Grundfos ECADEMY

Pump hydraulics

Horsepower and efficiency

GRUNDFOS

Possibility in every drop

Horsepower

- Once we know how much head our pump needs to deliver we need to know the amount of power required to move it.
- Horsepower is a measurement of the amount of work done and is the basic unit of work in the English system.
- It is measured in foot-pounds which is the work required to move a specific weight a specified vertical distance.

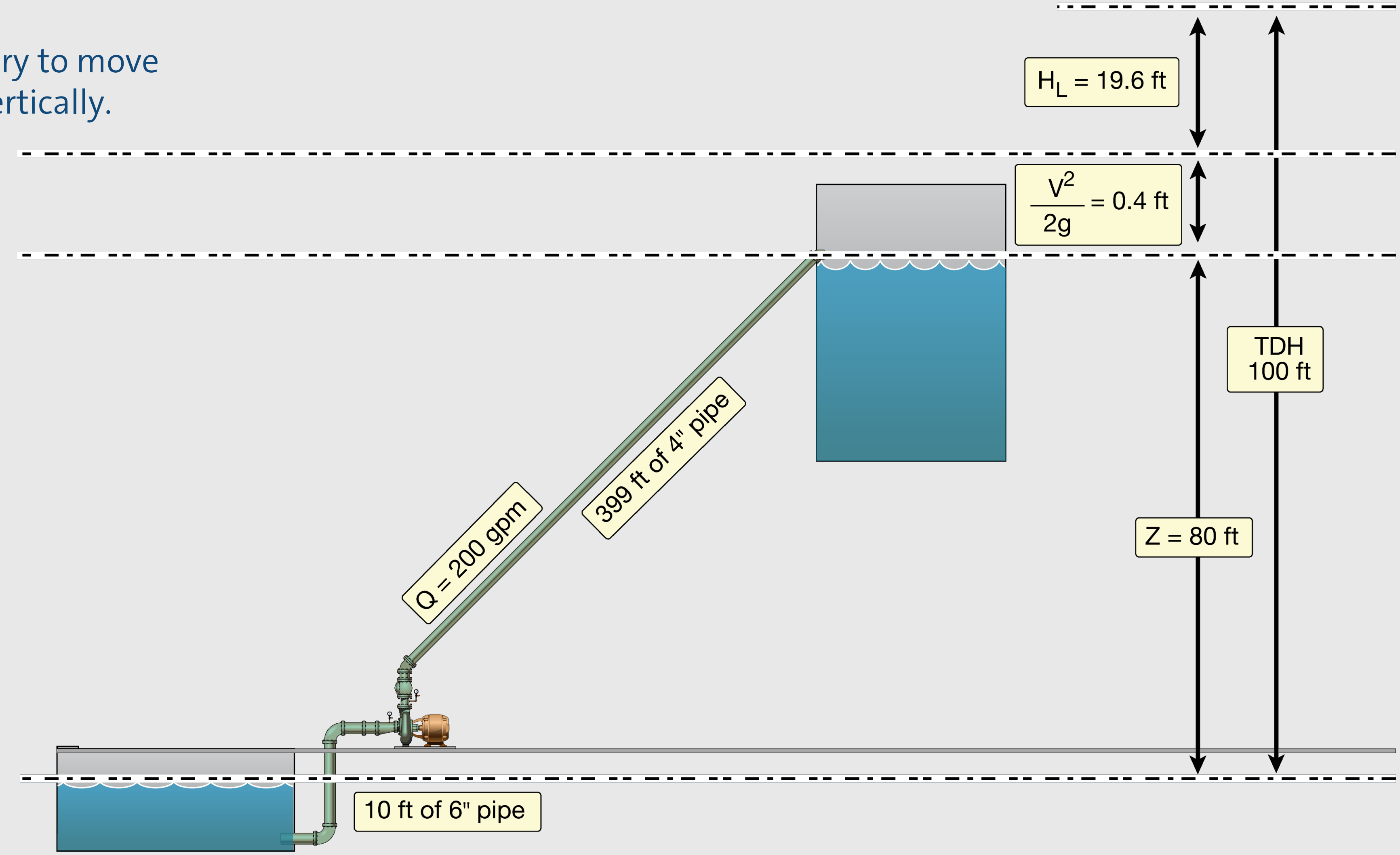
A measurement of the amount of work

Basic unit in the English system

Measured in foot-pounds

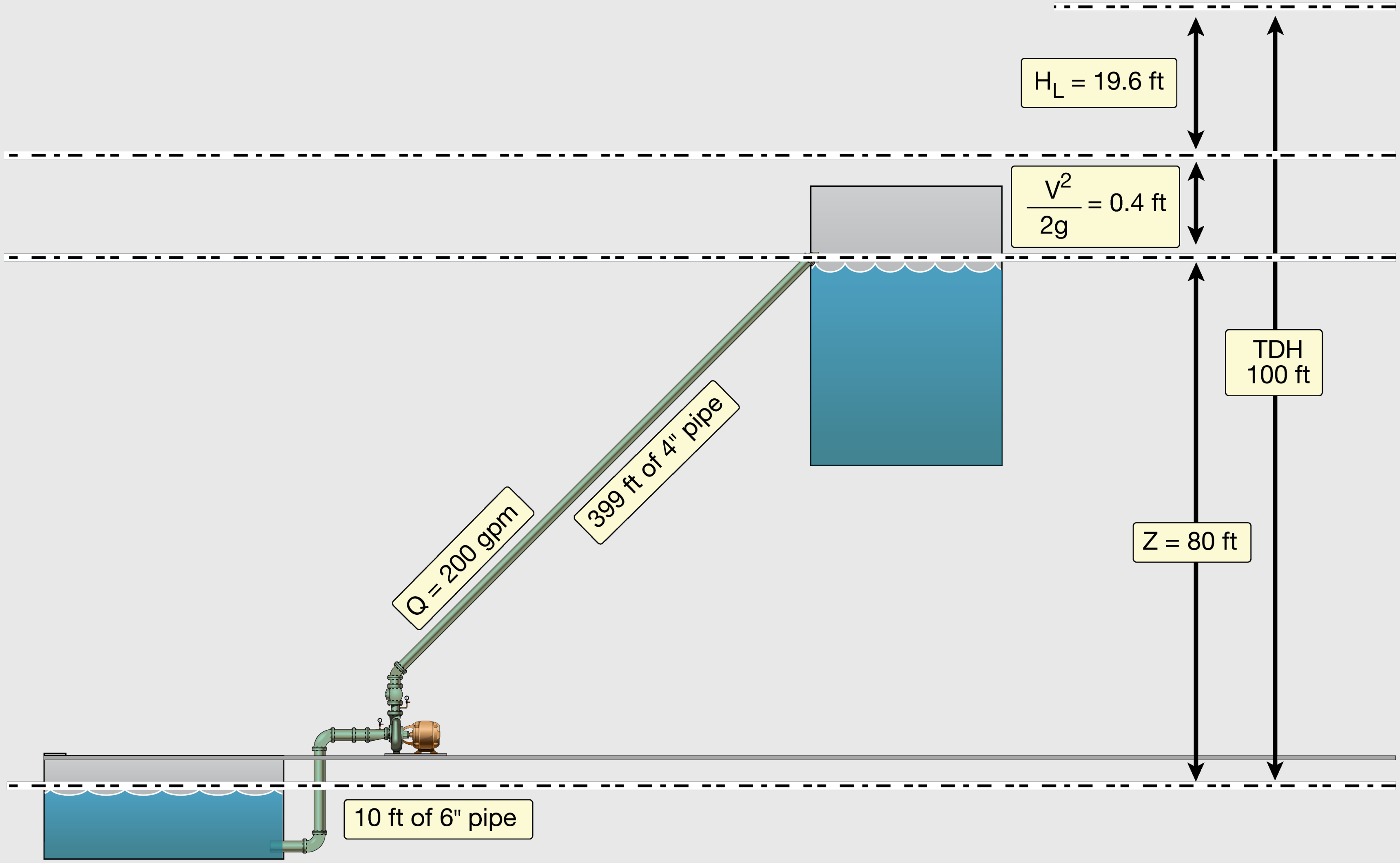
Horsepower example

- Let's calculate the work necessary to move 200 gallons of water 100 feet vertically.



Horsepower example

- Since work is expressed in foot-pounds we need to convert gallons to pounds.
- We know there are 8.34 pounds per gallon so 200 gallons times 8.34 pounds per gallon equals 1,668 pounds.
- We need to move 1,668 pounds 100 feet vertically so <click> 1,668 pounds times 100 feet equals 166,800 foot pounds.



Horsepower

- 166,000 foot-pounds of work is required to move 200 gallons of water vertically 100 feet.
  - Notice there is no reference to time
  - It will require this much work regardless of the amount of time taken to move the water.

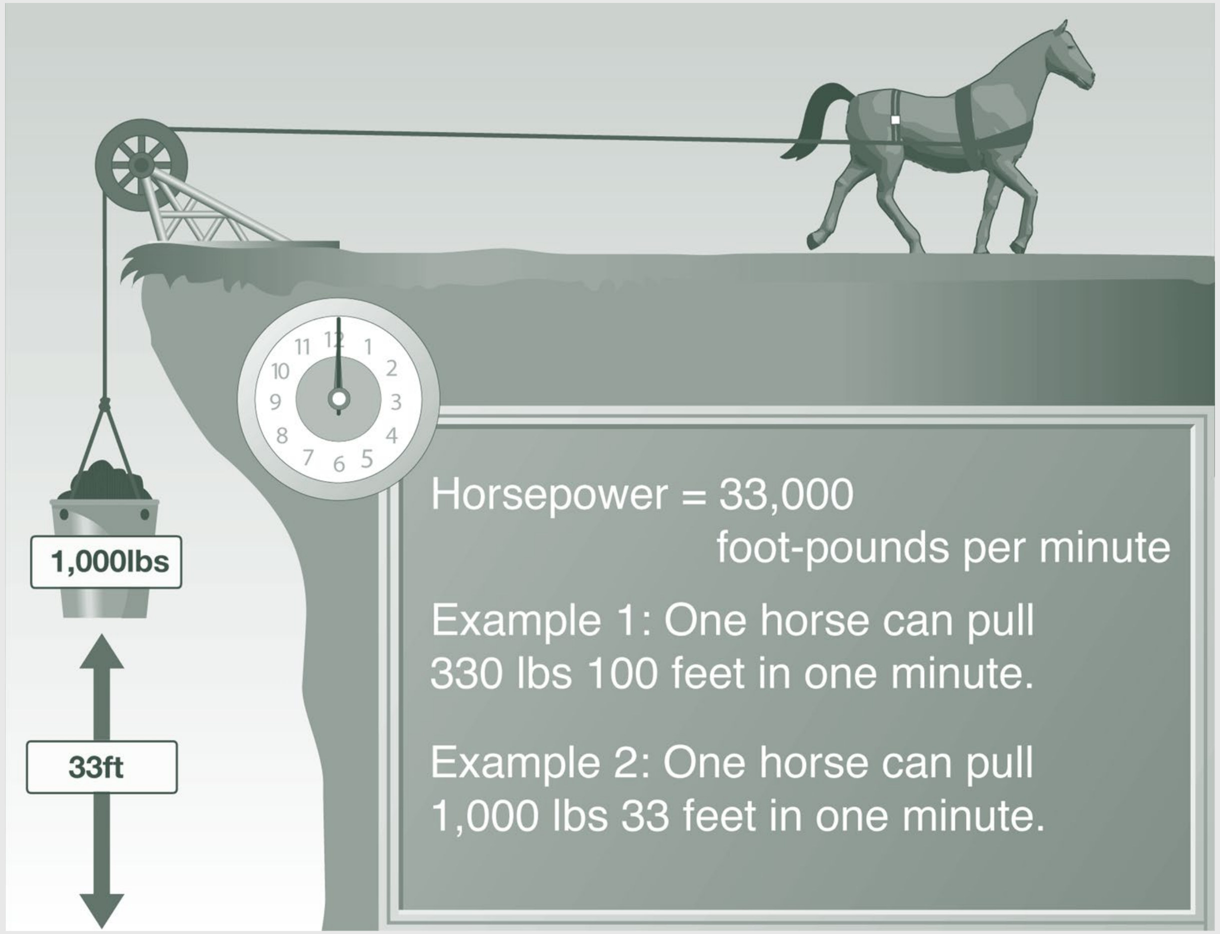
- If a time line of 1 minute is added then it will require 166,000 foot-pounds of work be performed every minute.

- In the English system: work performed on a time base is expressed in horsepower and is defined as:

1 Hp = 33,000 foot-pounds of work per minute

Horsepower

- So horsepower is 33,000 foot-pounds per minute.
- This means that one horse can pull 330 pounds 100 feet in one minute
- This also means that one horse can pull 1,000 pounds 33 feet in one minute.



Horsepower

- Knowing that one horsepower equals 33,000 foot pounds we can then calculate what is called water horsepower.
- 166,000 foot pounds divided by 33,000 gives us 5.05 Water Horsepower.
- So to move 200 gallons of water, 100 feet will require 5.05 Water Horsepower (WHp)

$$\frac{166{,}00 \text{ ft-lbs}}{33{,}000 \text{ ft-lbs/min/Hp}}$$

$$= 5.05 \text{ WHp}$$

Horsepower definitions

- There are actually three types of horsepower involved in pumping.
- The first is what we just covered, Water Horsepower which is the energy transferred directly to the water by the pump.
- Then there is Brake Horsepower (BHp) which is the energy transferred from the motor into the pump.
- Then there's Electrical Horsepower (EHp) which is the energy transferred from the power system into the motor.

Water horsepower

Brake horsepower

Electrical horsepower

Horsepower and efficiency

- The difference between EHp and BHp is the efficiency of the motor
  - EHp is the energy into the motor
  - BHp is the energy out of the motor

- The difference between BHp and WHp is the efficiency of the pump
  - BHp is the energy into the pump
  - WHp is the energy out of the pump

Horsepower equation #1

- When the flow rate and Total Dynamic Head (TDH) are known, Water Horsepower can be calculated using Equation number one where:
- WHp = Water Horsepower
- Q = flow in gpm
- TDH = Total dynamic head in feet
- d = density: for water this is 8.34 pounds per gallon
- 33,000 is a constant in foot pounds per minute per horsepower

$$WHp = \frac{TDH \times Q \times d}{33{,}000}$$

Horsepower equation #2 & 3

- To simplify things a little more, if the liquid being pumped is water, which weighs 8.34 pounds per foot (Equation #2)

- We can then reduce the equation for Water Horsepower to be equal to the flow times the head, divided by 3,960 (Equation #3).

$$WHp = \frac{TDH \times Q \times 8.34}{33{,}000}$$

$$WHp = \frac{TDH \times Q}{3.960}$$

Knowledge check#2

- Find the water, brake and electrical horsepower for a pumping installation with the following characteristics:

TDH of 100 feet of head

Flow of 200 gpm

Pump efficiency of 70%

Motor efficiency of 90%

Knowledge check#2

- The Water Horsepower will be as we've just learned
- Using the longer formula, Equation #2, we get 5.05 Water Horsepower.

$$WHp = \frac{TDH \times Q \times 8.34}{33{,}000}$$

$$\frac{100 \times 200 \times 8.34}{33{,}000} = 5.05 \text{ WHp}$$

Knowledge check#2

- For Brake Horsepower we divide our Water Horsepower by the pump efficiency.
- 70% in our example which is 0.70 as it needs to be expressed at a decimal.
- This give us 7.2 for brake horsepower.

$$WHp = \frac{WHp}{\eta_{pump}}$$

$$\frac{5.05}{0.7} = 7.2\ BHp$$

Knowledge check#2

- The Electrical horsepower is the Brake Horsepower divided by the motor efficiency.
- So we take 7.2 divided by 0.9 which is 90% expressed in decimal form.
- This gives us 8.0 for Electrical Horsepower.

$$EHp = \frac{BHp}{\eta_{motor}}$$

$$\frac{7.2}{0.9} = 8.0\ EHp$$

Knowledge check#2

Summary:

- To provide 5.05 Water Horsepower, 8 Electrical Horsepower is required.
- 3 Horsepower is lost to friction in the pump and motor:
    - Bearings
    - Packing/Shaft seal
    - Recirculation of water
    - Electrical losses in the motor

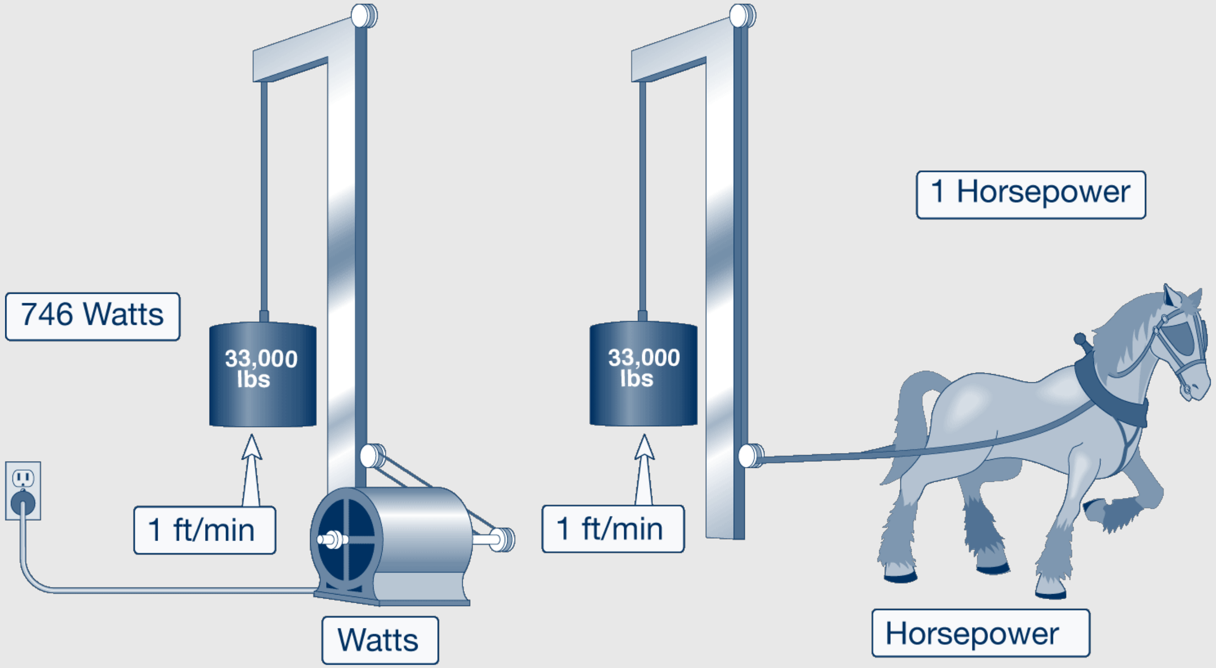
5.05 WHp

8.0 Ehp

3 Hp loss

Conversion of Horsepower to Watts

- Since our electric bills are in kiloWatt hours, we need to convert Horsepower to Watts.
- There are 746 Watts per horsepower.



1 Hp = 764 W

Conversion of Horsepower to Watts

- For our example we'll convert horsepower to Watts.

- Remember that 1 Horsepower is equal to 746 Watts

And 1,000 Watts is equal to one kiloWatt

- So to Convert 8 EHp to Watts we take 8 times 746 Watts per horsepower which equals 5,968 Watts

- We can convert this to KiloWatts by dividing by 1,000, we get 6 kiloWatts

$$8 \text{ Ehp} = 8 \times 746 \text{ w} = 5{,}968 \text{ W}$$

$$\frac{5{,}968 \text{ W}}{1{,}000} = 6 \text{ kW}$$

Efficiency

- The Horsepower requirement to pump 200 gpm at 100 ft TDH are 5.05 WHp.
- However, the pumping system requires 8 Electrical Hp in order to perform 5.05 horsepower worth of work.
- That is about a 3 Hp loss
- Where did the 3 Hp of energy go?
- What causes this loss?
- Since energy cannot be created or destroyed it must be converted from one form to another. In our case, all of the energy not used to move the water comes out in the form of heat.