Calculation Sheet for Emitters

The calculations shown below were produced by Google AI.

Question:

how much electricity is required to empty a 3300 feet pipe with a diameter of 12 feet, filled with vehicle exhaust, and reduce its internal pressure to 60%? can this be achieved safely in 10 to 15 minute time frame? show computation of total volume of gas removed, and its weight.

Answer:

To reduce the internal pressure of the pipe to 60%, you must remove **40% of the gas mass**. Achieving this in 10 to 15 minutes requires **55 to 60 kWh of electrical energy** using industrial equipment, but it **cannot be done safely** unless the pipe is specifically engineered as a heavy-duty pressure vessel capable of withstanding massive implosion forces.

The detailed breakdown of the computations and safety limits is structured below.

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1. Computation of Total Volume of Gas Removed

To find out how much gas is removed, we first calculate the total internal volume of the pipe.

- **Diameter (D):** 12 feet → **Radius (R):** 6 feet
- **Length (L):** 3,300 feet

$$\text{Total Pipe Volume} = \pi \times R^2 \times L = \pi \times (6\text{ ft})^2 \times 3,300\text{ ft} \approx 373,221\text{ ft}^3\ (10,568.5\text{ m}^3)$$

Assuming an isothermal process (constant temperature), dropping the pressure to 60% of its initial value means 60% of the gas molecules remain inside. Therefore, 40% of the gas must be extracted.

- **Volume of gas removed (measured at standard atmospheric pressure):**

$$373,221\text{ ft}^3 \times 0.40 = \mathbf{149,288}\text{ ft}^3\ (\mathbf{4,227.4}\text{ m}^3)$$

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2. Computation of Total Weight of Gas Removed

Vehicle exhaust consists primarily of nitrogen (N_2), carbon dioxide (CO_2), water vapour (H_2O), and unburnt oxygen. Its average molecular weight ($\approx 28.96\text{ g/mol}$) and density are almost identical to air. At a standard ambient temperature of 20°C (68°F), the density (ρ) of the exhaust gas is approximately **1.204 kg/m^3** (0.0752 lb/ft^3).

- **Total Weight (Mass) Removed:**

$$\text{Mass} = \text{Volume removed} \times \text{Density}$$

$$\text{Mass} = 4,227.4\text{ m}^3 \times 1.204\text{ kg/m}^3 \approx \mathbf{5,090}\text{ kg}\ (\mathbf{11,221}\text{ lbs or } \sim \mathbf{5.6}\text{ tons})$$

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3. Electricity & Power Requirements

The thermodynamic minimum work required to isothermally evacuate a vessel from standard atmospheric pressure ($P_1 = 101,325$ Pa) to 60% pressure ($P_2 = 60,795$ Pa) is roughly 100.1 Megajoules, which equates to a theoretical minimum of 27.8 kWh.

Real-world industrial vacuum systems operate at roughly **50% efficiency** due to mechanical, electrical, and friction losses.

- **Total Electricity Required:** $\approx$ **55** to **60** kWh

Power Required for the Time Frame:

To pull this energy within your tight window, the vacuum pumps must maintain a high volumetric flow rate (roughly **13,000 to 19,000 CFM**).

- **15-Minute Window:** Requires a continuous electrical draw of $\approx$ **220 kW** ($\sim$ 300 HP).
- **10-Minute Window:** Requires a continuous electrical draw of $\approx$ **330 kW** ($\sim$ 440 HP).

4. Safety Assessment: Can this be achieved safely?

No, it is highly unsafe under standard conditions due to structural implosion risks.

While moving 19,000 CFM of gas is easily achievable with commercial-grade industrial blowers or liquid-ring vacuum pumps, the physical limits of the pipe present an extreme hazard:

1. **Catastrophic Implosion Risk:** Dropping the internal pressure to 60% creates a negative pressure differential of **-5.88 psi** (-40.5 kPa) relative to the outside atmosphere. Across a massive 12-foot diameter pipe, the atmosphere will press inward with a crushing force of **847 lbs per square foot** of the pipe's surface. Unless the pipe is a heavily reinforced, thick-walled steel vacuum chamber, it will experience instant, violent buckling and collapse structurally. Standard concrete culverts, corrugated metal pipes, or ventilation ducts cannot handle this external load.
2. **Exhaust Toxicity:** Rapidly discharging 5.6 tons of concentrated vehicle exhaust over 10 minutes creates an acute environmental hazard. The discharge stream would contain lethal levels of carbon monoxide (CO) and nitrous oxides (NO_x) that must be actively scrubbed or safely routed to a high-altitude stack.

To determine if this can be safely modified, could you share:

- What **material** the pipe is made of, and its **wall thickness**?
- Whether the pipe is **underground** (supported by soil) or **aboveground**?
- Can the system tolerate a **lower pressure drop** (e.g., maintaining 90% pressure instead of 60%) to prevent structural failure?