# IC 201P – Design Practicum

# Portable Oxygen Concentrator for Medical Application


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# Certificate

This is to certify that the work contained in the project report entitled " **Portable Oxygen Concentrator for Medical Application** ", submitted by Group 55 to the Indian Institute of Technology Mandi, for the course IC 201P – Design Practicum, is a record of bonafide research works carried out by him under our direct supervision and guidance.

Faculty Mentor -

**Dr. Gajendra Singh** Signature and Date

# Acknowledgment

I extend my heartfelt gratitude to **Dr. Gajendra Singh**, our esteemed course instructor and faculty mentor, for his invaluable guidance and support in finalizing the design of the Portable Oxygen Concentrator for Medical Application. His expertise and mentorship have been crucial in shaping the direction of this project.

I am also thankful to our student mentor, **Mr. Devesh Ojha**, and all teammates for their insightful contributions and feedback during the design refinement phase. Their input has been instrumental in enhancing the quality and functionality of our concept.

I deeply appreciate my peers and friends for their encouragement and collaboration during the brainstorming and decision-making stages of this project.

Additionally, I acknowledge the support and resources provided by our college, which have been essential in advancing our design efforts.

I am profoundly grateful to everyone who has contributed to the development and refinement of our **Portable Oxygen Concentrator** design.

# CHAPTER 1

# Introduction

## Problem Statement

The primary objective of this project is to develop a portable oxygen concentrator capable of supplying the necessary oxygen required for the survival of neonates by integrating it with a neonatal incubator. Our central focus is to extract and concentrate the available oxygen from the atmosphere efficiently.


## Abstract

This project presents the development of a portable oxygen concentrator designed to deliver essential oxygen to neonatal incubators, ensuring the survival of neonates. The device effectively extracts and concentrates oxygen from ambient air, providing a reliable and continuous supply of high-purity oxygen in a compact and portable form. The innovative design prioritizes ease of use,

portability, and integration with existing neonatal care equipment. By focusing on enhancing the oxygen delivery system for neonates, this project aims to significantly improve neonatal care in various medical settings, particularly in resource-limited environments, and most importantly, it is pocket-friendly too.

# Main Features

•**Compact design:** Compact design for easy transportation and mobility.
•**Cost-Effectiveness:** Create a solution that is cost-effective compared to traditional oxygen delivery methods.
•**Oxygen Concentration:** Efficiently extracts oxygen from the surrounding air, delivering a high concentration of oxygen to the user as prescribed by their healthcare provider.

# Problems Faced

.Finding a solution to make the design with a **limited budget** to make it more affordable.
•Making the design portable, i.e. lightweight and small enough to carry around.
•Deciding the material based on the solution that can work with the conditions required like high-pressure
Make a design integrating all the components and it should be as compact as possible.

## What we Achieved

•The total cost of the whole device is almost o**ne-seventh of any other model present in the market.**
•The model provides us with concentrated Oxygen which can be used in case of emergencies
•The model is very compactly designed keeping in mind that it occupies minimum space.

## Social Impacts

•The main impact of the device has is that it provides for the immediate requirement of Oxygen in case of emergency especially when connectivity is an issue.
•Also since it is cheap to produce, it can be easily installed in any remote hospital or even in every ambulance.
It can also be used for Oxygen Therapy sessions as it helps people with weaker lung functions.

# CHAPTER 2

# Prevailing Market Options

**Philips Respironics SimplyGo [5]** - It is one of the best Portable Oxygen Concentrators [POC] currently available in the market which comes with a continuous flow option. The rest don't usually have that but instead have a pulse dose system. It also is small enough to fit into the neonatal incubator.

The main flaw of this POC is that it is very costly (nearly ₹ 1,75,000 - ₹ 2,10,000). Another main concern in this product is that the battery life of the model is just nearly 1hr in continuous flow mode. We are aiming to provide the Oxygen Flow for a longer duration of time to cope with the emergencies.

**Inogen at Home[6]** provides sufficient oxygen at the proper concentrations, but it is meant for stationary use only. This limitation

may make it difficult to deliver to the hospitals in Nepal and will not allow users to continue oxygen treatment in their homes.

## O2 Concepts'[7]

portable oxygen concentrator is similar to that of Inogen One G4's product.

Their product boasts extended battery life but at the cost of expense which is a higher priority requirement. was not designed with our specific stakeholders in mind.

**OGSI's [8]** oxygen concentrator is another device that is catered more for communities outside of the one we were tasked with designing for. Although it generates the proper oxygen concentration and can be used by multiple users at a time, it is not portable.

# CHAPTER 3

# Methodology

## Main Topics of Research

We conducted extensive research on the fundamental principles of oxygen segregation from atmospheric air, with the objective of identifying the most cost-effective method. Our analysis determined that employing **zeolite 13X** for adsorption at high pressure was the optimal solution, balancing both budget constraints and portability requirements.

Additionally, we examined **materials capable of withstanding high pressure** to ensure adherence to safety standards.

Despite thorough investigation, **suitable air compressors** that fit within our budget of 30,000 INR were unavailable, posing challenges in terms of both cost and the portability of our prototype.

## Design

We brainstormed and developed various concepts for the portable oxygen concentrator, considering factors such as adsorption materials, pressure control mechanisms, user interface design, and compatibility with existing medical equipment. Preliminary design sketches and flow diagrams were created to visualize the system architecture and workflow. We evaluated these design concepts based on feasibility, cost-effectiveness, scalability, and their potential impact on improving neonatal care.

## Component Selection

1. Our next task was to select appropriate valves, sensors, coating materials, and other components for designing our prototype. We utilized **solenoid valves** to regulate the airflow, directing oxygen as the output and nitrogen as the residue. These valves operate only when supplied with an electric voltage. Furthermore, **each pipe used in the system was meticulously inspected to ensure it could withstand a maximum pressure of 8 bars.**

2. Additionally, we employed **pressure sensors** calibrated to accurately measure the pressure within the zeolite and oxygen storage tanks. These sensors are crucial, as the prototype requires alternating tank switching based on pressure values. The release of output and residue through the same tank opening is determined by decreasing pressure values.

3. Materials such as polypropylene, available online, were inadequate for handling high pressure. Consequently, w**e opted for mild steel tanks and lids, which were sealed airtight using O-rings and nut bolts**, capable of withstanding pressures up to 20 bars.

4. The unavailability of suitable air compressors presented a significant challenge. **Most compressors available were noisy, expensive, and large**. Therefore, we decided to use an **air pump as an alternative**, which can fill a tank up to a predetermined pressure level, aligning with our design requirements.

## Testing

To confirm functionality, accuracy, and dependability, comprehensive testing was conducted on both individual components and integrated system modules. Each tank was tested at varying pressures, up to six bars, followed by validation of the integrated design. The outflow rate at different pressures was also meticulously measured and calculated.

## Optimizing based on Tests

Throughout the project, we consistently identified areas for optimization and improvement. By iterating on our design and implementation based on test feedback, we enhanced the system's responsiveness and performance. **Leakage was a major issue**, which we addressed by extensively using **sealant tape and M-seal** to prevent leaks.

Additionally, we designed **steel stands for our tanks** to ensure that the pipes and connectors remained intact. Finally, an outer casing was constructed using **aluminum sheets and profiles, along with acrylic sheets**, to integrate and protect our design.

# CHAPTER 4

# Implementation of All Branch Insights

## 1. Coding Implementation

Here are the coding snippets for our prototype:

```
include "Wire.h" //allows communication over i2c devices
define LI 3 // Digital pin for solenoid valve 2
define LR 4 // Digital pin for solenoid valve 3
define RI 5 // Digital pin for solenoid valve 4
define RR 6 // Digital pin for solenoid valve 5
define LO 7 // Digital pin for solenoid valve 6
define RO 8 // Digital pin for solenoid valve 7

include "LiquidCrystal_I2C.h" //allows interfacing with LCD screens

const int pressureInput1 = A1; //select the analog input pin for the pressure transducer
const int pressureInput2 = A2; //select the analog input pin for the pressure transducer
const int pressureInput3 = A3; //select the analog input pin for the pressure transducer
const int pressureZero = 102.4; //analog reading of pressure transducer at 0psi
const int pressureMax = 921.6; //analog reading of pressure transducer at 100psi
const int pressuretransducermaxPSI = 100; //psi value of transducer being used
const int baudRate = 9600; //constant integer to set the baud rate for serial monitor
const int sensorreadDelay = 250; //constant integer to set the sensor read delay in milliseconds

float pressureValue = 0; //variable to store the value coming from the pressure transducer

bool start=1;
void setup() //setup routine, runs once when system turned on or reset
{
  Serial.begin(baudRate); //initializes serial communication at set baud rate bits per second
//  lcd.begin(); //initializes the LCD screen
  Wire.begin();

  pinMode(LO, OUTPUT);
  pinMode(LI, OUTPUT);
  pinMode(LR, OUTPUT);
  pinMode(RO, OUTPUT);
  pinMode(RI, OUTPUT);
  pinMode(RR, OUTPUT);

}
```

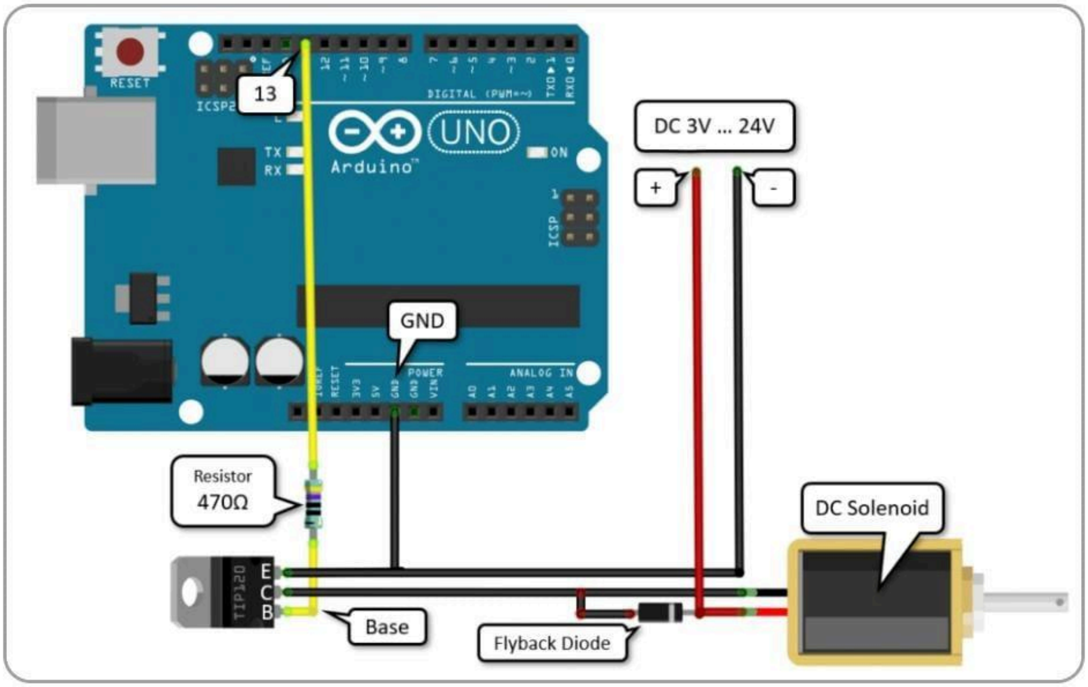
```
}

void loop() //loop routine runs over and over again forever
{
  pressureValue1 = analogRead(pressureInput1); //reads value from input pin and assigns to variable
  pressureValue1 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero); //conversion equation to convert analog reading to psi
  pressureValue2 = analogRead(pressureInput2); //reads value from input pin and assigns to variable
  pressureValue2 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero); //conversion equation to convert analog reading to psi
  pressureValue3 = analogRead(pressureInput3); //reads value from input pin and assigns to variable
  pressureValue3 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero); //conversion equation to convert analog reading to psi
  Serial.print(pressureValue, 1); //prints value from previous line to serial

  if(start){
    while(pressureValue1<65){
      digitalWrite(LI,HIGH);
      digitalWrite(LO,LOW);
      digitalWrite(LL,LOW);
      digitalWrite(RI,LOW);
      digitalWrite(RR,LOW);
      digitalWrite(RO,LOW);
      delay(sensorreadDelay);
      pressureValue1 = analogRead(pressureInput1); //reads value from input pin and assigns to variable
      pressureValue1 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
    }
    start=0;
  }

  digitalWrite(LI,LOW);
  digitalWrite(LR,HIGH);

  pressureValue2 = analogRead(pressureInput2); //reads value from input pin and assigns to variable
  pressureValue2 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
  while(pressureValue2<65){
    if(pressureValue1<55){
      digitalWrite(LR,LOW);
      digitalWrite(LO,HIGH);
```

```
  pressureValue2 = analogRead(pressureInput2); //reads value from input pin and assigns to variable
  pressureValue2 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
  while(pressureValue2<65){
    if(pressureValue1<55){
      digitalWrite(LR,LOW);
      digitalWrite(LO,HIGH);
      digitalWrite(LI,LOW);
    }
    else if(pressureValue1<45){
      digitalWrite(LO,LOW);
      digitalWrite(LI,LOW);
      digitalWrite(LR,LOW);
    }
    digitalWrite(RI,HIGH);
    digitalWrite(RO,LOW);
    digitalWrite(RR,LOW);
    delay(sensorreadDelay);
    pressureValue1 = analogRead(pressureInput1); //reads value from input pin and assigns to variable
    pressureValue1 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
    pressureValue2 = analogRead(pressureInput2); //reads value from input pin and assigns to variable
    pressureValue2 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
  }
  digitalWrite(RI,LOW);
  digitalWrite(RR,HIGH);
  digitalWrite(RO,LOW);
  # ASSUMING PRESSUREVALUE1<45
  while(pressureValue1<65){
    if(pressureValue2<55){
      digitalWrite(RR,LOW);
      digitalWrite(RO,HIGH);
    }
    else if(pressureValue2<45){
      digitalWrite(RI,LOW);
      digitalWrite(RR,LOW);
      digitalWrite(RO,LOW);
```

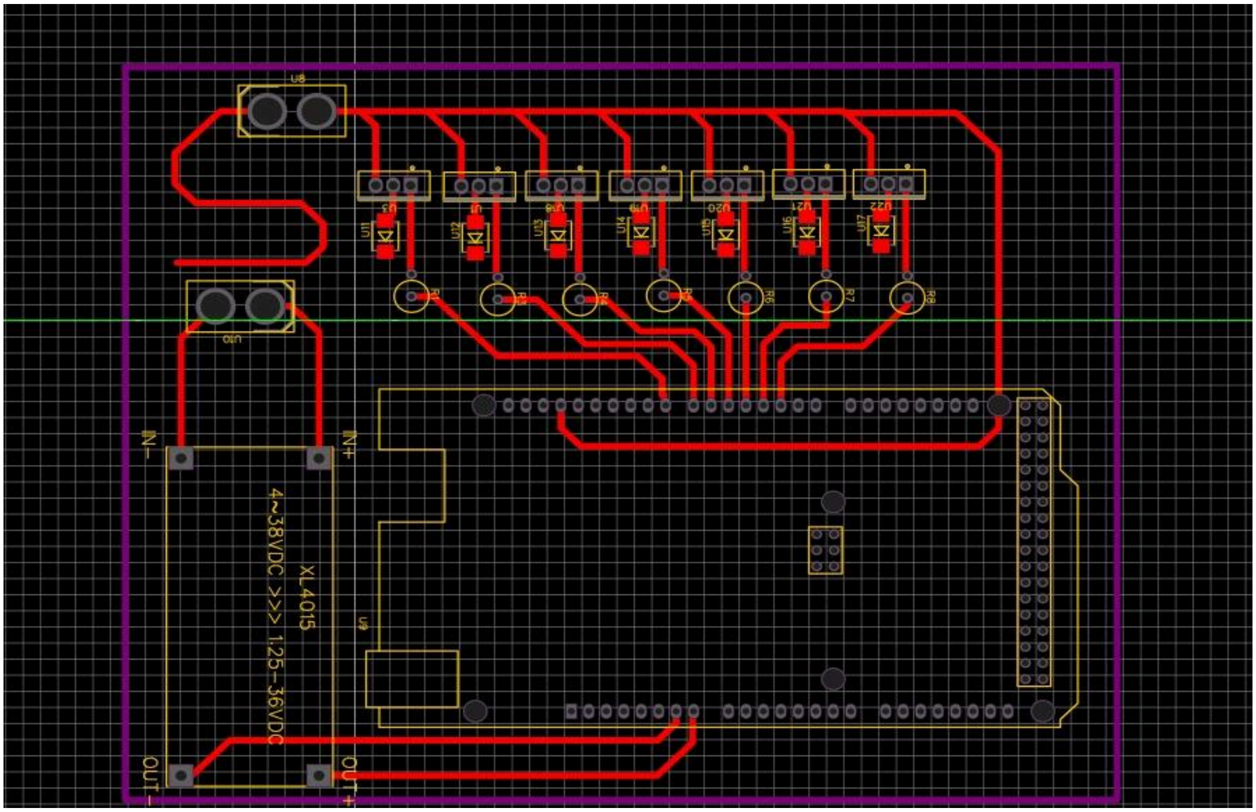
```
    }
    else if(pressureValue2<45){
      digitalWrite(RI,LOW);
      digitalWrite(RR,LOW);
      digitalWrite(RO,LOW);
    }
    digitalWrite(LI,HIGH);
    digitalWrite(LO,LOW);
    digitalWrite(LR,LOW);
    delay(sensorreadDelay);
    pressureValue1 = analogRead(pressureInput1); //reads value from input pin and assigns to variable
    pressureValue1 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
    pressureValue2 = analogRead(pressureInput2); //reads value from input pin and assigns to variable
    pressureValue2 = ((pressureValue-pressureZero)*pressuretransducermaxPSI)/(pressureMax-pressureZero);
  }
  delay(sensorreadDelay); //delay in milliseconds between read values
}
```

## 2. Electrical Implementation

The overall circuit design is here. Note that it has been shown for only one solenoid valve. The intense connections are shown in PCB connections only.

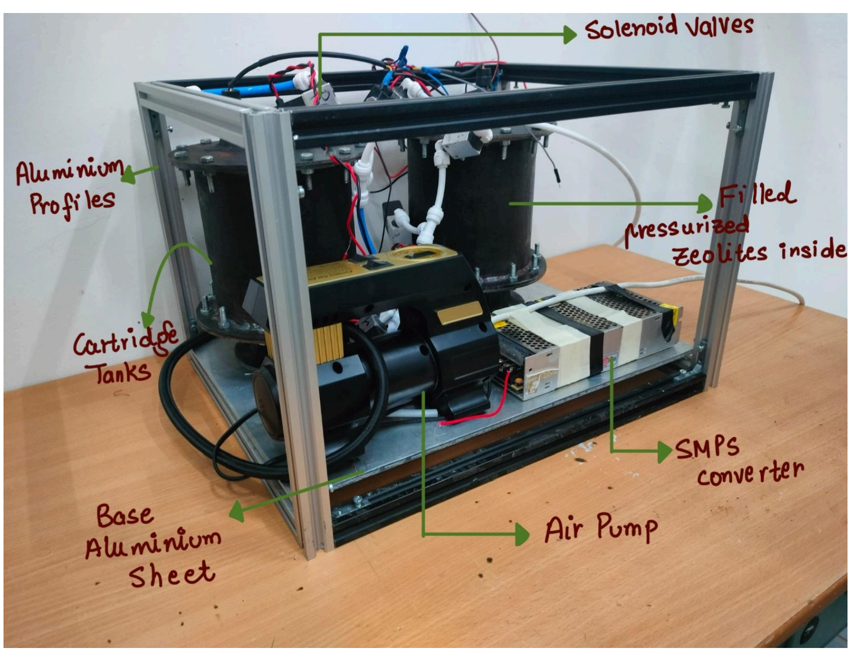



Following is a snapshot of final PCB connection design:



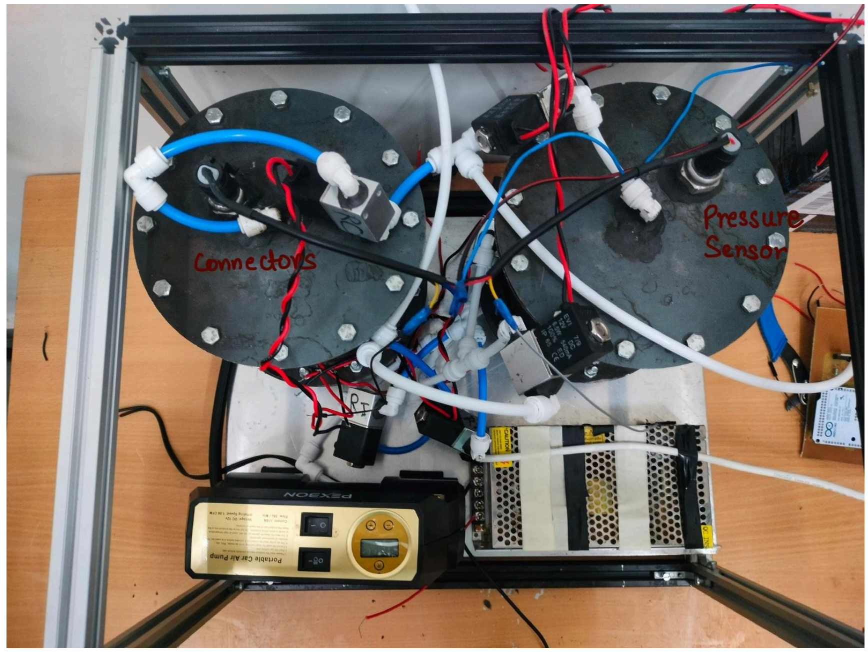

## 3. Mechanical Implementation

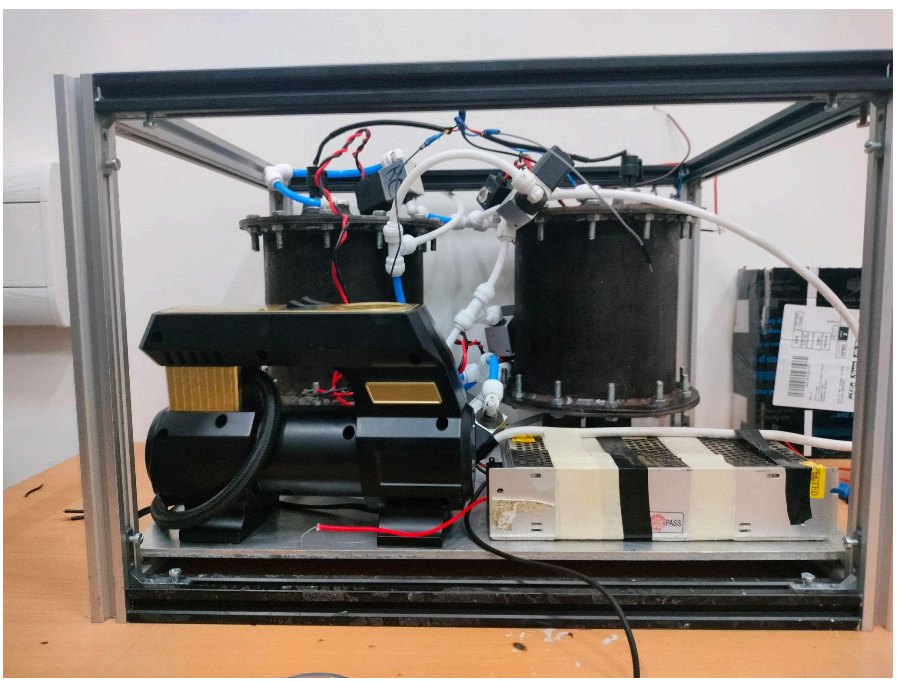
All the parts integrated have been shown in the different views of our final prototype which have been provided below:




Isometric View

Top View



Side View

## **Testing Results**

Upon the final conduction of tests, we concluded that:

Output Oxygen filled in 2 seconds = 500 ml
Output Oxygen filled in 1 second = 500/2 = 250 ml

Best Case Results = 250*60 = 15000 ml = 15 L per min.
Worst Case Results (considering all delays) = 7.5 L per min.
**Average Case Analysis = 11.25 L per min.**

*Note that average need of $O_2$ for a neonate is 5-8 L/min only.

# CHAPTER 5

# Futuristic Approaches

**1. Making it More Lightweight:** To reduce the weight of our project, we plan to use glass fibers and inbuilt capsules instead of heavy and bulky mild steel. Additionally, mild steel is quite expensive. By opting for these alternatives, we will significantly lower the manufacturing costs.

**2. Incorporating Wheels and Handles:** We will equip the bottom of the device with wheels, allowing it to be easily moved by any user. For additional support, handles will be attached to the sides and top. Furthermore, the design can be adapted into different versions, such as a backpack.

**3. Attached Oxygen Sensors:** Due to budget constraints, we were unable to include an oxygen concentration meter, as available meters are very costly. In the future, we plan to incorporate an O2 meter at the output point to provide real-time oxygen concentration measurements.

**4. Mobile Operated Design:** We envision developing a mobile application for our prototype, enabling users to operate the device via their phones, similar to Alexa. **This app would also**

**allow users to adjust the oxygen concentration as needed directly from their mobile devices.**

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