscience and Engineering Laboratory to confirm the accuracy of the design predictions and confirm the expected performance of the full-scale model. Report is available for review.

FIG. 2 Test stand at the University of Iowa, 1/8-scale unit on the left (cables); instrumentation and monitor on the right.

ATS has prepared its physical designs using the latest Computational Fluid Dynamics analysis, Finite Element Method (FEM) analysis, and electromagnetic and electronic design methods. Table I below shows how the ATS-63 unit configuration varies to meet head, flow and power output:

Table 1: Basic range of ATS-63 performance

	Power	Head		Flow		ID		OD		Length		Weight	
***ATS*-series**	**(kW)**	**(ft)**	**(m)**	**(CFS)**	**(m3/s)**	**(in)**	**(m)**	**(in)**	**(m)**	**(in)**	**(m)**	**(lb.)**	**(kg)**
63-100	100	5.0	1.5	310	8.8	63	1.60	90	2.29	64	1.63	3,650	1,656
63-200	200	8.0	2.4	395	11.2	63		90		64		3,956	1,794
63-400	400	12.5	3.8	500	14.2	63		90		64		4,550	2,064
63-600	600	16.0	4.9	580	16.4	63		90		64		5,250	2,381
63-900	900	21.0	6.4	660	18.7	63		90		64		5,940	2,694
63-1200	1,200	25.5	7.8	725	20.5	63		90		64		6,680	3,030
63-1500	1,500	30.0	9.1	775	22.0	63		90		64		7,960	3,611
63-2000	2,000	36.0	11.0	860	24.4	63		90		64		9,100	4,128
63-2500	2,500	42.0	12.8	925	26.2	63		90		64		11,850	5,375

(all data approximate)

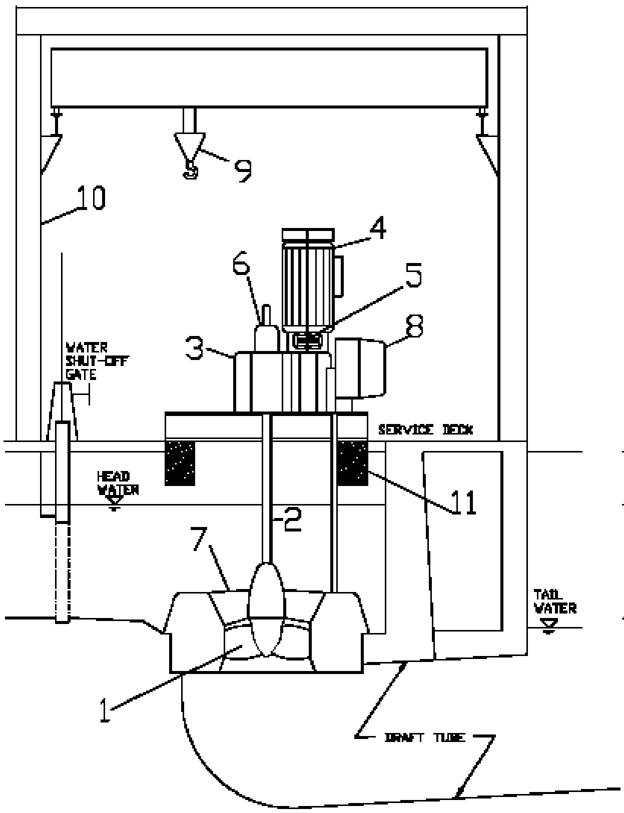
Applications

The power generated is dependent on head and water volume to enable corresponding power to be produced. Table 1 above shows a sample of possible combinations. At a 5ft (1.5m) head, the ATS-63 turbine produces **100kW** and needs a 330CFS (9.1m3/sec) water flow. At a 42ft (12.8m) head, the turbine/generator needs 925CFS (26m3/sec) and produces **2,500kW.** The midrange application is 16ft (4.9m) head using 570CFS (16.4m3/sec) and produces **600kW**. In larger rivers, multiple units can be installed in modules with common lifting systems. An ATS-63 turbine/generator can be placed in a weir, in-line in a conduit, in a siphon over a dam, in a river reach with water ducted through the turbine and returned to the river downstream. As a replacement the unit can fit directly in any similar size horizontal or vertically positioned conventional turbine location. The unit can be installed vertically, horizontally or at any angle.

Examples of installations

To demonstrate the differences between a conventional and *ATS* approach, the Figs. 3 and 4 illustrate how an *ATS* turbine/generator can replace a conventional hydro turbine. Fig. 3 shows a 2005 proposal for a vertical axis conventional 350kW Kaplan turbine (GE/Andritz) installation for the Burlington Street Dam in Iowa City, IA. The proposed installation includes mechanical flow controls containing over 70 moving parts. The main components necessary to operate and maintain this conventional turbine are numbered as follows: (1) separate turbine; (2) driveshaft; (3) gear box; (4) separate generator; (5) coupling; (6) runner-pitch hydraulic control; (7) wicket gates; (8) wicket-gate hydraulic control; (9) overhead crane; (10) powerhouse building; and (11) a heavy foundation.

Fig. 4, at the same Fig. 3 drawing scale, shows an equivalent installation with a 350kW *ATS*-63 turbine/generator. The *ATS*-63 turbine/generator contains only one moving part (instead of seventy or more moving parts), has one-fifth the weight and volume, can be serviced or replaced and be back into operation in one day. A hoist with a lifting track lifts the complete turbine/generator up into the "service" position and turns the unit 90 degrees for maintenance access. *ATS* turbine/generators do not use a gearbox or mechanical flow controls. The Amjet ATS-63 unit has a DC power variable speed generator. The *ATS*-63 turbine/generator efficiency is high (80+%) regardless of power output or rotational speed.



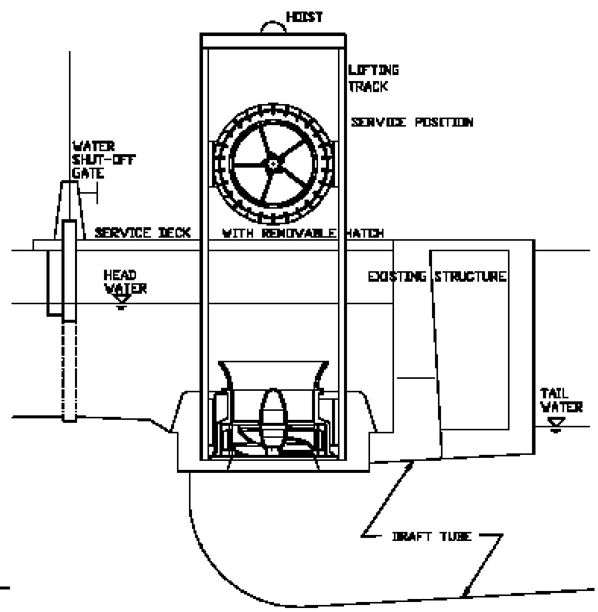


FIG. 3 Conventional modern generator (Andritz)
350kW, weight: 22,000lb (less crane and bldg.)

FIG.4 *ATS* turbine/generator same scale
350kW, weight: 4,500lb (no crane/bldg.)

Replacements from 5ft – 42ft (1.5m – 12.8m) head and 100kW – 2,500kW output can be provided.

Shaft Orientation

The example of Fig. 4 shows a vertical orientation, however the unit's orientation is universal and can be at any angle. The ATS-63 can replace older vertical equipment installations as it occupies less space and overall length. Depending on original arrangement it can replace a horizontal application with horizontal or vertical installation.

Other Examples

Figs. 5-10 provide examples of horizontal or angled installation possibilities from existing unit replacement , in-line conduit, siphon, bulkhead, run-of-the-river, canal drop, external dam and multiple unit installations. Examples 5-9 show installations that can be repeated in parallel or be placed in series

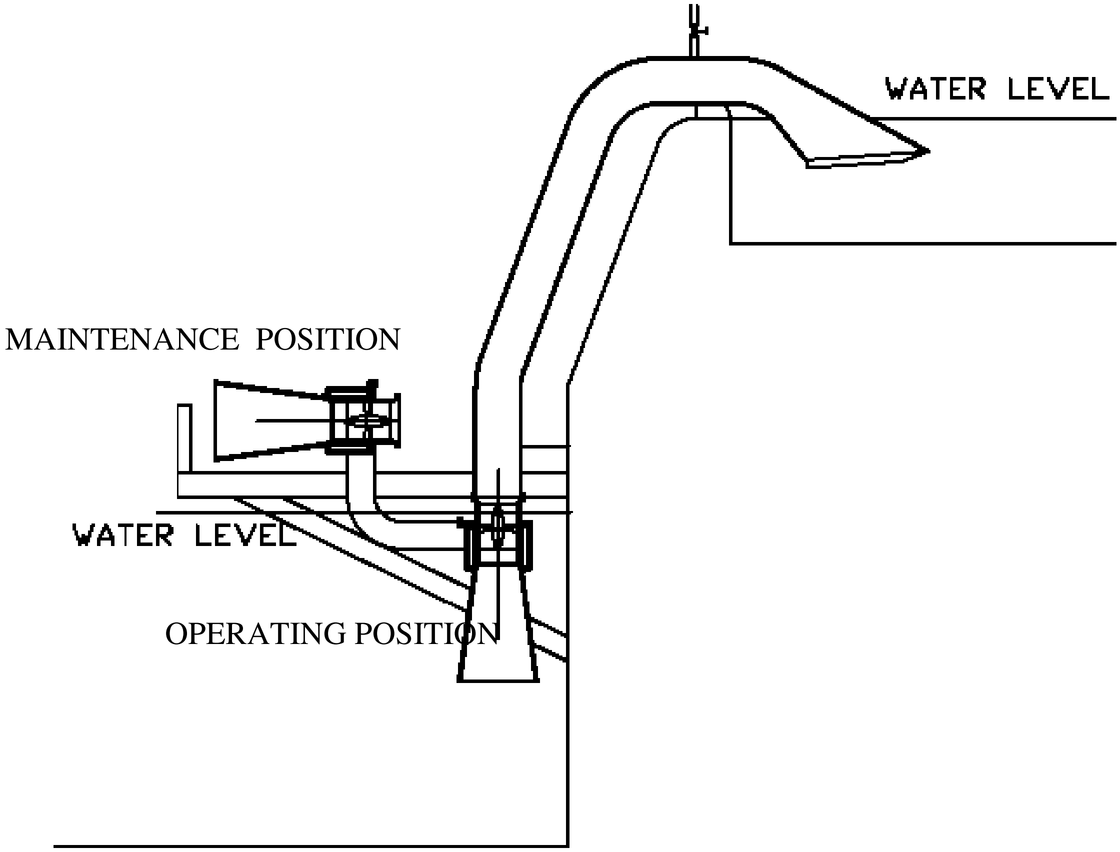


Fig. 5 Siphon with vertical turbine over dam or river bank. Applications from 5 to 42ft (1.5- 12.8m) 100kW to 2,500kW per unit. Multiple units can be placed in parallel.

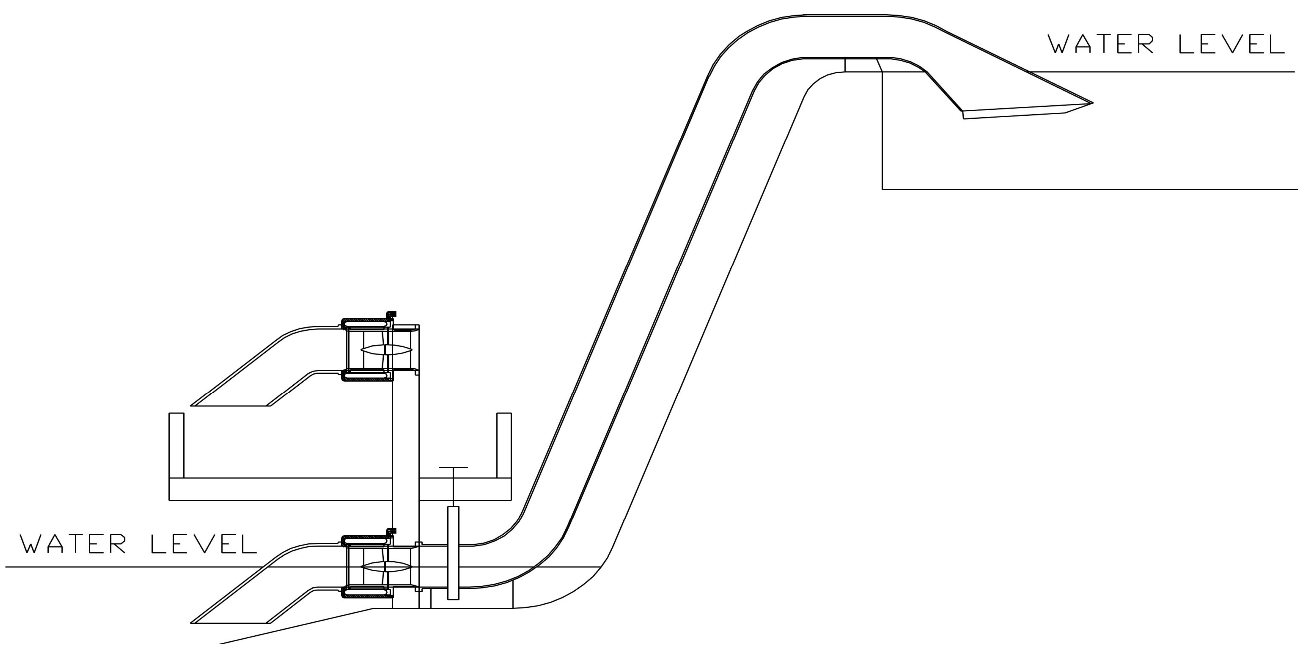


Fig. 6 Siphon with horizontal turbine over dam or river bank. Applications with heads from 5 to 42ft (1.5-12.8m) from 100kW to 2,500kW per unit. Multiple units can be placed in parallel.

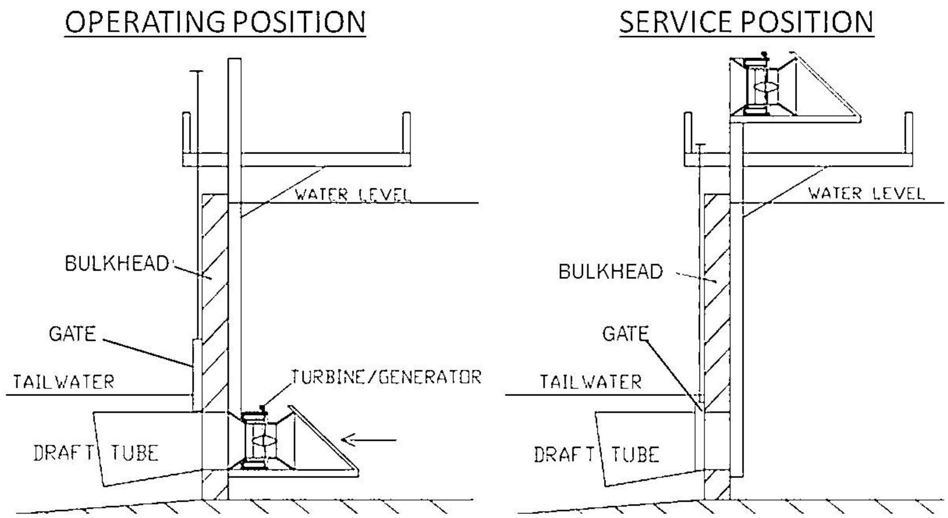


Fig. 7 Install on weir or bulkhead. Applications with heads from 5 to 20ft (1.5- 6.4m) 100kW to 1,200kW Multiple units can be placed in parallel.

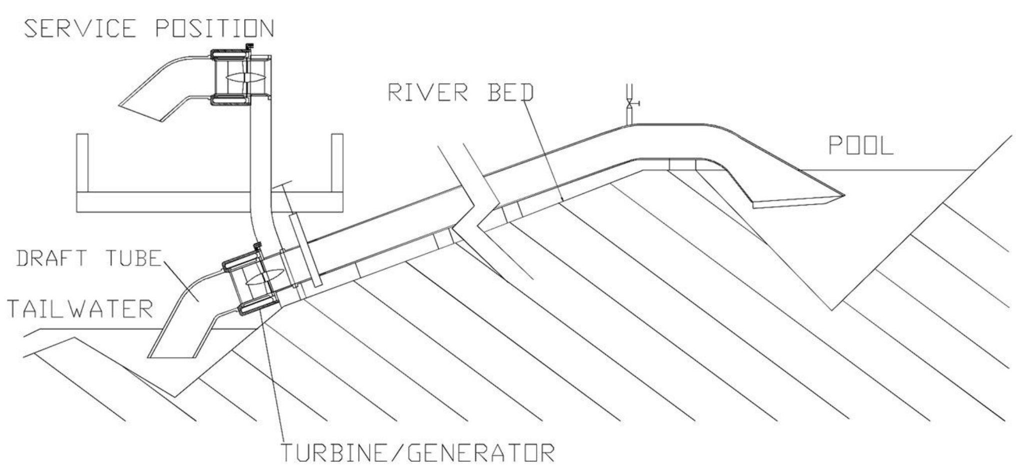


Fig. 8 Install on river reach with water return to river down-stream. Applications from 5 to 42ft (1.5 to 12.8m) and 100kW to 2,500kW. Multiple units can be placed in parallel.

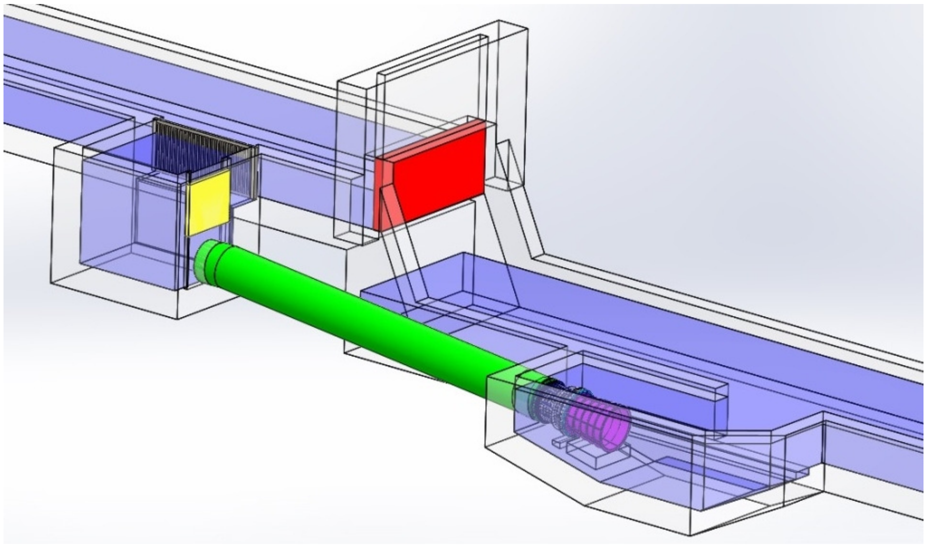


FIG. 9 Computer image of the installation of the *ATS*-63 hydro turbine generator in a canal drop or dam. The water flows from the high side intake pit via the Penstock (green) to the turbine (blue) and draft tube (purple). Head 5 to 30ft (1.5 to 9.6m) 100 to 1800kW. Larger pits will allow for more than one unit installation.

Operating Position Maintenance Position

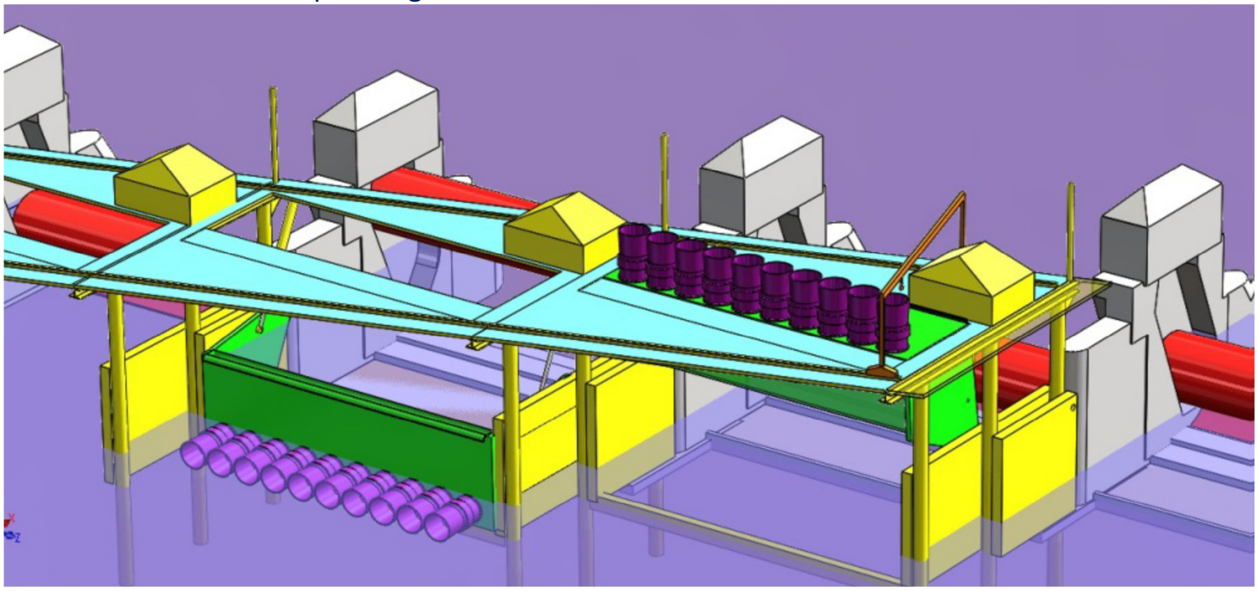
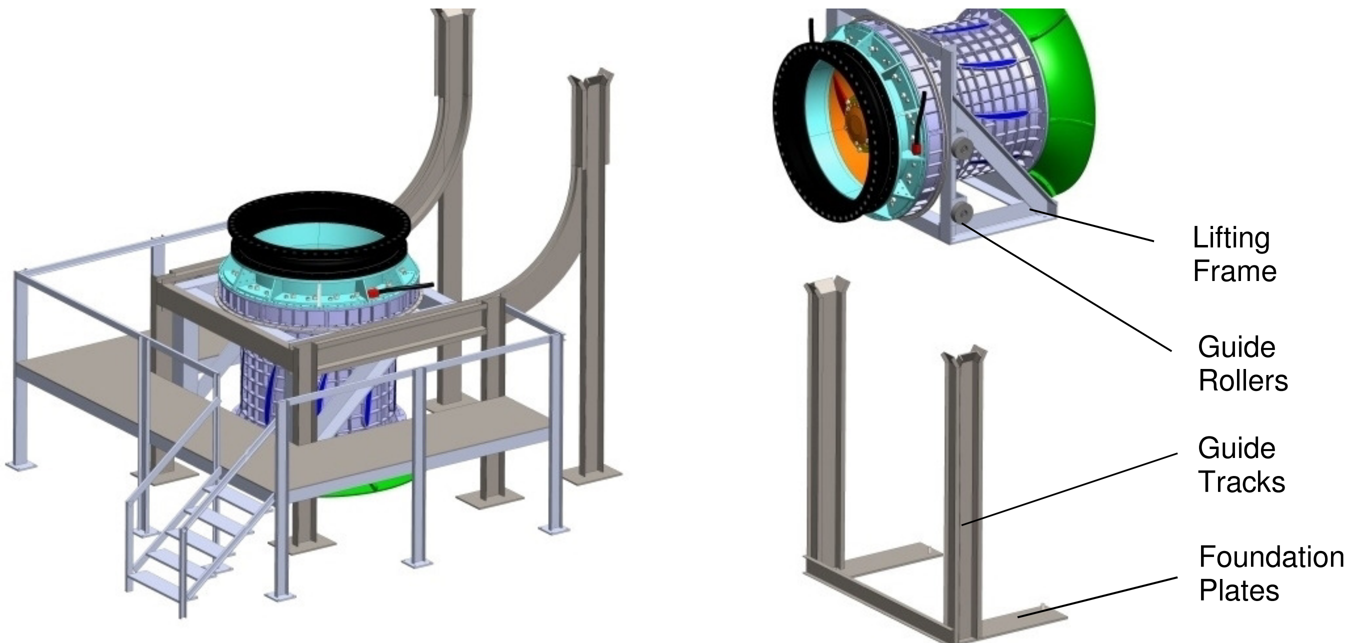


Fig. 10 Large river installation with multiple units per bay. Low weight allows simple construction of a moving barrier. Roller gates (red) remain in function as shut off gates. Up to 10 units per bay, 5 to 42ft (1.5 to 12.8m) and 100 to 2,500kW per unit or 1 to 25MW per bay.

Maintenance

The low weight makes the turbine/generator simple to lift for installation or maintenance service. Because of the universal, compact, low weight construction, no overhead crane or power house are needed. The ATS-63 has its own lifting arrangement and can be serviced or replaced in less than one day. The Amjet 63 unit installation and its maintenance is very simple and straight forward. Because of its low weight the turbine/generator can be easily lifted from its generating position into its maintenance position. The unit has only one moving part, so the time between maintenance periods is much longer than traditional machines, and when required the maintenance is quite straight forward and can easily be accommodated by a normal hydro maintenance person with limited training. Typical maintenance can be done is less than one day. To lift the ATS-63 from its generating position to its maintenance position, guide roller tracks are provided to raise and lower the turbine/generator and pre-align the turbine/generator with mounting bolts and to its s penstock and draft tube flanges. This provides for easy installation and removal for maintenance, repair or replacement. The maintenance service stand has a roller guide to rotate the unit for access to all serviceable components from the discharge end of the turbine. The low weight allows the use of a 10-15 ton mobile crane or a monorail crane to move the unit.



Service stand with guide track to rotate unit for access
Turbine/generator is designed for all access from discharge side
Fig. 11 Universal horizontal shaft installation with guide tracks and service stand

Progress

The first ATS-63-600 is being manufactured and will be installed in the Brainerd Public Utilities Dam in the Upper Mississippi River in Brainerd, Minnesota. Interest has been expressed from many sources for this low head technology. Amjet is taking quality assurance steps to make sure the design, manufacture, installation, commissioning and testing is carefully conducted at every step for the first installation.

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