Title of the Invention
"Pneumatic Massager with Rotary Valve Control and Method for Sequential Inflation and Pressure Regulation"

Background of the Invention

Pneumatic massagers are used in therapeutic and medical treatments to improve blood flow, assist lymphatic drainage, and aid in recovery after physical exertion. Conventional pneumatic massagers typically inflate bladders in sequence to apply pressure, but often suffer from bulky designs, complex air hose systems, high noise levels, and insufficient control over pressure or massage patterns.

There is a need for both an improved **device** and a **method** that simplifies the operation of pneumatic massagers, offering more precise control over sequential inflation and deflation, user-adjustable pressure settings, and adaptability for various therapeutic applications, including continuous use as an assistive device. The present invention addresses these needs by introducing a compact pneumatic massager, along with a method for controlling the inflation and deflation of multiple air bladders using a rotary valve system.

Summary of the Invention
This invention relates to both a **device** and a **method** for controlling the inflation and deflation of multiple air bladders in a pneumatic massager. The device consists of a flexible cuff that contains **multiple narrow air bladders** arranged in an overlapping sequence along a limb or torso, controlled by a **rotary valve system** and powered by **stepper motors**. The rotary valve controls airflow into and out of the bladders via a **single pressurized air line and a single four wire electrical cable**, simplifying the design and reducing bulk.

The invention also introduces a method for **sequentially inflating and deflating** the air bladders in any arbitrary pattern using a centralized control system. The control system monitors air bladder pressure through a single pressure sensor and adjusts the flow rate via a **proportional valve**, allowing for customized massage settings. The method can be used for a variety of therapeutic treatments, including lymphatic massage, venous insufficiency, and continuous assistive applications, ensuring patient comfort through user-adjustable settings.

Detailed Description of the Device

1. **Overview of the Device**:

- The pneumatic massager device consists of a **flexible cuff** (10) that can be worn around various body parts, such as limbs or torso. The cuff contains **narrow, long air bladders** (12) arranged along the body part in a stacked configuration, with each bladder connected to a **central pressurized air line** (14). The air bladders are slightly overlapped (16) to eliminate any gaps between the bladders thereby providing a more comfortable and thorough massage.

2. **Rotary Valve System**:
   - Each air bladder is controlled by a **rotary valve system** (20) driven by a **stepper motor** (22). The rotary valve contains a hollow rotor with intake and exhaust ports, allowing for the sequential inflation and deflation of each bladder. The valve positions are controlled in 90-degree increments by the stepper motor, allowing precise control over the airflow pattern. The stepper motor maintains a home position through a Hall Effect sensor positioned on the valve body and a small magnet positioned on the rotor.

3. **Chained Wiring and Control**:
   - A **chained wiring configuration** (24) with four wires per bladder, to power and control the valves, connects the valves to a **central controller** (26). The wiring allows for communication between the controller and each stepper motor, enabling the centralized control of the inflation sequence.

4. **User Control and Pressure Regulation**:
   - The device features a **user interface** (30) that allows the adjustment of **pressure**, **flow rate**, and **massage patterns**. The central controller monitors bladder pressure using a **single pressure sensor** (32) and adjusts inflation through a **proportional valve** (34). This system enables user-customizable massage patterns for various therapeutic uses, such as lymphatic massage or recovery from physical exertion.

5. **Continuous Assistive Applications**:
   - The device is designed with a **slim profile** and **low power consumption**, allowing it to be used as part of compression stockings (40) for continuous assistive applications. The system provides continuous, light-touch massage for edema sufferers or individuals needing therapeutic bodily fluid movement.

Detailed Description of the Method

1. **Overview of the Method**:
   - The method consists of controlling the **sequential inflation and deflation** of air bladders in a pneumatic massager using a **rotary valve system** and **centralized control**. The method can be applied to any body part where the massager is worn, such as a limb or torso, and is designed to accommodate different body shapes through adjustable pressure settings.

2. **Step 1: Initiating the Massage Sequence**:
   - The method begins by **activating the rotary valve system** (50) connected to each air bladder. The **central controller** (52) sends signals to the stepper motor (54), rotating the rotary valve to open the intake port for the first bladder in the sequence. Air is delivered through the **central air line** (56) at a user-adjusted flow rate.

3. **Step 2: Inflating Each Bladder**:
   - The **pressure sensor** (60) monitors the pressure within the air line and the first bladder. Once the user-defined pressure level is reached, the **rotary valve closes** both the intake and exhaust ports, sealing the bladder at the desired pressure. The method proceeds by **inflating the next bladder in sequence** following the same process, allowing for gradual inflation along the body part.

4. **Step 3: User-Adjustable Control**:
   - Throughout the process, the user can adjust the **pressure level** (62) and **flow rate** (64) using the interface, which communicates with the controller to modify the sequence as needed. Different **massage patterns** (66) can be applied depending on the therapy type, such as **wave-like inflation** for lymphatic massage or **upward compression** for venous insufficiency.

5. **Step 4: Deflation and Exhaust**:
   - After all bladders are inflated, the method enters the deflation phase, where the **rotary valve repositions** (70) to open the exhaust port for each bladder, releasing pressure in the reverse sequence of inflation. The method ensures that each bladder deflates smoothly, following the same controlled pattern.

6. *Continuous Assistive Application**:
   - For **continuous assistive use**, the method involves inflating and deflating the bladders as part of a **compression stocking** (80) or similar garment, providing continuous, light-touch massage while allowing for **flexibility and movement**. The massager’s lightweight design makes it suitable for continuous use.

Brief Description of the Drawings

1. **Figure 1** shows the overall view of the pneumatic massager, illustrating the cuff, air bladders, and rotary valve positions.
2. **Figure 2** details the layout of the air bladders and their arrangement along a limb, showing the inflation sequence.
3. **Figure 3** provides a cross-sectional view of the rotary valve, demonstrating how the intake and exhaust ports open or close based on the valve position.
4. **Figure 4** shows the wiring diagram illustrating the four-wire configuration (ground, Vcc,

SCL, SDA) and the chained wiring to the central controller.
5. **Figure 5** presents the control system, including the I2C bus, pressure sensor, and user interface for adjusting flow rate and pressure.
6. **Figure 6** shows the assistive application, with the massager worn as part of a compression stocking.

Abstract
The invention includes a pneumatic massager device and a method for controlling the sequential inflation and deflation of air bladders using a rotary valve and stepper motor system. The device features multiple air bladders arranged in a cuff that can be worn around various body parts, with each bladder controlled via a single pressurized air line. A rotary valve allows for precise control of airflow, and the user can adjust pressure and flow rate through a central control system. The method includes inflating the bladders in a controlled sequence based on user-adjustable settings, making the device suitable for therapeutic and assistive applications.

Detailed Description of the Drawings

Figure 1: Overall System View
This figure illustrates the pneumatic massager's overall structure, including the flexible cuff (10), which is designed to wrap around various body parts, such as the arm, leg, or torso. The cuff contains multiple air bladders (12) arranged longitudinally along the body part being treated. The bladders are connected to a central pressurized air line (14), which distributes air to each bladder. Positioned externally on the cuff are the rotary valve systems (16), each attached to a stepper motor (18) and controlled by a central controller (20). The flexible cuff is contoured to accommodate joints such as the knee or elbow, providing a snug and consistent fit for therapeutic massage.

Figure 2: Air Bladder Layout
This figure provides a detailed layout of the air bladders (30) within the cuff. Each air bladder is narrow, approximately 1 inch wide, and stacked with an overlap along the length of the limb. The bladders are shaped to contour around joints (32), such as the knee or ankle, ensuring even pressure distribution during inflation. The central air line (34) feeds air into each bladder in sequence. Each bladder has a designated rotary valve (36) that controls airflow, enabling sequential inflation from one end of the limb to the other. This arrangement ensures full coverage and adaptable pressure based on the specific body part being treated.

Figure 3: Rotary Valve Mechanism
This cross-sectional view illustrates the rotary valve system (40) in detail. The valve consists of a hollow rotor (42) with patterned holes (44) that align with the intake (46) and exhaust (48) ports. The rotor is driven by a stepper motor (50), which rotates the valve in 90-degree

increments, allowing for four distinct positions: both ports open, both closed, intake open/exhaust closed (for inflation), and exhaust open/intake closed (for deflation). The stepper motor maintains a home position through a Hall Effect sensor (52) positioned on the valve body and a small magnet (54) positioned on the rotor. The rotor is constructed from 3D-printed ABS material, softened and lapped into the valve body (54) using acetone to create an airtight seal. The valve controls the airflow into each air bladder and seals it when the desired pressure is reached.

Figure 4: Stepper Motor and Rotary Valve Assembly
This exploded view shows the assembly of the stepper motor (60) and rotary valve (62). The rotor (64) is attached to the motor's shaft, which drives its rotation within the valve body (66). The valve body includes openings for the intake and exhaust ports (68). The stepper motor is connected to a small PCB (70) that provides power and signal interpretation from the central controller (72). The rotor's movement is controlled by signals from the PCB, which ensures the valve switches between its four positions, thereby regulating air flow into and out of the connected air bladders. Upon powering up, the PCB detects the home position by rotating the valve until the Hall Effect sensor positioned on the valve body interacts with the magnet positioned on the rotor.

Figure 5: Wiring Configuration
This schematic diagram outlines the wiring configuration (80) for the pneumatic massager. The wiring is simplified, with only four wires connecting all valves: ground (82), Vcc (84), SCL (86), and SDA (88). The wiring is chained from one valve/stepper motor combination to the next, reducing complexity. Each valve assembly is connected to the central controller (90), which communicates with the stepper motors through an I2C bus (92). This configuration allows for sequential control of the valves, enabling independent inflation of each air bladder in a controlled sequence.

Figure 6: Control System with I2C Bus
This block diagram shows the interaction between the central controller (100), the I2C bus (102), and the pneumatic massager's components. The controller sends signals through the I2C bus to each valve/stepper motor assembly (104), dictating the valve's position based on the user's selected massage pattern. The pressure sensor (106) monitors the air pressure within the central air line (108), feeding real-time data back to the controller, which adjusts the system as needed. The controller also interfaces with the user control panel (110), where users can adjust settings such as pressure level, flow rate, and massage pattern. A bank if batteries (112) powers the device.

Figure 7: Pressure Sensor and Sequential Inflation
This diagram shows the relationship between the pressure sensor (120), the central air line (122), and the sequential inflation of the air bladders (124). As air is pumped into the system, the pressure sensor detects the pressure level within the air line and relays this information to

the central controller (126). The controller uses this data to ensure that each air bladder inflates to the desired pressure. Once the set pressure is reached, the rotary valve seals the bladder, and the system proceeds to inflate the next bladder in the sequence. This method allows for smooth, user-controlled massage patterns.

Figure 8: Continuous Assistive Application
This figure illustrates how the pneumatic massager can be integrated into a assistive application (130). The massager is shown worn as part of a compression stocking (132), with air bladders (134) placed along the limb to provide continuous light massage. The slim profile of the device allows for freedom of movement, making it suitable for use by edema sufferers or those requiring therapeutic movement of bodily fluids. The compression stocking ensures that the bladders remain securely in place without the need for bulky velcro straps or cinching systems.

Figure 9: User Interface and Control Elements
This diagram depicts the user interface (140) for controlling the pneumatic massager's settings. The interface includes controls for adjusting **pressure** (142), **flow rate** (144), and selecting **massage patterns** (146). The user can input desired settings, which are communicated to the central controller through the I2C bus. The interface is designed for ease of use, allowing the user to quickly adjust settings based on their therapeutic needs. Real-time feedback from the pressure sensor and controller is displayed on a digital readout (148), ensuring that the user is informed of the current status of the massage.

Device Claims:

1. **Broad Device Claim:**
   - **Claim 1**: A pneumatic massager comprising:
     - a flexible cuff configured to encircle a body part;
     - a plurality of air bladders arranged within the cuff;
     - a single pressurized air line connected to each of the plurality of air bladders;
     - a rotary valve system for controlling the airflow into and out of each air bladder, said rotary valve system comprising a hollow rotor, intake and exhaust ports, and a stepper motor configured to rotate the rotor to open or close the ports;
     - a central controller configured to monitor and adjust the pressure within each air bladder through a pressure sensor;
     - a proportional valve for adjusting the flow rate of the air through the pressurized air line;
     - and a user interface for adjusting pressure, flow rate, and massage patterns.

2. **Specific Rotary Valve Claim:**
   - **Claim 2**: The pneumatic massager of claim 1, wherein the rotary valve comprises:
     - a hollow rotor with a specific pattern of holes;
     - said rotor being constructed from a 3D-printed ABS material and softened using acetone to create an airtight seal within the valve body;

    - wherein stepper motor rotates the rotor in 90-degree increments, providing four distinct positions: both ports open, both ports closed, intake open with exhaust closed, and exhaust open with intake closed.
    - and wherein stepper motor maintains a home position through a Hall Effect sensor positioned on the valve body and a small magnet positioned on the rotor.

3. **Chained Wiring Claim:**
   - **Claim 3**: The pneumatic massager of claim 1, wherein the rotary valve system is connected via a chained wiring configuration comprising:
    - four wires per valve: ground, Vcc, SCL, and SDA;
    - and wherein the wiring is connected to the central controller through an I2C bus for sequential control of the valve system.

4. **Pressure Regulation Claim:**
   - **Claim 4**: The pneumatic massager of claim 1, wherein the central controller monitors the pressure in each air bladder using a single pressure sensor connected to the pressurized air line, and adjusts the inflation of each bladder by controlling the rotary valve system to reach a user-specified pressure level.

5. **Continuous Assistive Application Claim:**
   - **Claim 5**: The pneumatic massager of claim 1, wherein the massager is configured for use in assistive applications, the flexible cuff being slim and lightweight, and designed to be worn as part of a compression stocking, allowing for continuous massage without restricting movement.

Method Claims:

1. **Broad Method Claim:**
   - **Claim 6**: A method for sequentially inflating and deflating air bladders in a pneumatic massager, the method comprising:
    - providing a plurality of air bladders arranged within a flexible cuff;
    - delivering pressurized air to the air bladders through a single pressurized air line;
    - controlling the flow of air into and out of each air bladder using a rotary valve system, said rotary valve system comprising a hollow rotor and intake and exhaust ports;
    - rotating the rotor using a stepper motor to position the rotary valve in one of four positions: both ports open, both ports closed, intake open with exhaust closed, or exhaust open with intake closed;
    - and monitoring and adjusting the pressure in each air bladder using a central controller and a pressure sensor.

2. **Sequential Inflation Method Claim:**

- **Claim 7**: The method of claim 6, further comprising:
  - sequentially inflating the air bladders, wherein the central controller monitors the pressure in each air bladder and directs the rotary valve to close the intake and exhaust ports once the desired pressure is reached in each bladder;
  - and inflating the next air bladder in sequence.

3. **User Adjustable Control Method Claim:**
   - **Claim 8**: The method of claim 6, further comprising:
     - allowing the user to adjust the pressure and flow rate of air into the bladders using a proportional valve;
     - and selecting predefined massage patterns, wherein the central controller adjusts the sequential inflation and deflation of the air bladders based on the selected massage pattern.

4. **Pressure Sensing Method Claim:**
   - **Claim 9**: The method of claim 6, further comprising:
     - sensing the pressure within the central air line using a pressure sensor;
     - and adjusting the flow of air into each bladder based on the pressure reading from the sensor to ensure that each bladder inflates to the desired user-specified pressure level.

5. **Continuous Assistive Application Method Claim:**
   - **Claim 10**: The method of claim 6, wherein the pneumatic massager is applied in assistive use, comprising:
     - wearing the pneumatic massager as part of a compression stocking or other garment to provide continuous therapeutic massage to a user with edema or requiring lymphatic drainage;
     - and inflating and deflating the air bladders in sequence without restricting movement of the limb.