Novel Aerosol-Reducing Mask: A Low-Cost Mask for Non-Invasive Ventilation

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Objective

During the COVID-19 pandemic, large patient volumes resulted in a global shortage of ventilators and care staff, contributing to high mortality among otherwise treatable patients. Expanding the use of non-invasive ventilation (NIV) to patients with respiratory infections would increase ventilation therapy availability in clinical contexts and improve patient access to care. Thus, this project aims to develop an open-source, self-monitoring NIV mask capable of maintaining 5 cmH_2O of therapeutic pressure that prevents viral aerosol leaks and CO_2 accumulation.

Description of Engineering Design Process and Final Design

The engineering design process involved two parallel and integrated systems: The **mask** and the **sensor and alarm cluster** (Figure 1). The **mask** supplies O_2 concentrations up to 80% from a connected CPAP or O_2 cylinder through the central port, and outputs and clears expiratory air of viral aerosols via HEPA filters through the lateral ports. A silicone seal covering the patient's nose and mouth and a flexible polycarbonate shell satisfy leak requirements at the patient-mask interface. Ensuring that leak prevention did not compromise the mask's ability to clear CO_2 was the most significant mask design consideration - this was achieved by connecting fans to the filters to aid in the clearing of CO_2 during expiration, and by employing CFD to optimize the mask's internal geometry to minimize dead space where CO_2 can accumulate. The **sensor cluster** consists of flow, CO_2, and voltage sensors, which read and send data to the controller at 10 Hz; all system code being written in C++ for speed. When safe operation thresholds are exceeded, an LED and buzzer specific to the fault activate within 0.5 seconds, meeting requirements set by IEC 60601-1-8 and allowing care staff to oversee multiple patients using the mask.

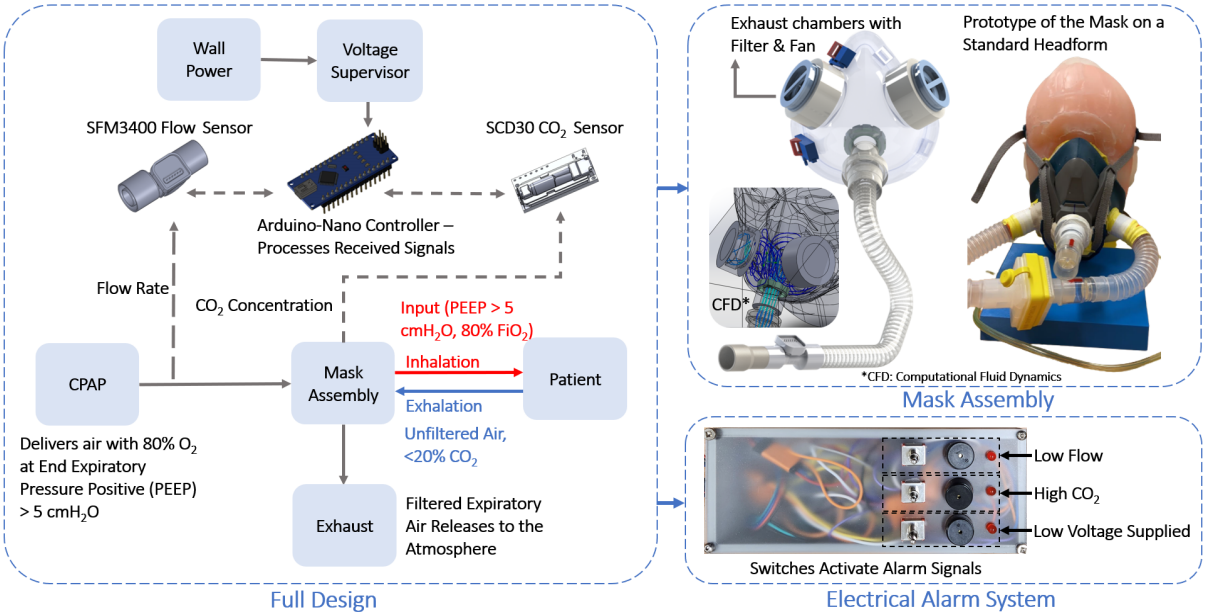

Figure 1: Integration of Mask Assembly and Alarm System

Impact

Lower-cost NIV therapy with lower staffing requirements, as achieved by this design, affords greater resilience and care capacity to Canadian health systems during respiratory virus outbreaks, and provides physicians with an accessible and low-risk intermediate treatment alternative prior to invasive ventilation. The project's open-source and standard-compliant design additionally enables its use in international and low-resource clinical contexts, allowing wider global use of NIV therapy and improved outcomes for patients with respiratory infections.