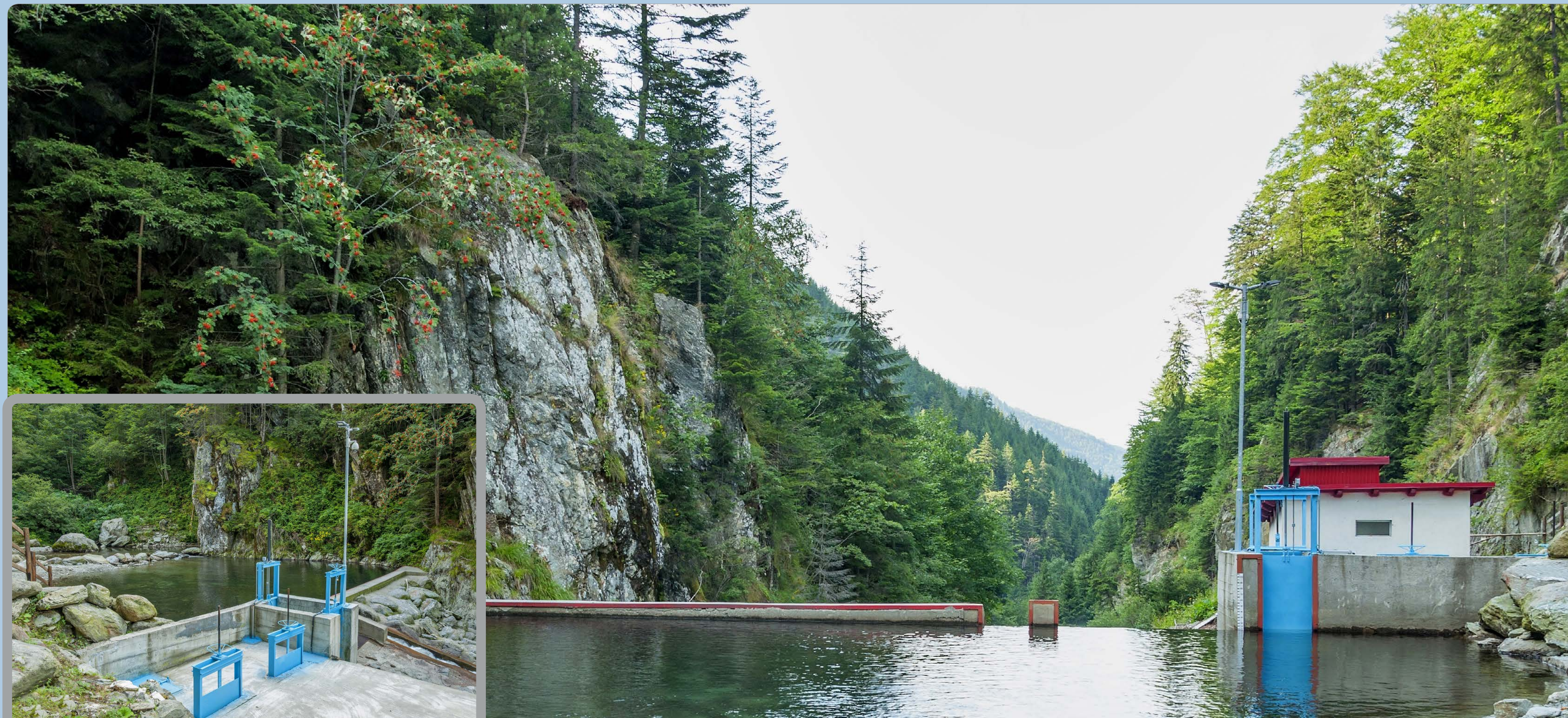
INTERNATIONAL STAINLESS STEEL FORUM

Stainless Steel in Micro Hydro Turbines



Cover picture: Micro power plant in the Carpathian mountains

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Small, distributed renewable energy production is attractive

The necessary development of renewable energy to mitigate climate change has sparked a new interest for micro hydro power, now seen as a necessary part of the renewable energy sources mix.
As the sites are usually located in remote areas, local communities are very interested in having a local energy production, which may be a source of revenue and reduce their dependence on big energy providers.
In a number of cases, various incentives schemes are offered to attract investors.

Micro Hydropower (10kW – 1MW) is able to tap into small hydro potential

Water power has been recognized for more than a century as a provider of renewable electricity energy. Most of the sites suitable for medium to large hydro power production (above 1MW) have already been exploited, sometimes with big environmental concerns.
Tapping into smaller streams or any low head flow with micro hydro turbines (roughly 10kW to 1MW) has thus become attractive and many small-scale projects have been carried out, or will be developed in the near future:

- On rivers and streams, environmentally friendly designs that, among other features, do not harm the fish or impact the landscape.
- Between uphill drinking water reservoirs and downhill consumer locations.
- In process industries, any significant downward fluid flow may be used to generate some power and decrease the energy requirements.

The power generated by a hydro turbine is given in the following formula:

$P = Q*H*g*R$ in which:

P: Power (kW)
Q: Flow (m^3/s)
H: Head (m)
g: a constant 9.81 m/s^2
R: efficiency ratio: about 80% or 0.8

Technologies

The main technologies used to produce hydropower are shown in Figure 1 (ref1). A few links to videos are provided at the end of this brochure.

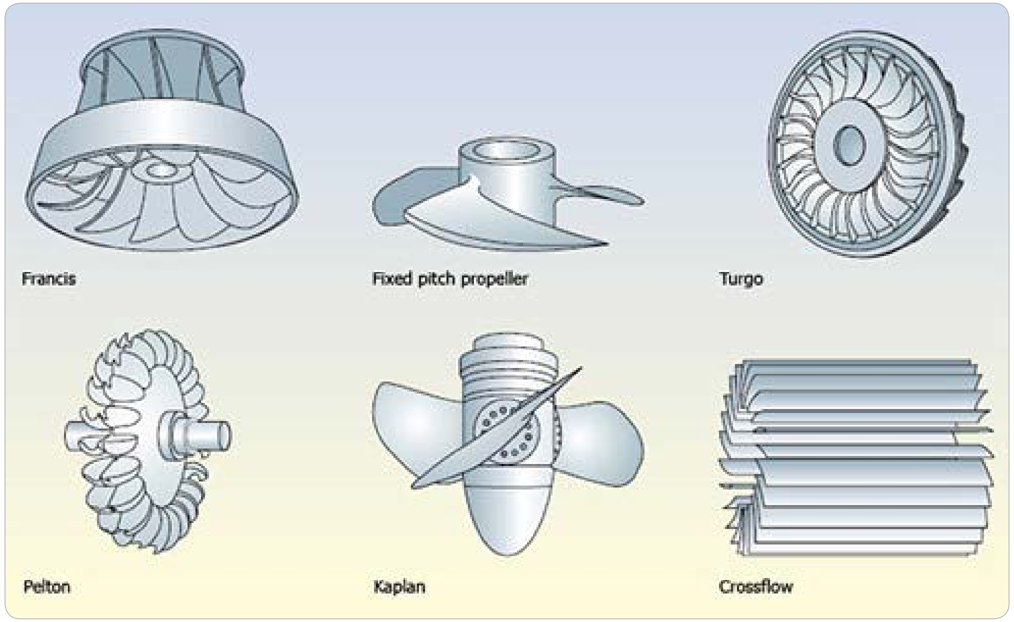


Figure 1: Representation of the main technologies used to produce hydropower

The choice of the right technology depends foremost on the head and the flow of incoming water, as shown in Figure2 (from Ref.2):

- High heads, low flow: Pelton turbines
- Low head, high flow: Kaplan or propeller-type turbines
- Intermediate: Francis, Turgo, crossflow* turbines (*also called Ossberger or Banki turbines)

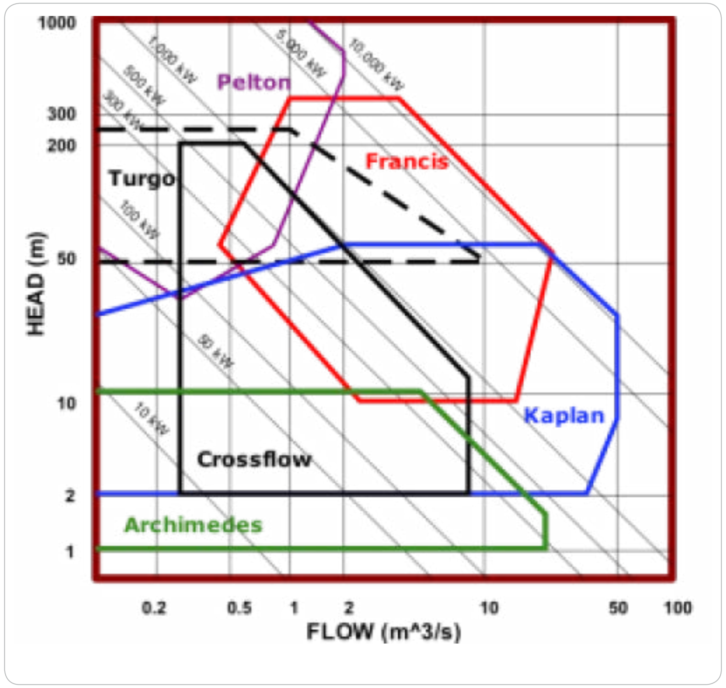


Figure 2: Representation of the main technologies used to produce hydropower as per forehead and flow of incoming water

As can be seen on Figure 2, there is a considerable overlap in the operating range of the technologies based on Head/Flow considerations only.

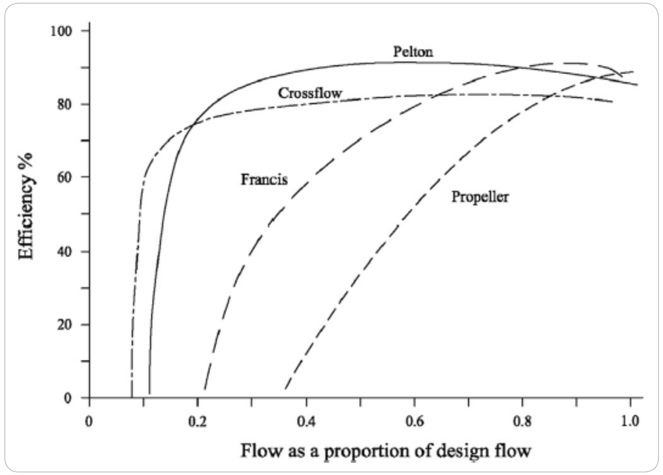


Figure 3: Efficiency of the operation compared to the flow

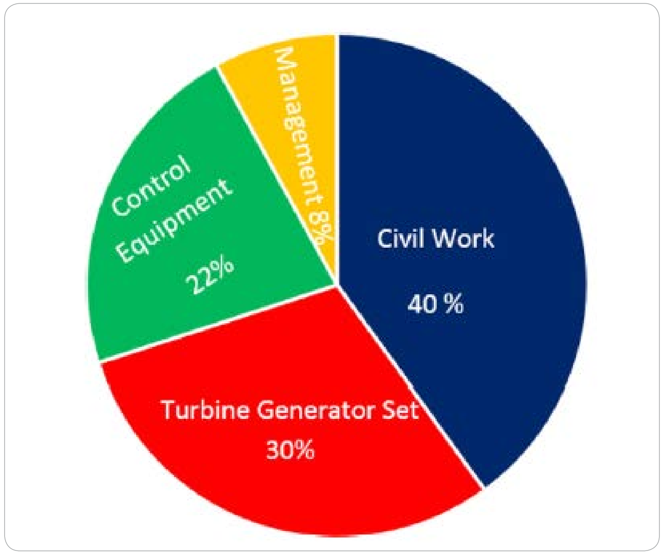
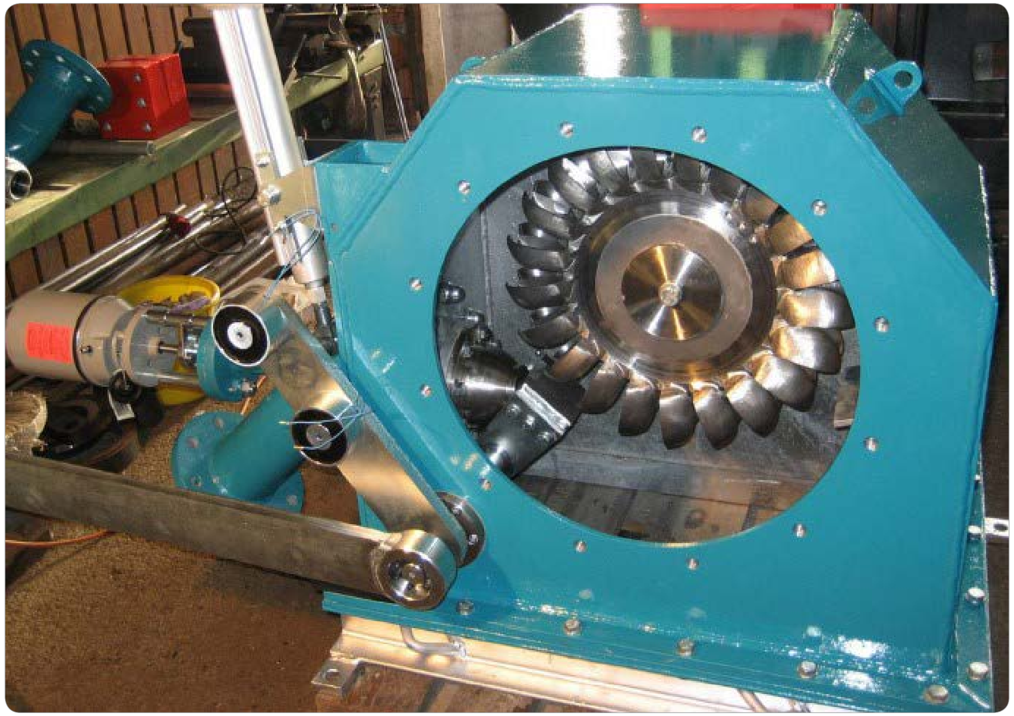


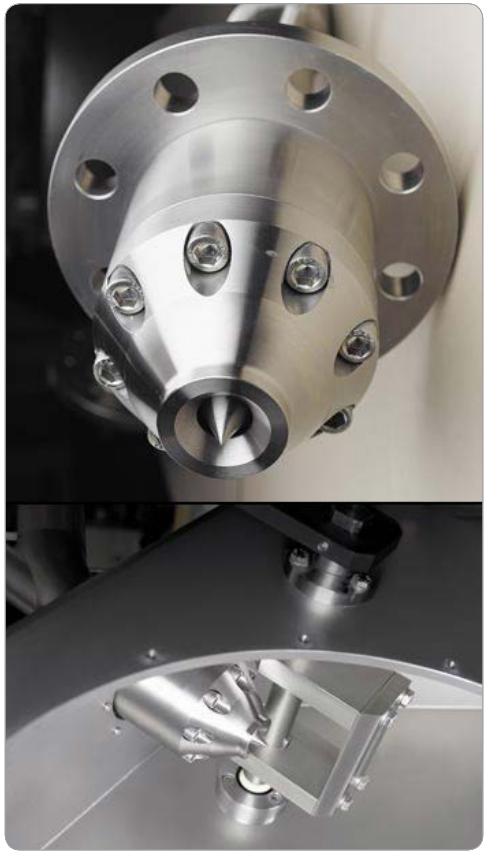
Figure 4: Typical breakdown between civil work, turbine set and control of equipment costs

Micro Pelton Turbine, Gradecka, Macedonia
Power: 936kW Head: 304 m Flow:0.35 m3/s
Picture courtesy of Gugler GmbH, Austria

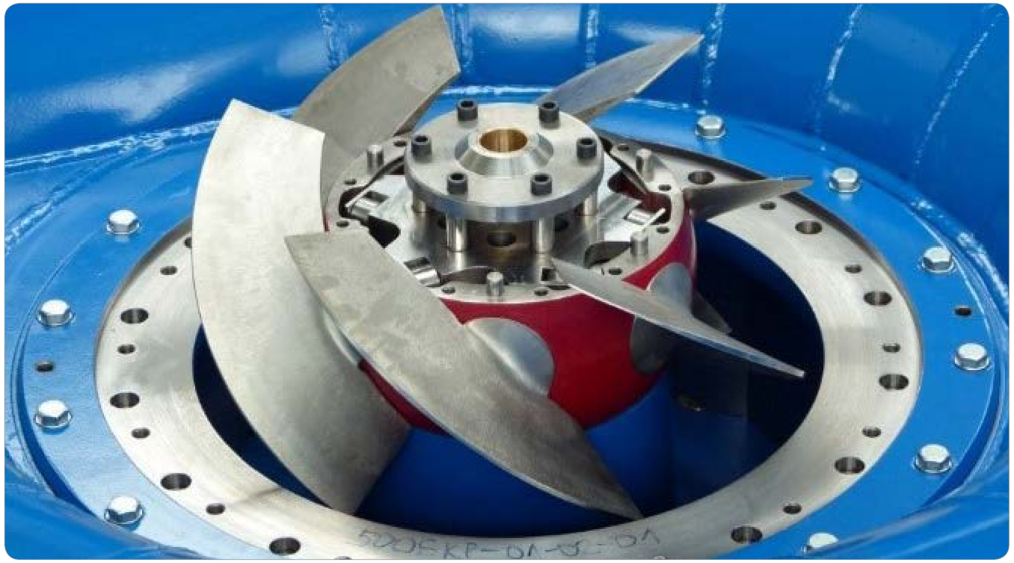
Another important consideration is the efficiency of operation, particularly when there is a variation in the flow rate, Figure 3 (ref2). The cost of installation is obviously a major concern as well. Figure 4 (from Ref1) shows a typical breakdown between civil work, turbine set and control equipment costs.
The environmental impact is taken into consideration, usually by providing “fish ladders” and screens that prevent the fish entering the turbine.
Very small size turbines (below 10kW), sometimes called “pico hydro turbines”, are also available. Their cumulated power output is negligible compared to the above categories and will not be considered in this publication. Flow turbines on rivers will be the next development. Currently, as demonstration units are the bulk of the installations, they will not been included in this document.



Open view of the micro hydro turbine of Caraglio, Italy
Power 61kW Head: 175m Flow: 0.04m3/s
Picture courtesy of Gugler GmbH, Austria



Nozzle and Needle for flow control of a Pelton turbine
Pictures courtesy of Lingenhoele GmbH



Francis micro hydro turbine in Kvernerud, Norway
Power: 507kW Head: 59m Flow: 1.2m3/s
Refurbishment in 2008 of a 1917 plant
Top: complete installation with turbine (blue) and generator (red)
Left: open view of turbine outlet and gates for flow control
Pictures courtesy of Hydrohrom s.r.o. Czech Republik

Kaplan micro hydro turbines
Right: Standard Kaplan in Cannunciaro, Italy
Power: 870kW Head: 11m Flow: 9m3/s
Picture courtesy of Gugler GmbH, Austria

Top: Spiral Kaplan in Lapradelle Puilaurens, France Power: 98kW
Head: 11.7m   Flow: 0.98m3/s
Picture courtesy of Hydrohrom s.r.o. Czech Republik

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Stainless steels in micro hydro turbines

For all parts in contact with water, and particularly moving parts, corrosion resistance is essential.

High water impact speeds customary in impulse turbines and high flow rates of Kaplan and Francis turbines require a good cavitation erosion resistance. Stainless steel grades 1.4313 and 1.4418 are the most suitable materials for this application, and are used in all large scale turbines such as those of the huge Three Gorges dam in China.

Grades form EN 10088-3 Standard (2014)	**1.4313 (See Note1)**			**1.4021 (See Note2)**		**1.4301 (See Note3)**
ASTM/AISI/ACI	**ACI CA6NM**			**AISI 420**		**AISI 304 ACI CF3**
Metallurgical Condition	Heat treated			Heat treated		Solution Annealed
	Q&T 700	Q&T 780	Q&T 900	Q&T 700	Q&T 800	
YS (MPa), min	520	620	800	500	600	190
UTS (MPa)	700 - 850	780 - 980	900 - 1100	700 to 850	800 to 950	500 to 700
Min Elongation (%), min	15	15	12	13	12	45
Corrosion resistance	Cavitation damage resistant			Wear resistant		Good corrosion resistance
Main application	Runners and guide vanes			Nozzles and wear rings		Housing & casings

Note 1 Grade EN 1.4418 has similar properties but a better corrosion resistance
Note 2 Other grades may be used as well, with increasing wear resistance: EN 1.4028, EN 1.4034, EN 1.4122
Note 3 Grade EN 1.4317 may replace EN 1.4301. For improved corrosion resistance EN 1.4404 or duplex grades are recommended
For very low heads, grades EN1.4301 and EN1.4401 are used as well

Left: Crossflow turbine
Picture from Ossberger
Right: Close-up of a stainless steel rotor
Picture from Irem spa

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Additional information: Videos on how hydraulic turbines work

- How a run of the River hydroelectric power station works
https://www.youtube.com/watch?v=rm9JqQGDwN0
- Introduction to Hydroelectric Turbines (Kaplan, Francis, Pelton)
https://www.youtube.com/watch?v=AT7B7IWm0tU
- Francis Turbine (in English) - How it works
https://www.youtube.com/watch?v=IZdiWBEzISM
- Francis Turbine
https://www.youtube.com/watch?v=JD4VkzHk6rk
- Kaplan and Francis Turbine (Difference) Learn and Grow
https://www.youtube.com/watch?v=FyX0dMOZGIk
- Kaplan Turbine Working , Power and Efficiency
https://www.youtube.com/watch?v=VeljEI_aWKo
- Hydraulic micro turbine design
https://www.youtube.com/watch?v=WvQ-5A8aIaY
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https://www.youtube.com/watch?v=Qwh6N_PSZ_Q

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About ISSF

The International Stainless Steel Forum (ISSF) is a non-profit research and development organisation which was founded in 1996 and which serves as the focal point for the international stainless steel industry.

Who are the members?

ISSF has two categories of membership: company members and affiliated members. Company members are producers of stainless steel (integrated mills and rerollers). The association has 56 members from all over the world and currently represents approximately 90% of the total production of stainless steel.

Vision

Stainless steel provides sustainable solutions for everyday life.

More information

For more information about ISSF, please consult our website worldstainless.org.
For more information about stainless steel and sustainability, please consult the sustainablestainless.org website.

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