

# The Multipurpose Model Steam Turbine
# A Guide to successful Scratch-Building

by Werner Jeggli

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# Turbines Index





# The Multipurpose Model Steam Turbine

## 1. Introduction

Thinking about building a model turbine? Well, the idea of directing a jet of liquid or gas onto a bladed wheel and then using the resulting torque to do work – this idea is simple, elegant and old. Man has developed its use over centuries for driving mills, moving ships, generating electricity and conquering the sky to an extent that, these days, is taken today for granted. It also kindled men's spirit to build corresponding toys or models of these machines. The model aeroplane fraternity has been very successful in building jet engines for their planes. They benefited from the high fuel energy density/high power requirement of the models with high fuel consumption rate (necessary to keep the engine running) and the 3 dimensional, unrestricted field of action for their planes.

For model railway locomotives up to gauge 1, ships or small auxiliary power turbine-generators the situation is different. There, turbine shaft power output requirement would be in the 2 - 10 Watt range. A steam turbine drive would seem to be a viable option. More power cannot be transferred to the rails, the wheels would slip and/or the train speeds would become unmanageable.

A search in the hobby press and in the internet with its various forums reveal that quite a number of attempts have been – or are being made to tackle this issue. But nearly all of the contributions peter out without any tangible results, indicating that the builders never came to a satisfactory end and gave up. This indicates that this seemingly easy task is far from being that simple.

There is a notable exception - with due humility - my own contributions in this field. In the course of the past 18 years I have designed and scratch-built 4 steam turbine driven gauge 1 locomotives, "Der Mathematiker" and "Dampfsprinter" with turbine-electrical drive, both freelance, as well as "LMS Turbomotive" and the "Pennsy PRR-S2", both historical models and turbine-mechanically driven. They all run quite satisfactorily. They can be seen in action - video clips are to be found on Youtube.

At the time of writing, I'm 84 and I have decided not to build locomotives any more. My present ambition is to sum up my experience gained in the course of the years on construction and operation of model steam turbines and make it available to interested model engineers. The goal is to develop a multipurpose model steam turbine which, by just changing nozzle- and steam exit inserts, can be adapted to a variety of applications such as railways, boats or whatever. Additionally, I intend to help in sourcing the critical turbine parts such as rotors and nozzles. Anybody deciding to take on such a project would have my support as long as it is done in a methodical and properly managed way. The "how" is what I'll be trying to show you in the next few sections.

I also had the privilege of getting support from scientific experts in this field – George Held/Germany and Byron Hanchett/USA. Both of them have great knowledge of the behaviour of steam in larger turbines. They can calculate steam speeds, friction losses and resulting rotor torque etc. The problem is implementing their recommendations often do not bring the expected results. Possible reasons are inadequate tolerances of the small, manufactured parts (I'm

*Der Mathematiker*

*Dampfsprinter*

*LMS Turbomotive*

*Pennsy PRR-S2*

# 7. Designing the Power Train

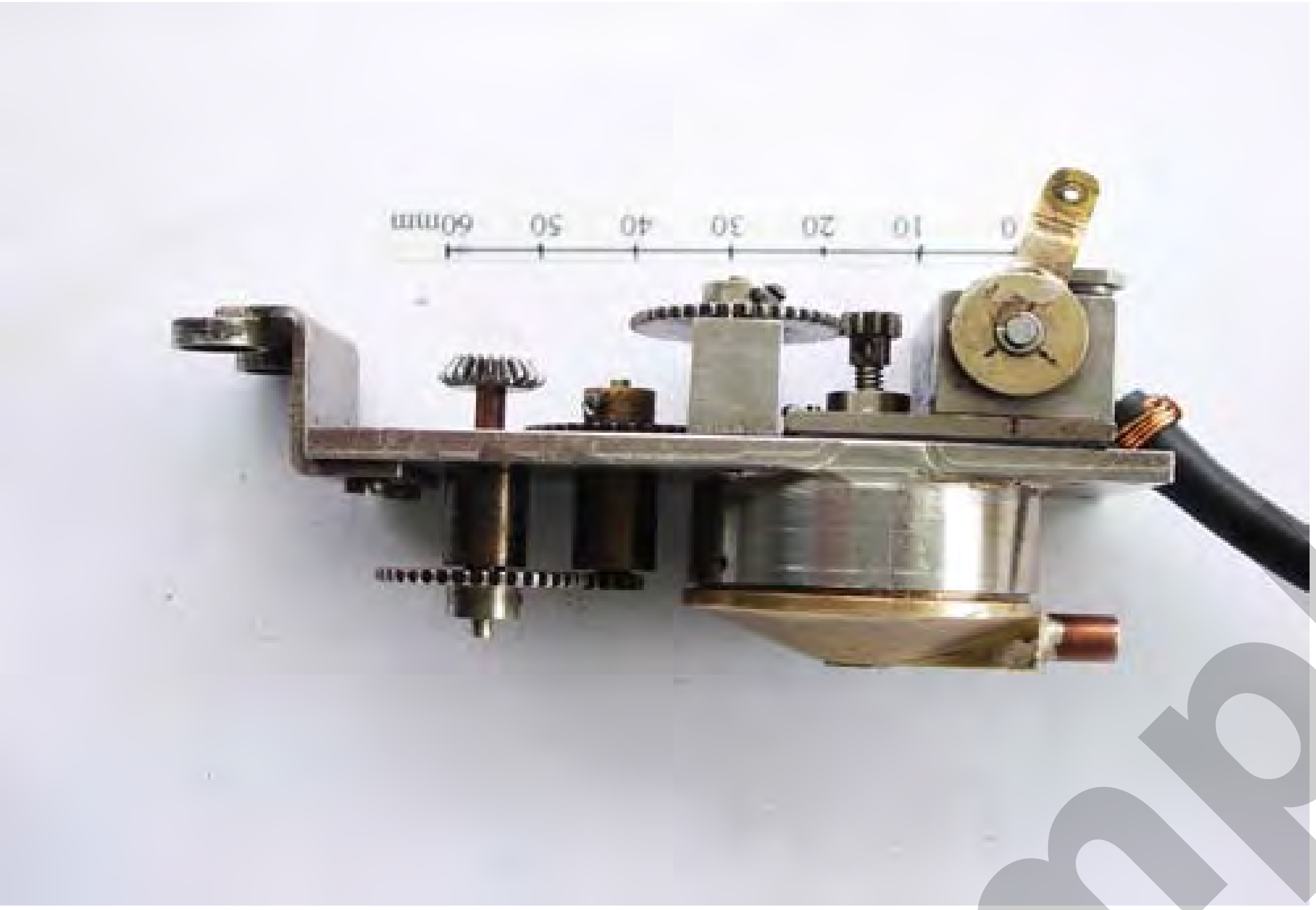
## 7.1 Mechanical Transmission

For a railway engine, the power available at the rails, its speed and the corresponding turbine rpm are now known. The size of the drivers determines at what rpm they have to turn to reach this speed. For a sample speed of 1m/s and a sample driver diameter of 54mm this would amount to:-

1m/(0.054m x Π x 60s) = 354 rpm.

A sample turbine rpm of 35000 would call for a reduction gear ratio of 35000 rpm/354 rpm = 99/1

As to the gear size, Module 0.5 would be appropriate for our range of power. Commercially available servo motor gear attachments may use a lower module. But then, they do not have to cope with the higher turbine rotor mass and impatient hands pushing the model around. Given the restricted space inside a loco frame the gear train will probably require 4 to 5 stages. Sufficient space should be available on the turbine housing base plate as shown. Ball bearings are a must and case hardening of the gear wheels also, at least for the initial stage. Here is an example of such a reduction gear.



Please disregard the built-on steam admission valve unit on the upper right. In the present proposal it would be an independent unit, not covered by this write-up. The bevel gear goes onto the driver axle. The axle bearing supports are also mounted to the base plate. The whole unit, inclusive drivers, is spring floated inside the loco frame.

On a ship building application a similar calculation is required to arrive at the required propeller shaft rpm.

*[Ed:*
*1. Mechanical engineers in Europe, use the module instead of circular pitch.*
*m=p/Π where m is the module and p the circular pitch. The units of module are customarily millimeters*
*2. Different countries have different conventions for numbers. Great Britain and the United States are two of the few places in the world that use a period to indicate the decimal place. Many other countries use a comma instead. Likewise, while the U.K. and U.S. use a comma to separate groups of thousands, many other countries use a period instead, and some countries separate thousands groups with a thin space. To avoid confusion in this book the convention are:-*
*No separators in large whole numbers. Hence 35000 rpm.*
*A period to indicates the decimal place. Hence 0.054m ]*

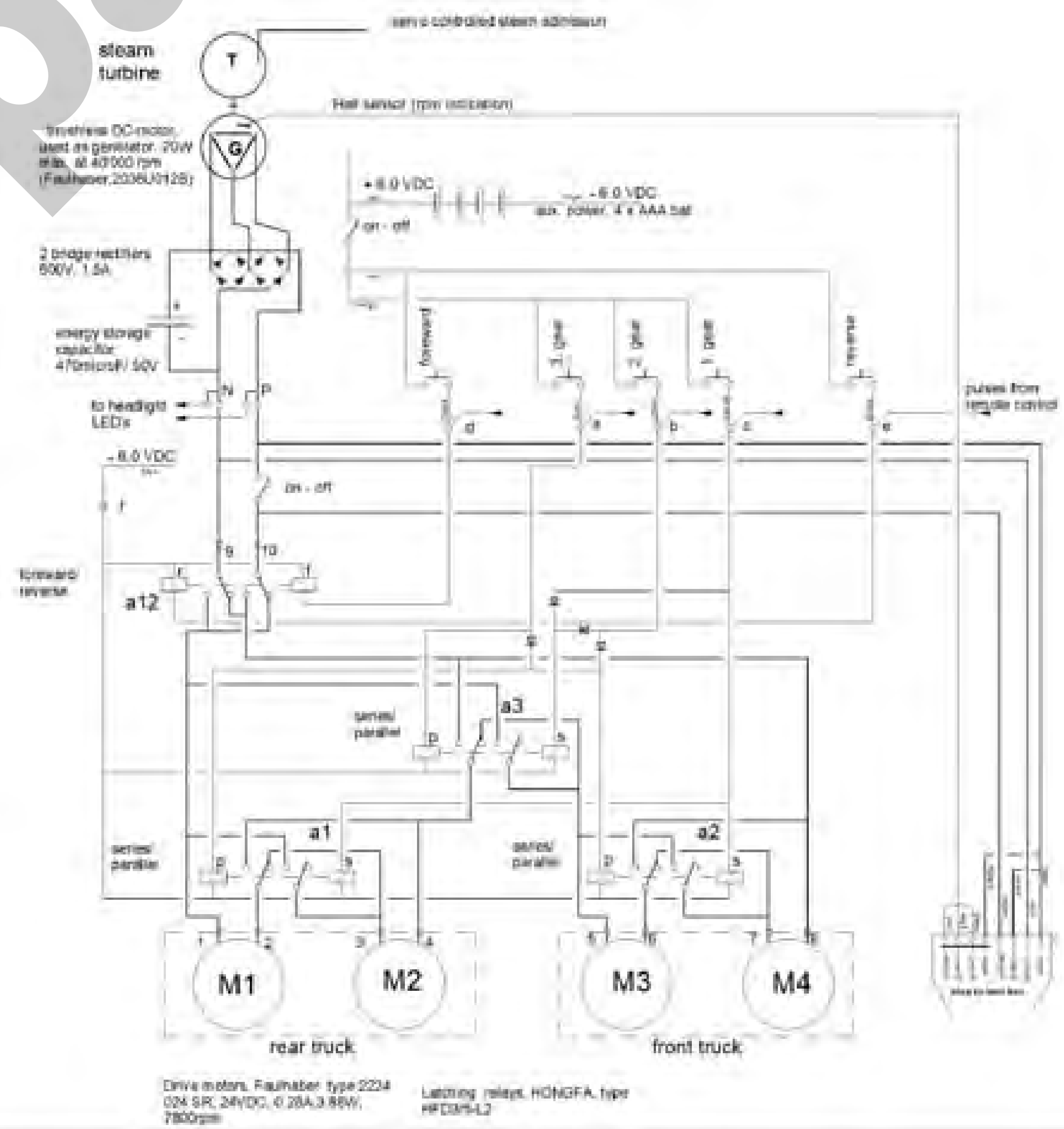
### 7.2 Electrical Transmission

Here, generator and drive motor characteristics depend on brands and their quality. I therefore base my calculation on data of the Faulhaber generator I'm using. It is the brushless DC servomotor 2036 U 012 B used as generator. Its speed constant is 1506 rpm/V. If the turbine turns the generator at 35000 rpm it will produce:-

35000 rpm/1506 rpm/V = 23.2 V, 583 c/s, 3 phase, no load.

Rectified and loaded with 200 mA DC I measure a DC Voltage of 20.0 V. These values can now be used to search for suitable DC drives. In railway applications, the motors most probably will be installed in 4 or 6 wheel trucks. They will be axle hung and have to be small. Small motors have high rpm and need to be geared down. The maximum ratio you can get for one stage reduction is 1/5 for a driver wheel of 31mm. Then, the motors must be lightly loaded to keep their internal losses low. Multi motor drives have as an additional advantage the possibility of switching them in series or parallel – the electrical version of gear change. To illustrate this point, see the schematic diagram of the "Dampfsprinter". Control is still done with very small, old fashioned bistable relays (solid state technology is not my forte!). Do not be put off by its complexity. A corresponding 2-motor version is much simpler to realise.

A word about coupling turbine to generator: make sure there is a little play between male and female part in any position of the coupling. At these elevated rpm's, even small amount of binding will eat away quite a chunk of your precious turbine power! At present, there are UK suppliers I know of, who offer axle hung drives. Have a look at http://www.abcgears.co.uk/html/traction_motors.html or www.fosworks.co.uk . However, I did not get any answer on my request for more technical information. Another possibility would be Facebook.com/appletreerailway/ . Their motors are either 9V or 12V DC. This would then call for a Faulhaber brushless DC-servomotor used as generator, series 1226 S 006B, nominally rated 6V. At 35'000 rpm, after rectification of the 3 phase AC by bridge rectifier, it will deliver approx. 10V DC. Although smaller than the series 2036 one, its power rating is still adequate.




Test Set-Up:
A: nozzle A;
B: nozzle B;
C: brushless generator;
D:pressure gauge 0-4 Bar
E: steam temperature reading, turbine entry.
G: LPG cartrige superheating;
H: superheater loop;
K: Pennsy PRR-S2 used as boiler
L: exhaust steam condenser, water filled;
M: LPG cartridge boiler;
N: instrumentation box (0-500mA, 0-30V, 0-99999 rpm.
O: load resistor box

Testsheet 30.June.2020.docx



### 9.3 Reverse Operation

For a serious engineer blowing steam onto the wrong side of the rotor blades is not really a valid option. If it helps shunting an engine by itself and in a simple way – why not! The expected performance can be seen from the test results shown below.

### Multipurpose Model Steam Turbine 2019 Performance Test Date:02.June.2020

- Rotor: Impulse type, cast, dia. 30, 6 mm, width 3 mm, 48 blades, blade height 1 mm, shrouded.
- Nozzle inserts: max. 2, cast, axial under 15°.
- Steam generation: boiler of gauge 1 turbine driven steam locomotive PRR-S2; liquid gas fired (butane/propane mix) with two 0.2 mm dia. burners. Steam pressure at turbine entry adjusted by regulator valve. Steam (super) heating by separately fired coil outside locomotive.
- Load: brushless Faulhaber DC-Servomotor, Series 2036012B used as generator (efficiency 70%). 3 phase current bridge rectified (efficiency 95%) and connected to load potentiometer; Generator hall sensors used for rpm indication.

| Run Time (min) | Active Steam Nozzle(s) 0.6mm | | Steam Dir-ection forw. rev | | Steam Press. at Boiler (Bar) | Steam Press. at Turb. Entry (Bar) | Steam Temp. at Turb. Entry (°C) | Turbine Speed ($10^3$ rpm) | Load DC Voltage (V) | Load DC Current (mA) | **Resulting useful DC Power (W)** | Resulting Turbine Shaft Power (W) | Steam Mass Flow (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | A | | X | | 5 | 3 | 142 | 35 | 20 | 70 | 1.4 | 2.1 | --- |
| 0 | A | | X | | 5 | 3.5 | 146 | 35 | 20 | 120 | 2.4 | 3.6 | --- |
| 0 | A | | X | | 5 | 4 | 147 | 35 | 20 | 150 | 3.0 | 4.5 | --- |
| 0 | B | | | X | 5 | 3 | 143 | 8.8 | 5 | 50 | 0.25 | 0.4 | --- |
| 0 | B | | | X | 5 | 3.5 | 145 | 8.8 | 5 | 50 | 0.25 | 0.4 | --- |
| 0 | B | | | X | 5 | 4 | 148 | 10.5 | 6 | 60 | 0.36 | 0.5 | --- |

Test Person : Werner Jeggli

Remarks:

- The purpose of this test is to evaluate the feasability of running a small, turbine-mechanical driven locomotive backwards by simply directing a steam jet to the wrong side of the rotor blading (awfull engineering!) This would eliminate the need for a complicated switchable reduction gear.
- Real life steam turbine locos sometimes were equipped with a auxiliary reverse running turbine which permitted shunting of the loco only.
- The exhaust insert opposite nozzle B has been blocked off. The steam is therefore forced to leave via exhaust A.
- The torque available at the drivers is proportional to the load current of the test generator. In our case in reverse it is about 40% of the forward torque which should be sufficient to move the loco only.
- The loco speed then is proportional to the voltage of the test generator and will be about 25% of the design speed.
- The design speed depends on the reduction gear ratio you have selected and the expected shaft power available at the turbine at 35000rpm. As a rule of thumb, 50% of the shaft power should be available at the drivers/ loco hook .
- For test set-up see pictures of test sheet 30.June.2020.docx Testsheet 02.June.2020.docx

## 10. What about the costs?

I hope, the preceding chapters have captured your imagination and started a burning desire to also be creative in this field. But then, reality comes into play with the question like "can I afford it (without wife and children going hungry)?" The list below gives you an idea of the costs to be expected.

My costs shown are in Swiss francs (CHF).

- Rotor, bronze cast 100
- Nozzle insert, bronze cast 80
- Exhaust insert, bronze cast 80
- 3/7/3mm Hybrid ball bearing 10
- Krytox GPL105 oil, 20g 30
- 

Exchange rates end 2019 were approximately as follows:

1 CHF = 0.95€; 0.83£; 1.0 US$

# Epilogue

Having spent so much time, brain power, craftsman ship and money on the subject I would like to pass on my experience to other, hopefully younger modellers.

Looking back on my activity in this field over all these years, a popular wisdom of my student days of unknown origin comes to my mind:

*"Sag', Freund, was ist denn das, die Theorie?"*
*"Wenn's gehen sollt und geht doch nie."*

*"Und was ist denn das Praktikum?"*
*"Frag nicht so dumm - wenn's geht und keiner weiß warum!"*

And here my feeble attempt at transposing it poetically into English:

*"Tell me, friend, what use is this theory?"*
*"If it should work tho' that never be.*

*"And what about the practical lesson?"*
*"Ask no dumb questions - if it works tho' nobody knows the reason."*

It goes without saying that science and engineering has produced marvels in our one to one world. But somehow, with increasing scale factor, the situation becomes blurred.

I would love to hear if my efforts have helped to spawn further activities in this field. Let me know - wjeggli*at*hotmail.com!

Werner Jeggli
(G1MRA member 701)
26 October 2020

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# Editorial

When I was asked to help publish *The Multipurpose Model Steam Turbine - A Guide to successful Scratchbuilding by Werner Jeggli* I realised it was the closing chapter in what has been a fascinating story. Werner has been publishing his work in many places, including the G1MRA NL&J, since 1997, which shows how much time & thought he has put into G1 turbine locomotives. I read his articles over many years. You will find a list of his publications in the Resources section at the back of this book.

I had the pleasure of editing some of his articles when I was the G1MRA NL&J Editor. The Swiss group visited UK in October 2005. They had a day running on my old track at East Horsley, from which I have a video showing Der Mathematiker in action, giving me a personal recording of its technical excellence.

I was delighted when Werner received the JvR award in 2011 - I have to declare a self interest here since I proposed the G1MRA JvR award specifically to recognise those G1MRA members who both innovate in G1 and go the extra mile to publish so that other G1MRA members can understand their work. His work in creating this book continues to help others who want to think about building their own steam turbines.

Werner provided two additional articles that add to the story: the first describes making miniature steam turbine rotors, and the second the evolution of "Der Mathematiker" into an alternative turbine design. These are on the next few pages.

I have followed these with reprints of Werner's other G1MRA articles as the prequels to this work. It makes them available to readers who have still to discover what they are missing by not joining G1MRA. Also it saves G1MRA members having to go online to the G1MRA website to track them down. These articles describe the journey that led to this book. Both the successes and the failures on a path that proved steam turbines are possible in G1.

Martin Hulse
(G1MRA member 584)
Editor
G1MRA Vice President



 