THE APPLICATION OF GILKES IMPULSE TURBINES IN SOUTH EAST ASIA

DESIGNED AND BUILT IN THE UK

HEAD OFFICE

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APPLICATION OF THE TURGO IMPULSE TURBINE IN SE ASIA

1.0 Introduction

This section outlines the advantages gained using the Turgo impulse turbine for hydropower generation within South East Asia. Their major features and the benefits obtained by using these machines on suitable sites are reviewed. The paper briefly summarises Gilkes experiences with this type of machine in the region.

2.0 Summary

Turgo impulse turbines are well suited to power generation in South East Asia. Their robust design features and simple construction provide good reliability and availability. Machine efficiencies are maintained over a wide flow range and progressive efficiency reductions due to erosion by silt present in the water are minimal.

Sri Lankan Powerhouse

In common with other impulse turbines the Turgo has a flat efficiency profile over a typical site operational envelope. This contrasts with reaction machines where the comparable efficiency profiles are quite peaky and thus effective utilisation of available water is compromised, particularly in installations where the flow varies over a wide range during a year. The Turgo impulse turbine's flat efficiency profile can be further enhanced by the use of twin jet machines, and thus utilise more effectively the available water during seasonal flow variations.

Impulse machines are both simple and robust pieces of mechanical plant, and unlike their reaction cousins do not rely upon maintenance of close operational clearances for their continued efficient operation. In addition to reducing efficiencies, primarily due to increased internal leakage flows, Francis machines can be subjected to an increased axial thrust loading which in extreme cases could cause premature bearing failure.

Turgo impulse turbines are less affected by the erosive characteristic of silt laden water than Peltons where wear on the splitter edge leads to quite rapid reductions in efficiency. The runner geometry of a Turgo impulse turbine is such that even where blade leading edge erosion occurs the blade angles are essentially preserved and thus the efficiency reduction due to adverse flow incidence angles is negligible. We have experience with machines running under particularly arduous conditions that have suffered severe erosion damage without the Owner being aware of a reduction in performance.

3.0 South East Asian Topography

The geographical region of South East Asia is vast and covers all possible types of potential hydropower sites. The Turgo Impulse Turbine, as we have already stated, is ideally suited to heads where Peltons and Francis commonly overlap. The region boasts many sites where Turgos would be ideally suited.

Much of the region has a monsoon climate that provides a wide flow range during the year. The flat efficiency profile of the Turgo Impulse Turbine is ideally suited to this wide range of seasonal flow, and twin jet operation further enhances the machines capabilities of effectively utilising available flows throughout the year.

Periods of heavy precipitation frequently cause high silt burdens to be carried in the run off waters. Soil erosion in some areas possibly aggravated by timber and agricultural operations is particularly acute and further adds to the silt burdens naturally carried by the run off waters. In conventional dam fed hydro schemes this silt burden precipitates in reservoirs, causing a progressive reduction in useable storage capacity.

Run of river schemes are frequently fitted with silt traps. These are designed to catch much of the silt and thus avoid it passing through the turbines, however silt traps are seldom totally effective. Paradoxically at times of high run off, with silt burdens at their highest, flow through the turbines is maximised to generate maximum power. During these conditions velocities through the silt trap are at the highest value and therefore their effectiveness is minimised.

Barcaple Project Intake Sri Lanka – 1 x 2 MW

Regular maintenance of silt traps is necessary to remove accumulated debris. This task if not performed at suitable intervals severely compromises the effectiveness of the silt trap. Clearly if silt burdens are not effectively removed from water to be passed through turbines efficiencies of machines sensitive to close internal operational clearances are bound to reduce as these clearances are increased by wear accelerated by silt particles carried through by the water flow.

Experiences gathered from our operational Turgo sites all over the world have demonstrated that the Gilkes Turgo design is tolerant of high silt burdens over lengthy periods with only very gradual degradation in performance.

4.0 Gilkes Experience

Gilkes began manufacturing Turgo impulse turbines to our originally patented design in the 1920's. Throughout the intervening years we have made a number of substantial and continuous incremental modifications to the design to keep the unit ahead of the field.

Our experience with this machine is unrivalled with some 200 installed in the field since the 1980's ranging from a few KW to 5 MW and over 1,000 units produced in total. These machines find application in arduous environments ranging from remote jungle sites in Asia to copper mines high in the Peruvian Andes.

4.1 Malaysian Installations

Gilkes have supplied 16 Turgo units into Malaysia to NEB for their rural electrification programme designed to bring economic electricity to isolated villages. These units have provided reliable and effective service since installation with minimal spares requirements, despite being situated on sites where silt burdens in the water are quite heavy. The Turgo Impulse Turbine was particularly attractive to the user, as their experiences with Francis turbines on sites with similar hydraulic conditions had shown unacceptable downtime due primarily to the erosive nature of the water.

4.2 Thai Installations

Gilkes supplied four twin jet Turgo units to Thailand for the Provincial Electricity Authority (PEA). These units are part of a rural electrification scheme for regions in the north of the country close to the border with Myanmar. These developments were encouraged by the King of Thailand as a way of reducing deforestation and bringing economic prosperity to the residents of these remote areas.

Mae Ya Project Thailand - 1 x 1.1 MW

Gilkes have since supplied 3 further Turgo impulse units to the PEA for the Nam Man and Nam San Projects. These units are large 43" mean diameter twin jet units operating on relatively low heads in the region of 100 m that traditionally are where a Francis unit would normally be considered. The units range in power output from 3 MW to 5 MW

Operational experience has demonstrated the reliability and effectiveness of these Turgo impulse turbines in run of river plants where similar silt burdens would cause internal clearances to increase on reaction machines and reduce their efficiency.

4.3 Philippine Applications

Gilkes supplied 23 Turgo Impulse Turbines of various sizes into the Philippines in a period when the Government was actively promoting rural electrification. Our feedback, although limited, suggests that these units are providing reliable service in mostly isolated applications.

4.4 Indian Applications

The hydro market in India is particularly active for the full range of machines. Gilkes has had some successes in obtaining contracts for a range of machinery in India. In the late 1980's we supplied 6 Turgo machines in addition to some Francis units for power generation and grid support in remote regions. In the 1990's we supplied 2 x 1.5 MW Turgo units for the Mizoram State Electricity Board. There are a large number of Turgo turbines operating in India further supporting the thesis that this type of machine is well suited to use in the region.

4.5 Sri Lankan Applications

Sri Lanka derives 75% of its electricity from hydroelectric generation. A substantial part of this is large hydro (stations above 40 MW) but there has been a long tradition of utilising small hydro power plants especially in the tea-growing region.

Gilkes supplied 400 water turbine driven units to tea factories in Sri Lanka between 1890 and 1965. A few of these machines are still running but with the development of large hydro, the spread of the electricity grid and the vagaries of the tea market, many small hydro units were abandoned or had fallen into disrepair in the 1970's and 80's.

The demand for electricity on the island increased well beyond generation capabilities and, with the rejuvenation and privatisation of the tea industry, the need for continuous and secure electricity was identified.

There was limited potential for more large hydro and a reluctance to develop thermal power plants. Small hydro became critical again in the sustainability of power supplies in the country.

Carolina Project Sri Lanka - 3 x 850 KW

Since 1996 Gilkes have supplied equipment to a number of projects in Sri Lanka including the Carolina Project, 3 x 850 KW TJ Turgos on 90 m head and the Barcaple Project, 1 x 2 MW TJ Turgo on 100 m head. Both projects have been operating successfully for a number of years

5.0 Annual Energy Production

In certain instances the Turgo impulse turbine although it has lower full load efficiency than a Francis unit on a given site may provide more annual energy over the year. The Turgo impulse unit can operate down to 10% of the rated flow whereas a Francis unit can typically only operate down to 40% of the rated flow.

The Turgo impulse unit has a flat efficiency curve giving reasonable efficiencies at lower flows at which point the efficiency of a Francis unit is beginning to taper off as illustrated in the performance curve shown in Fig. 1 below

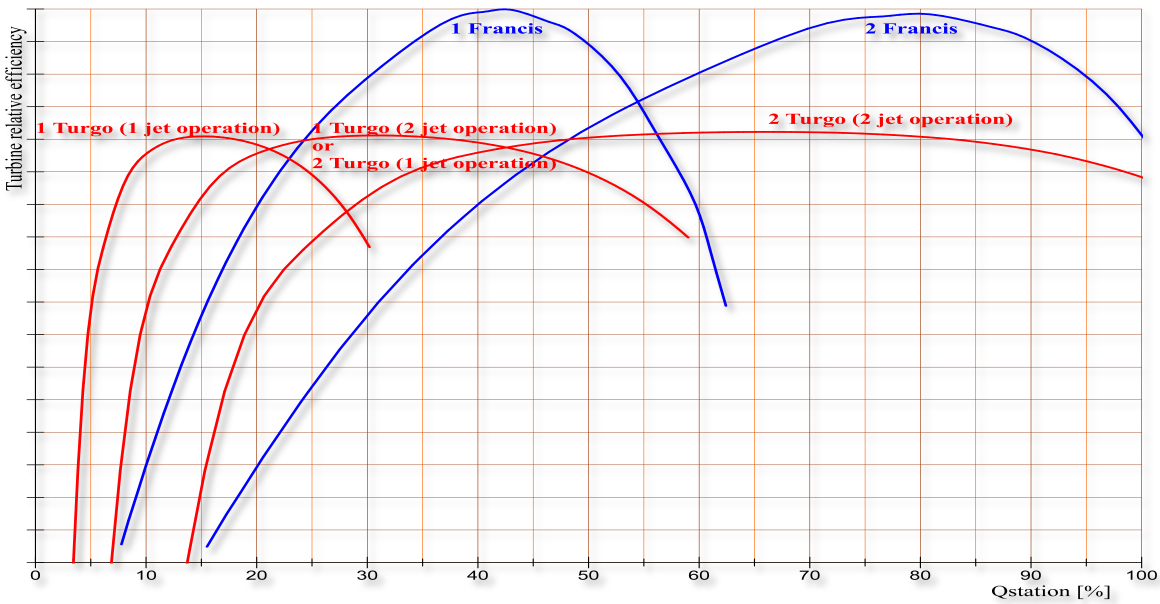


Fig. 1 Turgo vs Francis Performance Curves

A typical flow duration curve for the SE Asian region is shown in Fig. 2 it is steep and has long periods of low flow where the Francis unit may be operating at a low efficiency or shutdown completely because the low flow limit has been reached whereas the Turgo unit can carry on generating.

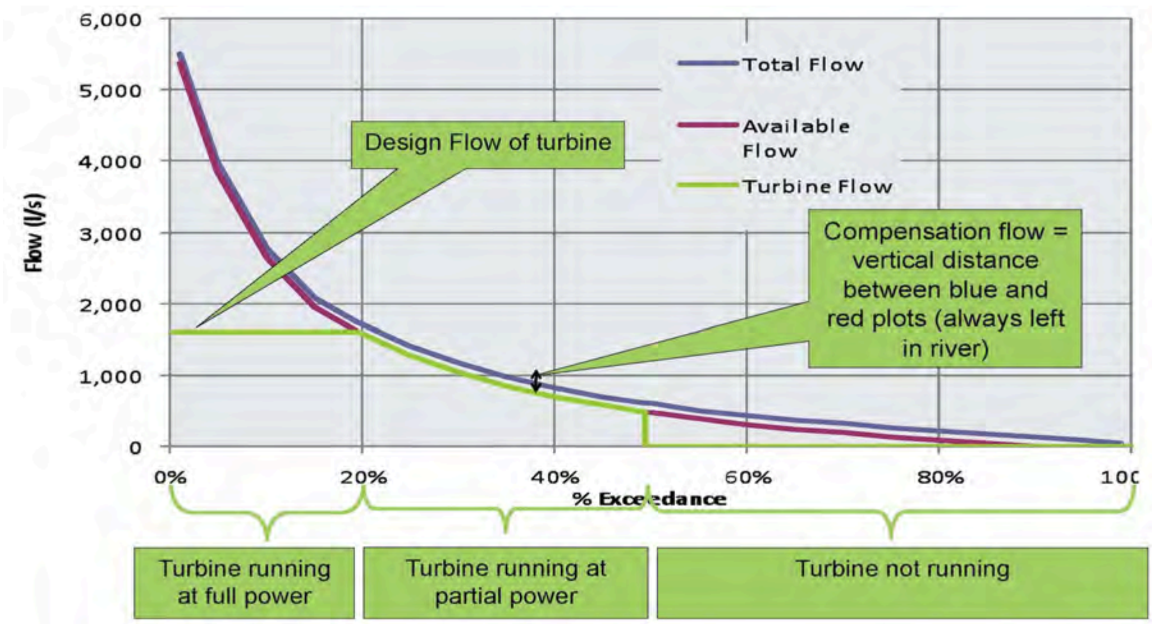


Fig. 2 Typical Flow Duration Curve

6.0 Conclusion

The simple and robust Turgo Impulse turbine provides reliable power generation even on water supplies with silt burdens.

It offers a number of advantages particularly over reaction turbines especially in SE Asia that have been covered above.

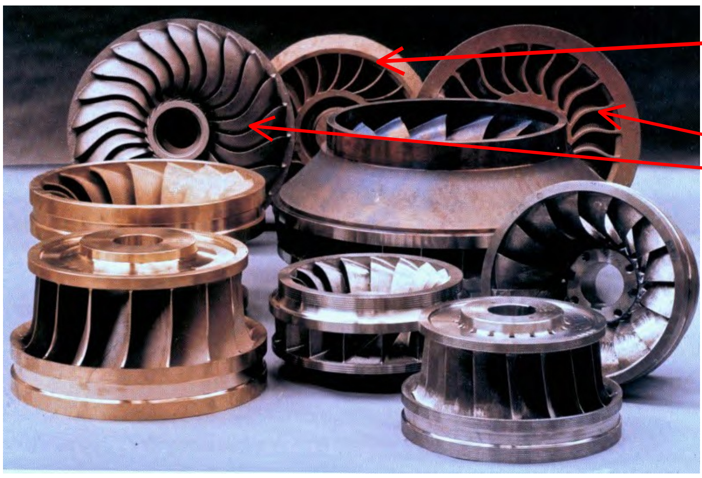
In summary:

- ***The Turgo has a higher specific speed than Pelton turbine resulting in smaller faster rotating turbine generator unit for a given head and flow***
- ***High tolerance to erosive particles in the water with no significant reduction in efficiency***
- ***Low maintenance design***
- ***Deflector speed control giving a fast response to load / frequency changes***
- ***Modular design approach***
- ***Flexibility in turbine design, layout and configuration***
- ***Runner manufactured from single piece fully CNC machined forging***
- ***No penstock surge in response to a change in load or frequency***
- ***No penstock surge on emergency shutdown on loss of grid***
- ***Operation possible down to 10% of rated flow***
- ***A higher annual energy may be possible than is available from reaction turbines on projects with long periods of low flow***
- ***Gilkes are the original inventors of the Turgo impulse turbine with nearly 100 years of experience on 1,000 Turgo units in 50 different countries***
- ***Ability to offer Turgo impulse turbines on significantly higher net heads at significantly higher power outputs up to 10 MW than other turbine suppliers (Refer to enclosed reference list)***

The information used to produce this paper was originally prepared for presentation at the "Small Hydro 1996" Conference held at the Pan Pacific Hotel in Kuala Lumpur on 28th to 30th October 1996, organised by "International Water Power and Dam Construction" magazine by Prof. D A Williams and Dr. C. P. Graves

High Head Turgo Impulse Units – HCTI **Head >150.0**

Year	Site Name	Country	Turbine	Head (m)	Flow (l/s)	Speed (rpm)	Power (kW)
2014	Pungwe C	Zimbabwe	28" Twin Jet HCTI	180	3000	750	4301
2013	Pungwe B	Zimbabwe	4 x 28" Twin Jet HCTI	175.7	3000	750	4204
2006	Pant Yr Afon	Wales	13.5" Single Jet HCTI	150	350	1500	425
2004	Kasidaya	USA	25" Twin Jet HCTI	165	2490	900	3208
2004	South Fork	USA	18" Twin Jet HCTI	173	1360	1200	1912
2004	Draper	USA	12" Single Jet HCTI	193	334	1800	511
2002	Oguchigawa	Japan	25" Twin Jet HCTI	158	2610	900	3320
2002	Jhankre	Nepal	13.5" Twin Jet HCTI	174	455	1500	653
2000	Karpenision	Greece	15" Twin Jet HCTI	175	750	1500	1076
1996	Kau Talubung	India	2 x 16.5" Twin Jet HCTI	190	1000	1500	1575
1990	Guatape	Colombia	20" Single Jet HCTI	195	750	1200	1232
1989	La Herradura	Bolivia	13.5" Single Jet HCTI	150	260	1500	323
1989	Burney Creek	USA	25" Twin Jet HCTI	186	2265	900	3530
1989	Olsen Creek	USA	31" Twin Jet HCTI	167.4	3964	720	5648
1986	Dry Creek	USA	22.5 Twin Jet HCTI	238	2152	1200	4393
1986	Silver Springs	USA	18" Single Jet HCTI	168	622	1200	891
1986	John Day Creek	USA	18" Single Jet HCTI	186	648	1200	1020
1984	South Fork	USA	18" Twin Jet HCTI	173	1360	1200	1912
1983	Lower Salmon, Alaska	USA	38" Single Jet HCTI	244	2832	720	5917
1983	Slate Creek	USA	25" Twin Jet HCTI	170	2832	900	4060
1983	Boulder Creek, Montana	USA	12" Single Jet HCTI	182.88	226	1800	340
1982	Schenectady for Preston Hydro Power	USA	15" Single Jet HCTI	175.56	283	1200	429
1982	Lydenburg Municipality	South Africa	22.5" Twin Jet HCTI	160	1993	1000	2660
1982	OK Tedi	Papua N Guinea	22.5" Single Jet HCTI	330	818	1500	2105
1981	Oberberg 2b Power Station	W. Germany	38" Single Jet HCTI	235	3880	750	7527
1981	Cia Minera Alianza	Peru	2 x 22.5" Single Jet HCTI	163	1098	1707	1707
1980	Ormsary Estate	United Kingdom	21" Single Jet HCTI	174	500	1000	709



Gilkes 1936 Design head limit = 198m

Gilkes HCTI Design head limit = 300m

Note modifications leading to edge profile and runner rim profile

Large Diameter Turgo Impulse Units – HCTI **Mean Diameter > 25”**

Year	Site_Name	Country	Turbine	Head (m)	Flow (l/s)	Speed (rpm)	Power (kW)
2016	Hauna	Zimbabwe	28" Twin Jet Turgo HCTI	112	2500	600	2221
2015	Kupinga	Zimbabwe	25" Twin Jet Turgo HCTI	128	1543	750	1602
2015	Iraru	Kenya	25" Twin Jet Turgo HCTI	118.4	1650	750	1559
2015	Taodail	Scotland	28" Twin Jet Turgo HCTI	92.551	1736	600	1262
2015	Ndolela	Tanzania	25" Twin Jet Turgo HCTI	65	1550	600	792
2014	Glendale	USA	25" Twin Jet Turgo HCTI	49.5	1133	514	450
2014	Farmers Irrigation	USA	31" Twin Jet Turgo HCTI	107	3058	600	2600
2014	Keltie Water	Scotland	25" Twin Jet Turgo HCTI	78	1626	600	1017
2014	Pungwe C	Zimbabwe	28" Twin Jet Turgo HCTI	180	3000	750	4301
2013	Sg Perting	Malaysia	25" Twin Jet Turgo	140.4	1760	750	2324
2013	Pungwe B	Zimbabwe	28" Twin Jet Turgo	175.7	3000	750	4204
2011	Yugashima	Japan	25" Twin Jet Turgo	132	1900	750	2079
2006	Takizawa	Japan	38" Twin Jet Turgo	107	4250	429	3628
2006	Barcaple	Sri Lanka	28" Twin Jet Turgo	98	2600	600	2055
2005	Akechigawa	Japan	25" Twin Jet Turgo	119	1700	720	1682
2004	Kasidaya	USA	25" Twin Jet Turgo	165	2490	900	3208
2004	Puueo	USA	31" Twin Jet Turgo	115	2652	600	2462
2003	Surikamigawa	Japan	38" Twin Jet Turgo	51	2882	333	1210
2003	Kastaniotiko	Greece	28" Twin Jet Turgo	62	1850	428	926
2002	Oguchigawa	Japan	25" Twin Jet Turgo	158	2610	900	3320
1999	Dworshak	USA	28" Twin Jet Turgo	123	2534	720	2521
1999	Power Creek	USA	43" Twin Jet Turgo	91	4530	400	3125
1998	Karasugawa I	Japan	25" Twin Jet Turgo	103.7	1530	720	1315
1997	Nam San	Thailand	43" Twin Jet Turgo	84	4365	375	3132
1997	Nam San	Thailand	43" Twin Jet Turgo	85	4365	375	3132
1997	Nam Man	Thailand	43" Twin Jet Turgo	119	5200	429	5202
1995	Isoya Gawa	Japan	25" Twin Jet Turgo	96	1669	600	1320
1992	Faure	South Africa	31" Twin Jet Turgo	130	1458	500	1475
1989	Burney Creek	USA	25" Twin Jet Turgo	186	2265	900	3529
1989	Olsen Creek	USA	31" Twin Jet Turgo	167.34	3964	720	5646
1986	Eklutna Hydro	USA	28" Twin Jet Turgo	44	1839	450	688
1986	Mink Creek	USA	28" Twin Jet Turgo	131	2831	720	3157
1986	Bidwell Ditch	USA	25" Twin Jet Turgo	108	1982	720	1844
1986	Sayles Flat	USA	28" Twin Jet Turgo	131	3256	720	3564
1985	Roaring Creek	USA	31" Twin Jet Turgo	88.3	3114	514	2297
1984	Ruedi Dam	USA	43" Twin Jet Turgo	82.9	5804	360	4050
1983	St George, Quail Creek	USA	38" Twin Jet Turgo	71.3	3935	450	2375
1983	Lower Salmon, Alaska	USA	38" Single Jet Turgo	243.84	2831	720	5915
1983	Slate Creek	USA	25" Twin Jet Turgo	170.08	2830	900	4060
1981	Little Cottonwood Creek, Murray	USA	38" Single Jet Turgo	120.3	2619	450	2579
1981	Blackheath Works, Cape Town	South Africa	38" Single Jet Turgo	56.4	1520	350	711