The RESAP Pelton turbine handbook

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July 4, 2010

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Contents

1 Available sizes

1.1 PTU-250

The PTU-250 has a pitch circle diameter of 250 mm and 18 buckets. It can be equipped with the following nozzles

Nozzle #11 This is the standard nozzle of 11 % pitch circle diameter (that is, 27.5 mm). It gives optimum performance at the rated maximum flow of the turbine.

Nozzles #9 and #10 These are smaller nozzles for part-flow conditions, still giving good efficiency.

Nozzles #12 and #13 Larger nozzles to allow more flow at low heads, with slightly lower efficiency. These nozzles should not be used above a certain head (60 m for the nozzle #12, and 45 m for #13), where the efficiency loss becomes too great.

To select a turbine for a given site, the maximum available flow rate and the net head must be known.

1.1.1 Net head calculation

The PTU-250 can use penstocks up to 150 mm diameter. Larger diameters are probably not economical since the increased cost is larger than the net head gained by smaller losses. The penstock usually enter the forebay about $H_I = 1$ m below the water level and protudes some distance into it. The free space below the turbine must be $H_T = 2D_P = 0.5$ m at full flow. The approximate penstock length can be found from figure 1 for some common penstock bend angles. Figure 2 shows the net head than can be expected for a given gross head.

1.1.2 Nozzle selection

Figure 3 shows the maximum flow and power depending on the available head for one and two jet variants of the PTU-250.

$$P_{max,2} = \frac{1}{4}\frac{\sqrt{2}\,\pi\,n_J\,\sqrt{g}\,C_v\,\gamma\,r_{JP}^2\,\eta_{max}\,\sqrt{H_n^3}\,D_{P,2}^2}{\eta_P}$$

$$P_{max,2} = 2\frac{\sqrt{8}\,\sqrt{2}\,Q_{max,2}^3\,\gamma\,\eta_{max}}{\pi^2\,\eta_P\,n_J^2\,g\,C_v^2\,r_{JP}^4\,D_{P,2}^4}$$

The diagram assumes the following efficiency values:

Manifold efficiency	$\eta_{man} = 98$ %
Belt drive efficiency	$\eta_{dr} = 95$ %
Generator efficiency	$\eta_{el} = 75$ %
Turbine efficiency	$\eta_T = 77$ %

From the diagram, the correct number of jets and size of nozzle for a given head and flow rate can be found. If there is no exact size of nozzle available, one size larger must be selected. After selection of jet number and nozzle size, the expected maximum power can be estimated from the diagram or calculated from the following equation:

$$P_{250} = (1.08 \cdot 10^{-4})\,n_J\,S^2\,\sqrt{H_n^3} \tag{1}$$

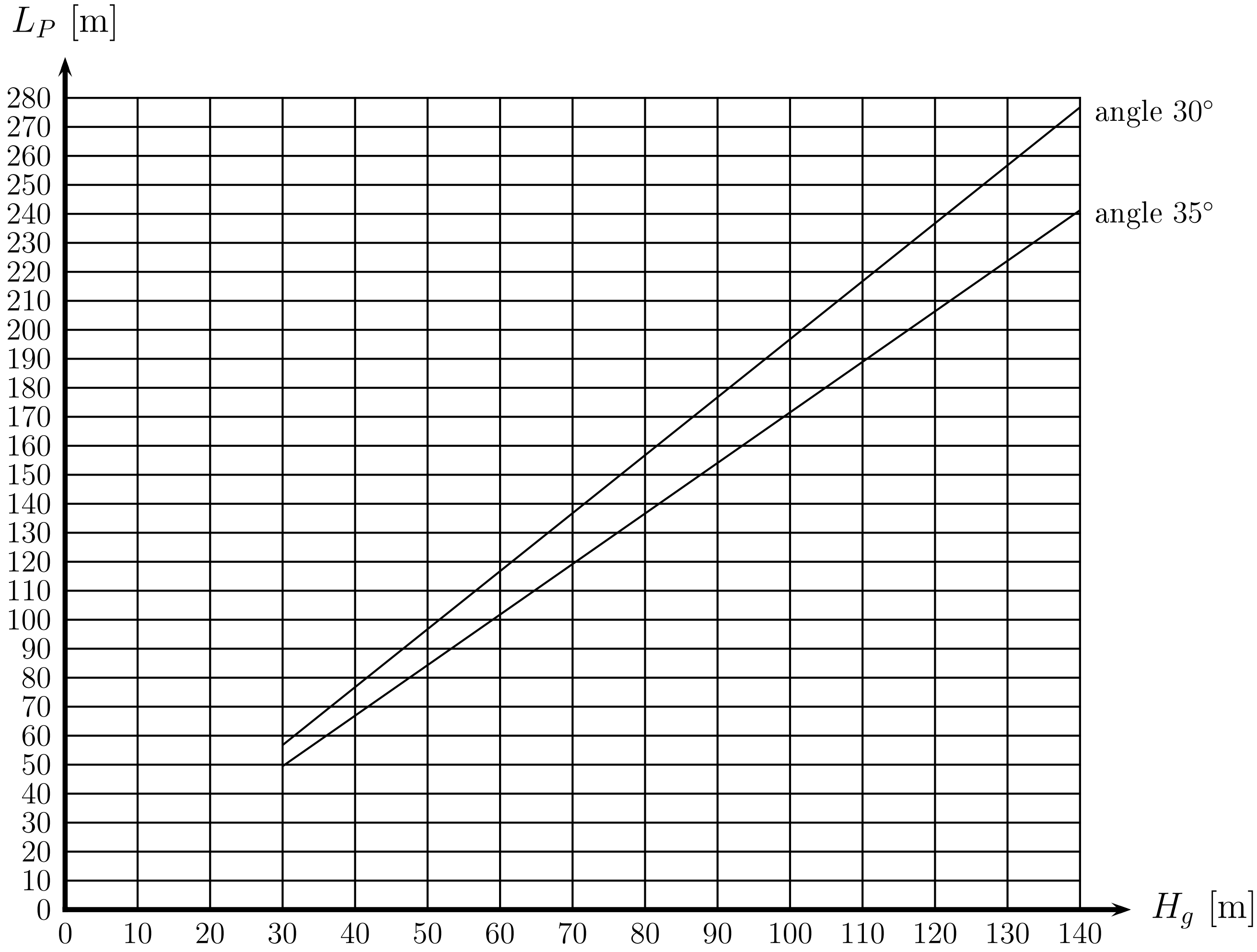

Figure 1: Approximate penstock pipe length for the PTU-250 in a standard installation as a function of gross head (inlet height $H_I = 1$ m, free height under turbine $H_T = 0.5$ m)

Sign	**Unit**	**Description**
H_n	m	Net head
n_J	—	Number of jets
S	—	Nozzle size
P_{250}	kW	Turbine maximum power

The maximum possible flow in $\frac{\text{l}}{\text{s}}$ for a given number and size of jets is

$$Q_{max} = 0.02063\, n_J\, S^2 \sqrt{H_n} \tag{2}$$

Examples A site has a net head of 65 m and a flow rate of 40 $\frac{\text{l}}{\text{s}}$. The correct selection is two jets with the nozzle #11, giving a maximum power of $P_{250} = 13.69$ kW. and a maximum possible flow of $Q_{max} = 40.26\frac{\text{l}}{\text{s}}$. Another site has 90 m of head, but only 35 $\frac{\text{l}}{\text{s}}$ of flow available. Again two jets is correct, but the small nozzle #9 needs to be installed. This will make use of only $Q_{max} = 31.71\frac{\text{l}}{\text{s}}$, and produce $P_{250} = 14.93$ kW. [1]

[1] A little more flow could be gained by installing one nozzle #9 and the other #10.

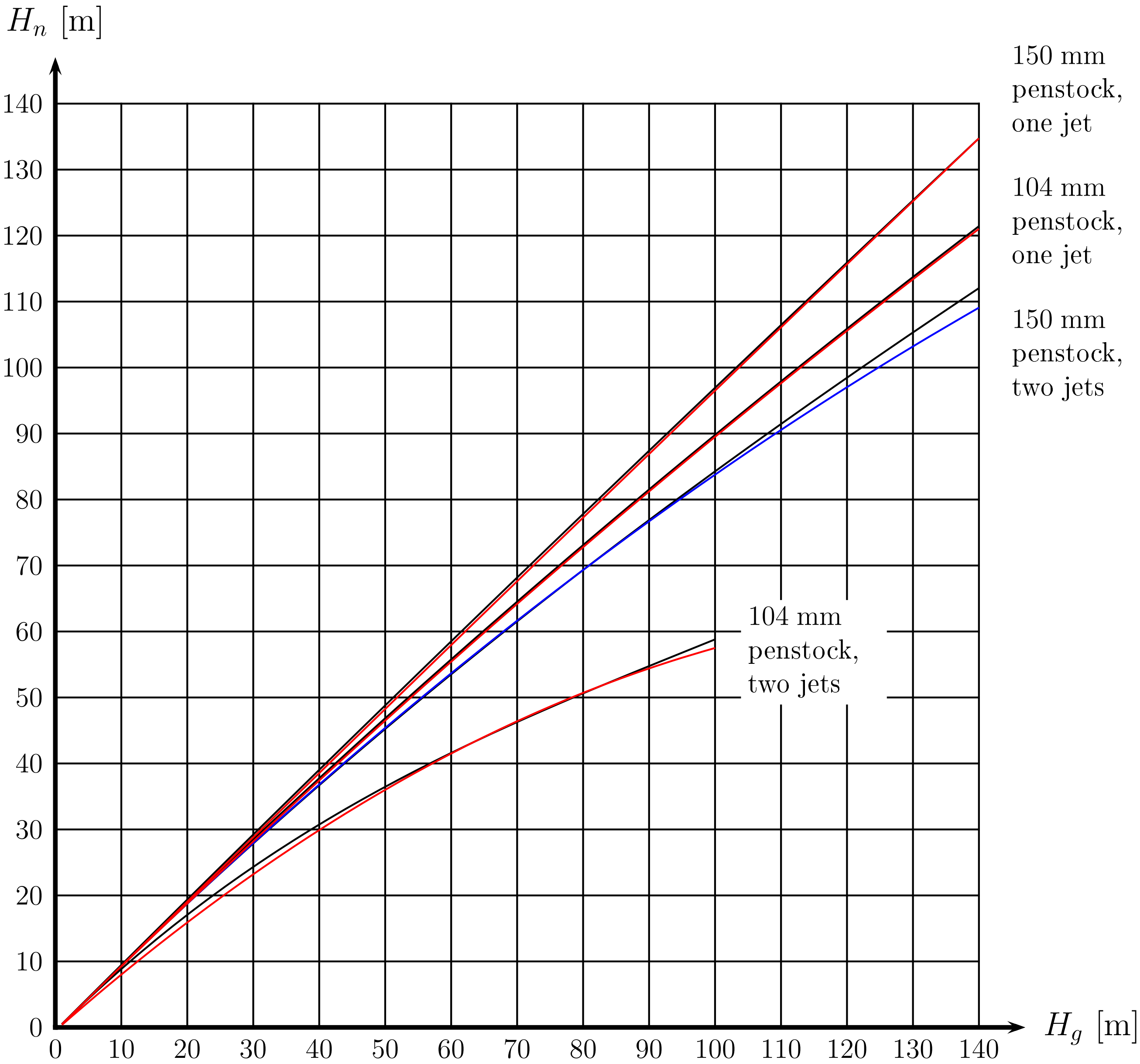

Figure 2: Net head for the PTU-250 as a function of gross head (for nozzle size 11)

1.1.3 Speed selection

The speed of the PTU-250 is determined only by the net head:

$$N_{250} = 147.7\sqrt{H_n} \tag{3}$$

Sign	**Unit**	**Description**
H_n	m	Net head
N	RPM	Rotational speed

This is the optimum speed, giving maximum efficiency. It is possible to operate the turbine at 10 % overspeed and 15 % underspeed with very little loss in efficiency. Figure 4 allows the selection of a suitable speed to match pulley sizes.

A speed higher than 1500 RPM is not allowed because it would place very large stresses on the runner of the turbine. The following table shows possible standard pulley sizes for given

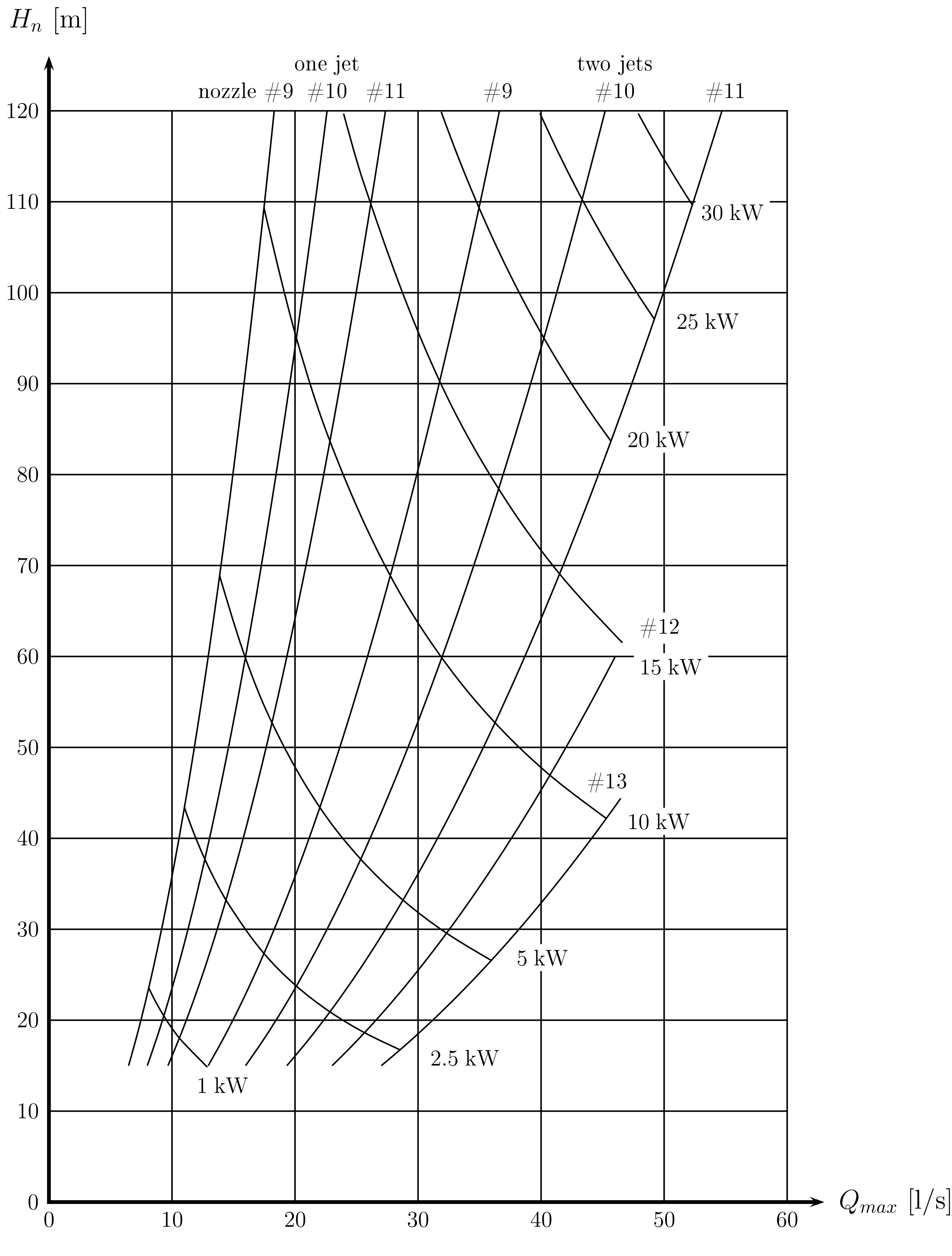

Figure 3: Flow and maximum system power of the PTU-250 as a function of the available head

Net head	Turbine speed	Pulley	Actual turbine speed	Max. power per belt
Turbine pulley 10 inch				
15 m	572 RPM	4 in	585 RPM	3 kW
20 m	661 RPM	5 in	750 RPM	3.3 kW
30 m	809 RPM	6 in	900 RPM	4.4 kW
40 m	934 RPM	7 in	1050 RPM	5.6 kW
50 m	1040 RPM	7 in	1050 RPM	5.6 kW
60 m	1140 RPM	8 in	1200 RPM	6.7 kW
70 m	1240 RPM	9 in	1350 RPM	7.7 kW
80 m	1320 RPM	9 in	1350 RPM	7.7 kW
90 m	1400 RPM	10 in	1500 RPM	8.7 kW
100 m	1480 RPM	10 in	1500 RPM	8.7 kW
110 m	1550 RPM	11 in	1650 RPM	9.6 kW
120 m	1620 RPM	11 in	1650 RPM	9.6 kW

Table 1: Alternator pulley diameter as a function of net head and turbine pulley diameter

turbine speeds. This assumes a generator speed of 1500 RPM.[2]

Examples The 65 m site of the previous example can be operated at 1200 RPM (always try to operate at higher speeds if possible, since this will reduce losses in the pulley/belt system). The turbine will run very near to the optimum speed of $N_{250} = 1191$ RPM. The second site of 90 m head can be directly coupled to the generator at 1500 RPM if operated at a slight overspeed. The optimum speed would be $N_{250} = 1401$ RPM.

[2]Note that using the small 4.3 in pulley gives large bending stresses on the belt, giving a reduced lifetime.

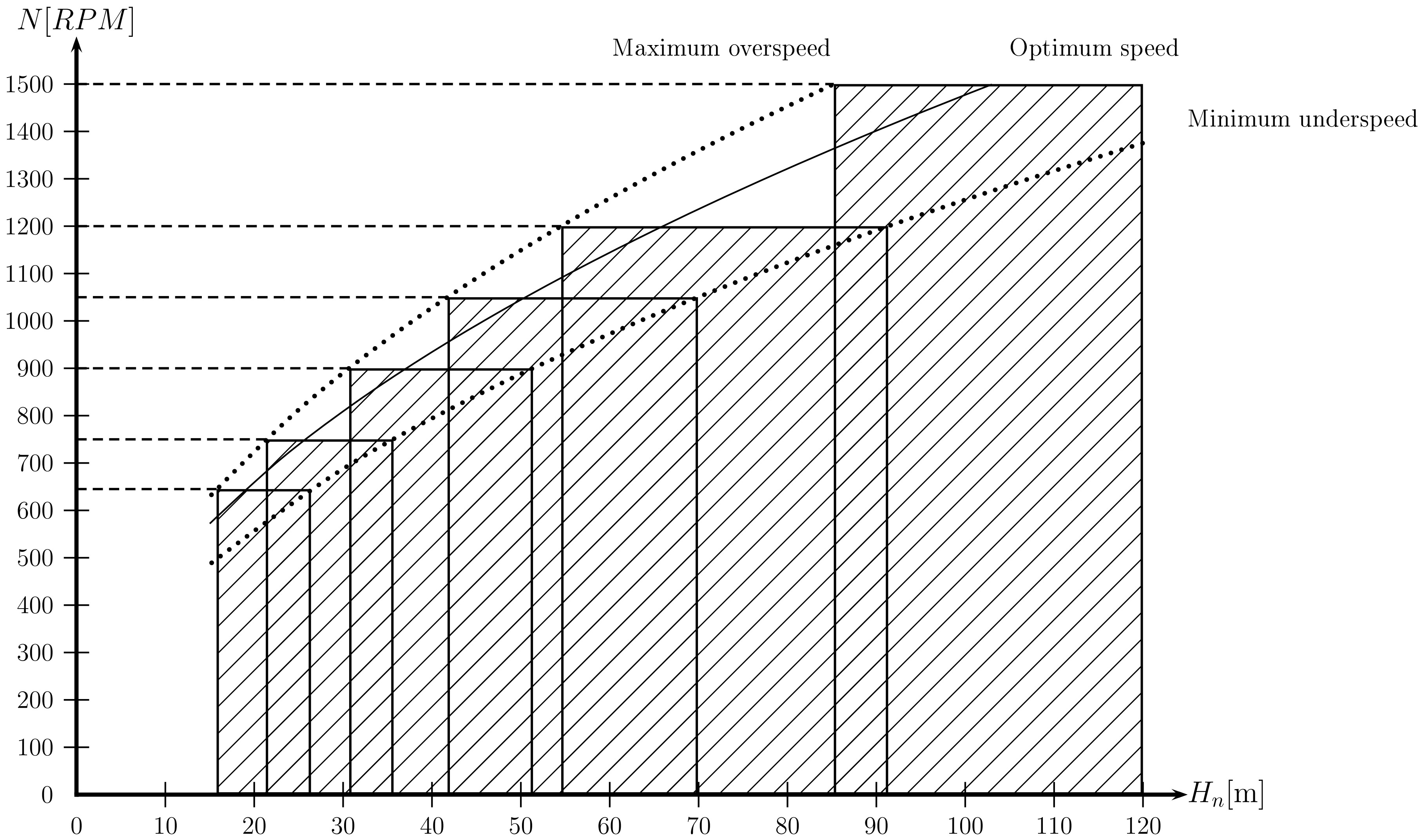

Figure 4: Turbine possible speed range. The hatched areas indicate the application range for different turbine pulley sizes