INDUSTRIAL SOLUTIONS LABORATORY

Company Information

Company Name	*United Protective Technologies, LLC*	**Date Submitted**	*03/31/2026*
Project Title	*Valve Stem Packing Wear and Leak Rate Study (UPT_VALVE)*	**Planned Starting Semester**	*Fall 2026*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your staffing estimate in the table below. The Senior Design Committee will adjust as appropriate based on scope and discipline skills.

Discipline	**Number**	**Discipline**	**Number**
Mechanical	4	Electrical	1
Computer	1	Systems	0 or 1
Total			5-6 Students‡
‡ Nontraditional students and veteran students are preferred.			

Company and Project Overview:

UPT produces thin film coatings that reduce friction and wear. These coatings are applied to a wide range of products, such as weapon parts, gears, bearings, actuators, molds, and other process tooling. A persistent pain point in industrial valves (manufacturers and end users) is the trade space between:

- Low operating torque / stable controllability (reduce stiction and stick-slip)
- Low fugitive emissions/leak tightness (maintain sealing performance over cycling)
- Durability (packing wear, stem wear, galling, friction drift)

Valve stems sliding through packing can see increasing friction and surface damage with cycling, temperature changes, and pressure exposure. This drives actuator oversizing, erratic control behavior, more frequent repacking, and an increased risk of fugitive emissions.

Thin-film coatings may reduce stem/packing friction, stabilize friction throughout the service life, reduce wear-track formation, and maintain leak-rate performance at lower packing loads.

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Project Requirements:

The project team will design and employ a bench-scale, reusable test cell that produces valve-industry-relevant data by quantifying:

- Static friction / breakaway force (stiction) after dwell
- Dynamic friction during reciprocating motion
- Stick-slip severity (force oscillation metrics)
- Leak-rate proxy across packing (pressure decay and/or flow)
- Wear/damage evolution on stems and packing

UPT is a subject matter expert in the bullet areas above and will provide training to the student team up front in the science areas not covered by their undergraduate curriculum so that they can succeed on this project.

The test cell must be modular to compare stem surface conditions, including at a minimum:

- Baseline polished stainless steel (reference)
- One “industry reference” surface (e.g., a hard chrome or a nitrided surface)
- UPT nanocomposite coated stem(s) (e.g., P51+™ or a valve-focused variant)

Test Cell (Core Architecture)

Mechanical System

- Reciprocating stem module: interchangeable stem specimens (≈ 3/8–3/4” diameter; 6–10” length)
- Packing gland cartridge (quick-swap): standardized stuffing box geometry supporting ≥2 packing types (e.g., PTFE-based, elastomeric, and graphite-based)
- Packing load control: adjustable gland follower compression via either:
  - disc springs (live loading), or
  - screw/fixture + load cell stack to set repeatable packing compression load
- Pressurized chamber below packing: nitrogen/air at modest pressure (target 50–200 psi) with relief/safety controls

Instrumentation & Data Acquisition (Minimum)

- Load cell (axial force) for friction force vs time
- Position/velocity measurement (encoder)
- Pressure transducer (process-side)
- Temperature sensing (gland and/or chamber)

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Expected Deliverables/Results:

Semester 1 (Design Only)

- Build-ready CAD assembly + detailed drawings
- Costed BOM (vendor part numbers + alternates) and procurement/long-lead plan
- Instrumentation + DAQ architecture (channels, sampling rates, wiring diagram)
- Risk/safety assessment (pressure, venting, pinch points, E-stop concept)
- Test plan + DOE + calibration plan + data reduction plan
- Poster summarizing concept, rationale, design, and planned testing
- Sponsor-ready design review package (PDF + file handoff)

Semester 2 (Build + Test)

- Fully functional test cell
- Operating manual
- Calibrations and repeatability/uncertainty characterization
- DOE dataset + data reduction scripts (Python/MATLAB) + raw data archive
- Final technical report + 1-page customer-facing summary (plots + key takeaways)
- Test cell documented computer source code.
- Test cell engineering documentation, including as-built dimensioned drawings of all manufactured parts, a fully costed BOM, and electrical schematic drawings describing system hardware.
- Team will propose a DOE executable within Semester 2
    - 3 stem surfaces
    - 2 packing types
    - 2 packing loads
- Data on valve stem performance when treated with the following surface modifications:
    - Uncoated
    - Hard Chrome / Hexavalent Chrome coated
    - Nanocomposite Coated (NCC)
- Full in-person training session for potential UPT users of the test cell 2 weeks prior to the Expo.
- Final report suitable for use as a basis for a conference presentation.
- Photographs of the system during construction and in use.
- Forensic photographs of the test articles should be included in the final report to support the report's conclusions.

Disposition of Deliverables at the End of the Project:

The test cell is intended to reside in the UNCC Senior Design lab during design, development and fabrication activities. The project supporter will take possession of the test cell and all electronic files at the conclusion of the Expo in May 2027. UPT will provide a truck to transport the cell to our facility.

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List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

- Mechanical Engineers should have completed Mechanics of Fluids and Mechanics of Materials courses prior to the start of the project.
- Mechanical fabrication experience, including machining and welding, would be beneficial.
- Experience with gearing or other power transmission mechanisms would also be beneficial.
- Computer Engineers should be familiar with Arduino controllers or other microcontrollers to support system design.
- Electrical engineers should be familiar with AC power requirements for equipment for laboratory use.
- Both Electrical and Computer Engineers should have experience with electronics fabrication, including soldering, wiring, and connectorization of cable harnesses.
- Both Electrical and Computer Engineers should be familiar with data acquisition from external sensors, including digitization of analog sensor signals and storage of data.
- Team knowledge of signal filtering and processing would be beneficial.
- The System Engineer should have multidisciplinary project experience via hobbies, internships, or other extracurricular activities.
- The System Engineer should have project leadership experience.