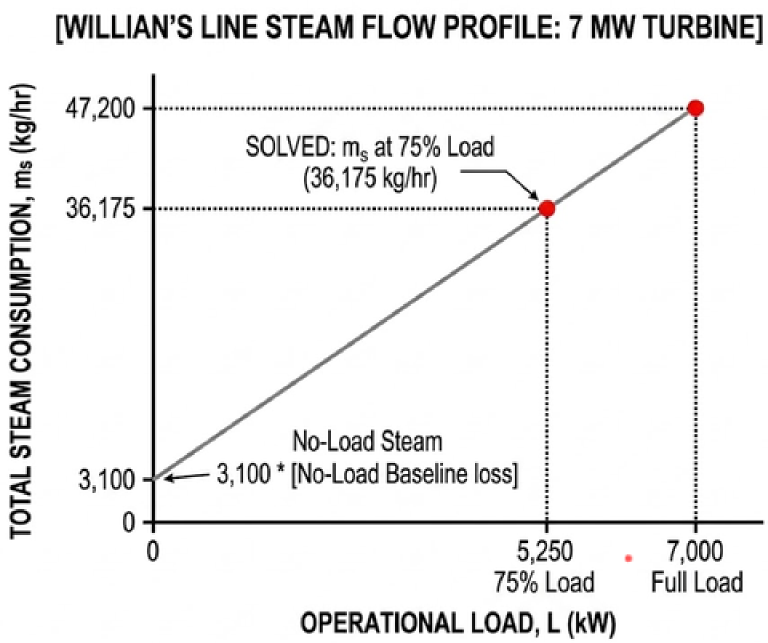
In thermal power plant engineering, predicting the mass flow rate of steam required to satisfy varying grid demands is essential for fuel budgeting and operational efficiency. For a throttle-governed steam turbine, this relationship is governed by **Willian's Law**. Willian's Law states that for a constant initial steam pressure and temperature, the total steam consumption (m_s) varies as a linear function of the electrical or mechanical load (L) on the turbine.



Mathematically, it takes the standard slope-intercept straight-line form:

$$m_s = aL + b$$

Where:

- m_s is the total steam consumption rate (kg/hr).
- a represents the **incremental steam rate** (kg/kWh), which defines the slope of the line and reflects how much additional steam is consumed per unit increase in power output.
- b is the **no-load steam consumption** (kg/hr), representing the y-intercept. This is the baseline steam required simply to maintain the turbine at synchronous speed against internal friction, windage, and thermal losses without exporting any useful power.
- L is the operational power output or **load** (kW).

Step 1: Analyze the System Parameters & Convert Units

Before substituting values into the empirical linear model, you must ensure that the units match. Board exams often introduce unit mismatches to test your attention to detail. The problem states that the turbine has a maximum rated plant capacity (L_{max}) of 7 MW. Because the slope coefficient a = 6.3 implies a demand per kilowatt (kW), the rated capacity must be converted from megawatts (MW) to kilowatts (kW):

$$L_{max} = (7\ MW)\left(\frac{1{,}000\ kW}{1\ MW}\right) = 7,000\ kW$$

Step 2: **Determine the Operational Load at 75% Capacity**

The question asks for the steam performance profile when the facility operates under a partial load condition of 75%. We can calculate the exact target electrical power output ($L_{75\%}$) as follows:

$$L_{75\%} = (Operational\ Factor)\left(L_{max}\right) = (0.75)(7,000\ kW) = 5,250\ kW$$

Step 3: **Substitute into Willian's Line Equation**

With the operational load isolated in the correct units, substitute L = 5,250 kW into the provided governing equation to solve for the total mass flow rate of steam (m_s):

m_s = (6.3)(5,250 kW) + 3,100 = **36,175 kg/hr**

The y-intercept (3,100 kg/hr) shows that even if the generator breaks its connection to the utility grid and outputs 0 kW, the boiler must still burn enough fuel to produce over 3 tons of steam per hour just to keep the turbine spinning at its rated speed.

This demonstrates why power plant operators prefer to run large baseload steam turbines as close to 100% capacity as possible: partial-load operations inherently lower thermal efficiency.