System Components

1. **Sensor-integrated skid modules** for inline detection
2. **Programmable logic controllers** with decision trees for feedback
3. **Modular ethanol and buffer dosing pumps** governed by logic
4. **Batch execution records** that log deviations and enable real-time alerts
5. **21 CFR Part 11–compliant documentation interface**

Claim 1 (Independent – Method of Fractionated Protein Manufacturing)

A method of producing a plasma-derived therapeutic protein in a GMP-compliant fractionation system, comprising:
(a) introducing plasma into a closed-loop skid-mounted fractionation unit;
(b) administering ethanol, glycine, or pH-modulating buffers in controlled ratios via automated dosing pumps;
(c) measuring real-time input variables including temperature, pH, conductivity, UV280 absorbance, turbidity, and zeta potential using inline sensors;
(d) comparing sensor values against predefined per-protein manufacturing profiles;
(e) adjusting ethanol concentration, temperature ramp rates, or buffer flow based on deviation triggers; and
(f) gating batch progression or release based on multi-parameter compliance with validated GMP specifications for the target protein.

Claim 2 (Independent – Sensor-Integrated Fractionation Skid)

A plasma fractionation system comprising:
(a) a stainless-steel or single-use skid with inline ethanol, pH, and temperature sensors;
(b) programmable logic controllers configured to execute control actions when sensor inputs deviate from GMP-defined bounds;
(c) a data acquisition and batch history module;
(d) auto-lockout functionality triggered when deviation severity exceeds critical thresholds.

Claim 3 (Dependent – Protein-Specific Control Logic)

The system of claim 2, wherein logic branches are differentiated based on the protein being isolated, such that:

- Factor IX low → adjust pH + extend precipitation time
- IVIG UV280 below threshold → increase ethanol %
- Fibrinogen turbidity spike → reduce flow rate and pause batch

Claim 4 (Dependent – Viral Inactivation Safety Interlock)

The method of claim 1, wherein a viral inactivation hold tank is equipped with temperature and pH sensors, and any deviation from validated hold conditions results in automatic batch hold or discard.

Claim 5 (Independent – GMP Buffer Cartridge System)

A buffer cartridge system for GMP fractionation comprising:
(a) disposable vessels for ethanol, glycine, NaCl, or phosphate-buffered saline;
(b) QR or RFID-coded labels containing buffer metadata, concentration, and expiration;
(c) a sterile port with weldable connection; and
(d) integration with the skid's programmable dosing controller and batch record.

Claim 6 (Dependent – Cassette Authentication Lockout)

The cartridge system of claim 5, wherein the skid controller verifies expiration and lot metadata, and locks out dosing if RFID verification fails.

Claim 7 (Dependent – Sensor Cascade and Logic Branching)

The system of claim 2, further comprising:
(a) logic modules that trigger alternate routing, delay cycles, or neutralization steps based on compound sensor output;
(b) real-time correlation of pH + UV280 + zeta potential to initiate precise precipitation or separation steps.

Claim 8 (Dependent – OEM Interface and Cloud Integration)

The system of claim 2, wherein the fractionation controller interfaces with cloud platforms for:
(a) real-time multi-site standardization of buffer schedules;
(b) deviation alert synchronization; and
(c) regulatory audit trail export in 21 CFR Part 11–compliant format.

CLAIM SET: PROTEIN-SPECIFIC FRACTIONATION LOGIC

1. A method of plasma protein purification comprising: (a) detecting real-time protein-specific signals including but not limited to turbidity, UV absorbance, pH, conductivity, or zeta potential; (b) identifying a deviation from target yield, purity, or activity of a plasma-derived protein selected from the group consisting of IVIG, albumin, fibrinogen, factor IX, alpha-1 antitrypsin, antithrombin III, IgA, IgM, C1 inhibitor, transferrin, and fibronectin; (c) adjusting at least one processing variable selected from ethanol percentage, buffer pH, flow rate, temperature, or salt concentration; (d) verifying that recovery, activity, or purity metrics fall within pre-defined GMP thresholds; and (e) recording said adjustments within a batch execution platform compliant with 21 CFR Part 11.
2. The method of claim 1, wherein said protein-specific deviation is detected via inline sensor data and triggers automatic actuation of ethanol or buffer pumps to correct the deviation in real-time.
3. The method of claim 1, wherein said control logic includes predefined process maps for individual plasma proteins, specifying response pathways to maintain target yield and reduce impurity co-elution.
4. The method of claim 1, wherein zeta potential measurements are used to determine and modulate the pH range for selective precipitation of target proteins from plasma.
5. The method of claim 1, wherein the presence of oxidation-sensitive proteins triggers temperature modulation, oxygen purging, or antifoam agent infusion.
6. A plasma fractionation control system comprising: (a) a programmable control unit configured to interpret real-time sensor data including turbidity, pH, conductivity, and UV absorbance; (b) an automated dosing module configured to adjust ethanol, buffer, and temperature in response to said data; (c) a logic engine programmed with protein-specific deviation thresholds and correction pathways; (d) an integrated audit log for process compliance; and (e) a user interface to enable override or confirmation of critical deviations prior to batch release.
7. The system of claim 6, wherein deviation triggers include: (i) IVIG yield below 85% prompting increased ethanol concentration; (ii) Factor IX activity below target triggering a pH shift; (iii) Fibrinogen viscosity above limit initiating pump deceleration.
8. The system of claim 6, wherein the dosing module is equipped with a multi-channel valve bank and sterile buffer cassettes encoded with lot data and dosing parameters.

PLASMA FRACTIONATION 2nd CLAIM SET: PROCESS CENTRIC

Title: *Modular Feedback-Controlled Plasma Fractionation System with Integrated Skid Sensors, Batch Lockouts, and Per-Protein Logic Architecture*

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Claim 9 – OEM Control Interface Protocol

A standardized OEM integration module for plasma fractionation systems comprising:
(a) an electronic interface supporting CAN bus, RS-485, or industrial USB protocols;
(b) a digital handshake protocol authenticating firmware and hardware compatibility between third-party OEM devices and the platform controller;
(c) auto-configuration of buffer schedules and skid logic via encrypted metadata exchange;
(d) compatibility with single-use and stainless-steel systems;
(e) versioning control to enforce validation status of OEM firmware and consumables.

Claim 10 – AI-Guided Fractionation Adjustment Engine

A machine-learning-based module integrated into a plasma fractionation skid, comprising:
(a) batch history archive storing protein yield, deviation responses, and ethanol/pH adjustments;
(b) neural network trained to predict optimal buffer gradients and temperature ramp profiles for each protein class;
(c) batch-to-batch retraining engine that refines protocol parameters based on real-time purity and recovery outcomes;
(d) override safeguards ensuring that predicted modifications do not violate GMP safety thresholds.

Claim 11 – OEM Fractionation Cartridge Compliance Engine

A software and hardware lockout system comprising:
(a) onboard RFID or QR scanner validating buffer cartridge origin, expiration, and match to skid firmware version;
(b) deviation prevention logic that blocks buffer delivery if unauthorized cartridge types are detected;
(c) cloud-synced compliance dashboard showing cartridge use history and per-batch metadata;
(d) batch-hold interlock that requires operator override for unverified cartridges.

Claim 12 – OEM Validation Integration and Logging System

A compliance record engine embedded in the fractionation platform, comprising:
(a) automated logging of cartridge lot, sensor serial number, and OEM device identifiers;
(b) validation status tracking against pre-approved equipment lists;
(c) interface for uploading third-party validation certificates;
(d) exportable GMP-compliant reports (XML/CSV/PDF) for regulator submission.