3

Scratch

nominal flow is translated to penstock flow

$$\Rightarrow \quad 0.37\ m^3/s = A\,(1.8\ m/s)$$

↳ this gives us d

↓

this gives us f

↓

this gives us Δp

$$A = \pi\left(\frac{d}{2}\right)^2 \qquad \left(\frac{d}{2}\right)^2 = \frac{A}{\pi} \qquad d^2 = \frac{4A}{\pi} \qquad d = \sqrt{\frac{4A}{\pi}}$$

get net head thru $\eta_t = \dfrac{\dot{W}_{shaft}}{\rho g \dot{V} H_{net}}$

and $\dot{W}_{shaft} = \eta_t \dot{W}_{max}$, $\dot{W}_{max} = \rho g \dot{V} H_{gross}$

Work

$$(0.37\ m^3/s)(1-0.15) = A\,(1.8\ m/s)$$

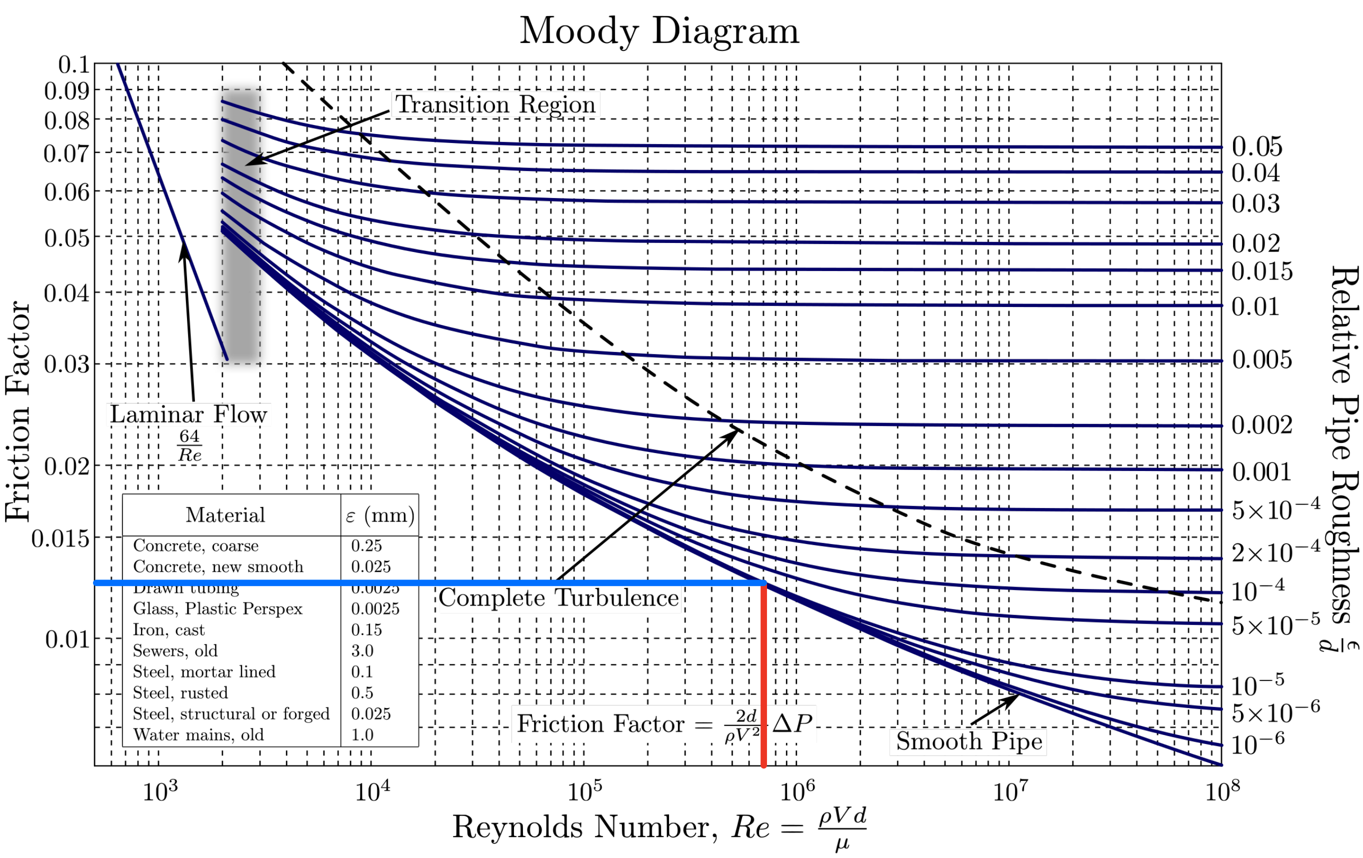
$$\Rightarrow A = 0.17\ m^2$$

$$\Rightarrow \boxed{d = 0.47\ m}$$

$$\frac{\varepsilon}{d} = \frac{0.0025\ \cancel{mm}}{0.47\ \cancel{m}}\left|\frac{1\ \cancel{m}}{10^3\ \cancel{mm}}\right| = 5.3\times10^{-6}$$

$$Re = \frac{\rho v d}{\mu} = \frac{(1000\ kg/m^3)(1.8\ m/s)(0.47\ m)}{0.001\ Pa \cdot s} = 8.5 \times 10^5$$

$$\checkmark \quad \frac{kg}{m^{\cancel{3}}}\ \frac{\cancel{m}}{s}\ \cancel{m}\ \frac{1}{Pa \cdot s} = \frac{kg}{\cancel{m} s^2}\left(\frac{m^{\cancel{2}}}{N}\right) = \frac{kg \cdot m}{s^2}\ \frac{1}{N} = \frac{N}{N} = 1$$



$f \sim 0.013$

$$\Delta p = f \frac{L}{d} \frac{\rho v^2}{2} = (0.013) \frac{(300m)}{(0.47m)} \frac{(1000 kg/m^3)(1.8 m/s)^2}{2}$$

$$\frac{kg}{\cancel{m^3}}\ \frac{\cancel{m^2}}{s^2} = Pa$$

~ 13 kPa

To account for this pressure drop with $\dot{W}_{max}$ (maximum power supposing no irreversibilities), convert this pressure drop to power by using

$$\Delta p \, A v = 4.2 \text{ kW}$$

and then subtract it from the maximum power to obtain a new maximum power with this particular irreversibility

$$\dot{W}_{max} - \Delta p A v =$$

$$= \rho g \dot{V} H_{gross} - \Delta p A v = \rho g A v H_{gross} - \Delta p A v$$

$$= (\rho g H_{gross} - \Delta p) A v = 104 \text{ kW}$$

$$\frac{kg}{\cancel{m^3}} \frac{m}{s^2} \frac{\cancel{m^3}}{s} m = \frac{kg\, m^2}{s^3} = \frac{N m}{s} = W$$

$$\frac{N}{\cancel{m^2}} \cancel{m^2} \frac{m}{s}$$

$$\dot{W}_{shaft} = \eta_t \dot{W}_{max} = 83 \text{ kW}$$

$$\eta_t = \frac{\dot{W}_{shaft}}{\rho g \dot{V} H_{net}} \rightarrow \rho g \dot{V} H_{net} = \frac{\dot{W}_{shaft}}{\eta_t} \rightarrow H_{net} = \frac{\dot{W}_{shaft}}{\eta_t \rho g \dot{V}} = 33.6 \text{ m}$$

$$\frac{kg}{\cancel{m^3}}\ \frac{m}{s^2}\ \frac{\cancel{m^3}}{s} = \frac{N}{s} \qquad \frac{s}{N}\ \frac{J}{s} = m$$

$$\underbrace{0.9}_{\eta_g} \cdot \underbrace{0.9}_{\text{additional loss}}\ \dot{W}_{shaft} = 67\ kW =: W_{electric}$$

Assuming this is run all day (24 hrs) and starts from midnight (00:00),

		demand per house	total demand (600 houses)
6h	00:00 – 06:00	0.1 kW	60
* 3h	06:00 – 09:00	0.5	300
8h	09:00 – 17:00	0.1	60
* 2h	17:00 – 19:00	1.5	900
5h	19:00 – 00:00	0.1	60

$$(\text{daily } E \text{ needed}) = 60\ kW \cdot 6h + 300\ kW \cdot 3h + 60\ kW \cdot 8h + 900\ kW \cdot 2h + 60\ kW \cdot 5h = 3840\ kWh$$

$$(\text{daily } E \text{ provided}) = 67\ kW \cdot 24h = 1632\ kWh$$

$$\boxed{3840 > 1632 \Rightarrow \text{Daily } E \text{ cannot be met}}$$

3.4

68 > 60 so for normal hrs req is met but peak times we need 4-13 times more efficient ones.
Possible mitigation: store energy somewhere to use it for peak hours.

Extra E (0-6): (68 kW - 60 kW)(6 hr) = 48 kWh
Lacking E (6-9): (300 kW - 68 kW)(3 hr) = 696 kWh

So even if we store all residue E from 0-6 we still cannot last the morning peak.

Extra E (9-17): 64 kwh
Lacking E (17-19): 1664 kWh
Extra E (19-24): 40 kwh

Every day:
Debt: 696 + 1664 = 2360 kWh
Extra Earning: 48 + 64 + 40 = 152 kwh

Debt is ~ 15 times more even if we store all unused energy so you should not move forward with this plant. Design better-performing power plants or use less.

As For Which Turbines Are Allowed

red green or blue all allowed (~~on~~ within the range)