



Multi-Sampling Device for DR/4000 Spectrophotometer

December 15, 2004

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Capstone Advisor: Professor Tom Christensen

Course Instructor: Professor Darrell Donahue

Designed For: Mr. Ken Johnson

INCORRECT TABLE

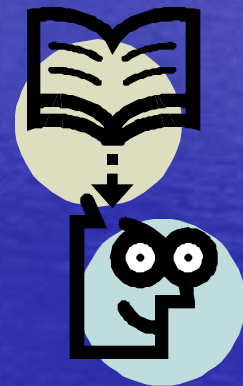
Type	Corrosion Resistance	Machinability	Weldability
Martensitic	Fair	Fair	Poor
Austentitic			
303	Good	45%	Good
304	Good	85%	Fair
316	Good	45%	Good

CORRECTED TABLE

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Presentation Overview

- Introduction
- Criteria for Design
- Examination of Available Auto-Samplers
- Investigation of Alternatives
- Final Design
- Process Steps for Automation
- Machining, Assembly, Wiring and Programming
- Cost Breakdown
- Possible Design Problems and/or Improvements
- Conclusions





Introduction



- Mr. Ken Johnson works for the Senator George J. Mitchell Center on the University of Maine campus.
- The Center works closely with the Environmental Protection Agency and performs acid rain monitoring for all of New England.
- Mr. Johnson recently purchased a DR/4000 Spectrophotometer to aid in the acid rain monitoring.
- The equipment can perform several different tests.
- For acid rain monitoring, phosphorous analysis is performed.



spectrophotometer



sample module



*10 cm path length
cell adapter*



10 cm path length cell



test tube

- Since there is no multi-sampling device, each sample must be loaded and discarded manually.
- In between samples, the cell must be flushed with de-ionized water to prevent contamination.
- The Center performs phosphorus analysis on thousands of samples per year.
- The cell is extremely fragile & costs approximately \$400.
- The analysis is run mostly by graduate students.
- Mr. Johnson would like a system designed to make the process more automated and eliminate unnecessary handling of the cell.

Criteria for Design

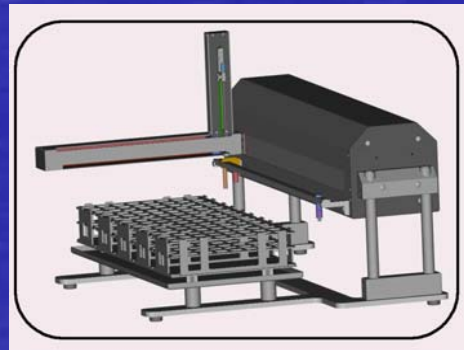
- Mr. Johnson indicated the following design criteria:
 - Automation of:
 - Placement of the sample into the cell
 - Movement of the cell into and out of testing area
 - Discarding of waste
 - Rinsing of cell
 - The system must be:
 - removable and relatively non-intrusive
 - manually reset between each sample
 - easy to operate
 - easily programmable
 - easy to install
 - able to fit on a workbench
 - The solution should cost no more than \$6000.
- Mr. Johnson preferred that the proposed system and the spectrophotometer not be integrated electrically.
- Waste can runoff to the sink.
- Test results must be manually recorded between each sample run, so it is implied that each new run be started manually.

Examination of Available Auto-Samplers

- Most utilize xyz sampling system
 - A syringe transfers the sample
- Advantages
 - Can be pre-programmed
 - Offer high speed, accuracy and high number of testings
 - Allow back to back running of samples without stopping
 - Different auto-samplers offer different sample holders
- Disadvantages
 - Expensive
 - Syringes are very fragile
 - Most can only pick up small amounts



OI Analytical's model 4551A



CAT's CaRo XYZ auto-sampler

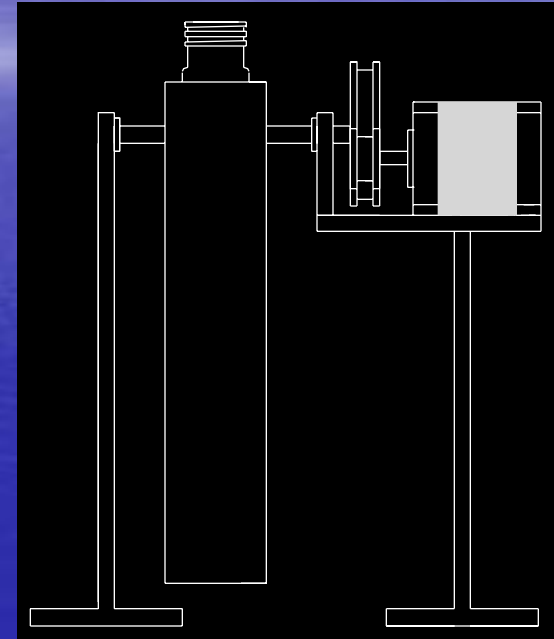


Analytik Jena AG's autosampler

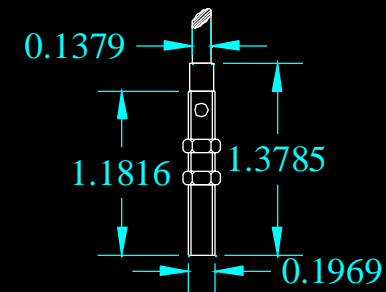
Investigation of Alternatives

Placement of the Sample into the Cell

- Test tube holder
 - UHMW
 - Lightweight
 - Corrosion resistant
 - Inexpensive
 - Low possibility of lab contamination
- Test tube suspension
 - Stainless steel type 303 rods
 - High corrosion resistance
 - High strength
 - Good machinability
- Rotation
 - Stepper motor with 3:1 reduction timing belt drive
 - Precise positioning
 - Smooth motion
 - Decrease necessary motor torque
 - Flanged bronze sleeve bearings
- Fill Level Detection
 - Stainless steel through-beam fiber optic sensor
 - High reproducibility and accuracy
 - High corrosion resistance
- Detection of Presence of Test Tube
 - Limit switch
 - Inexpensive
 - Easy to install



PHOTOELECTRIC SENSOR



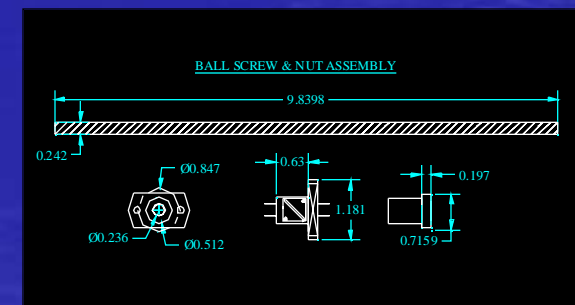
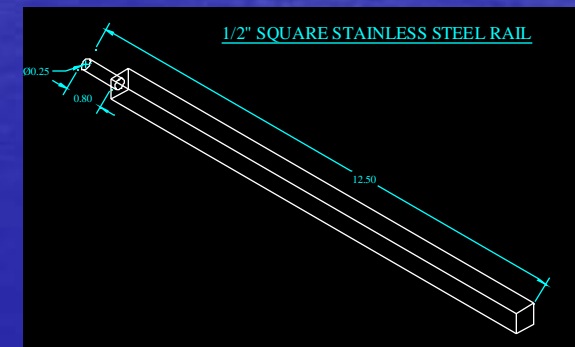
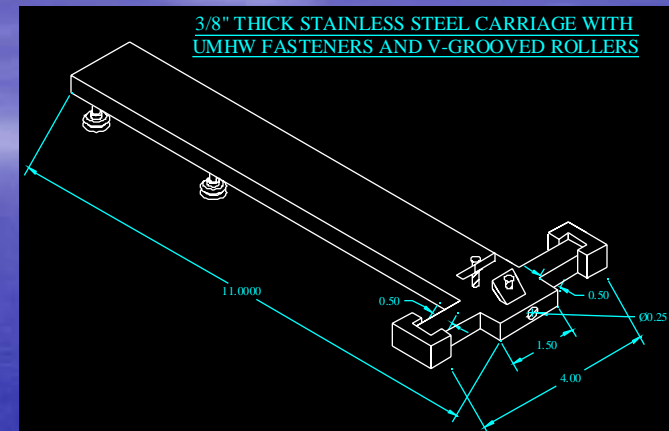
Movement of the Cell into and out of Testing Area

Options

- Rack and Pinion
- Belt conveyor on rollers
- Linear Actuator
- Machine Screw

Best Option

- Carriage
 - Stainless steel type 303
 - UHMW end brackets and fasteners with rubber backing to hold cell in place
 - V-grooved stud rollers
- Rail
 - Type 303 stainless steel square bar, rotated 45 degrees
- Screw Drive
 - Ball screw and nut assembly
- Linear Motion
 - Stepper motor with 3:1 reduction timing belt drive
- Flexible Coupling



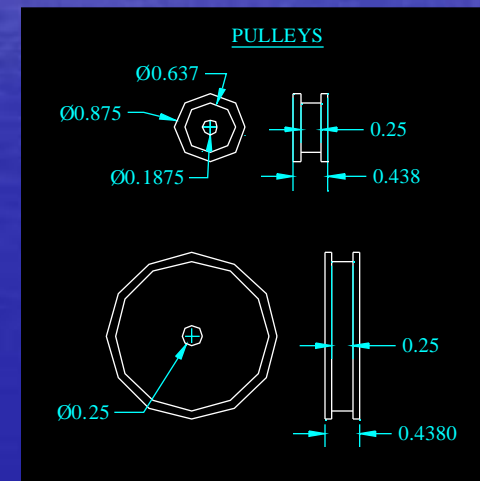
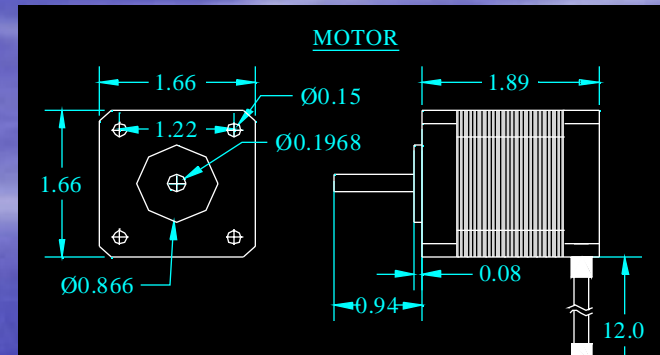
Discarding of Waste

Options

- Hose running from the cell with a shutoff for draining
- Pippetting

Best Option

- Inverting of the Cell
 - Rotate linear motion system about stainless steel type 303 rod
 - Rotation caused by stepper motor and 3:1 reduction timing belt drive
 - Flanged bronze sleeve bearings
- Waste container
 - Small rectangular container positioned directly under cell
- Runoff to sink via hose



Rinsing of the Cell

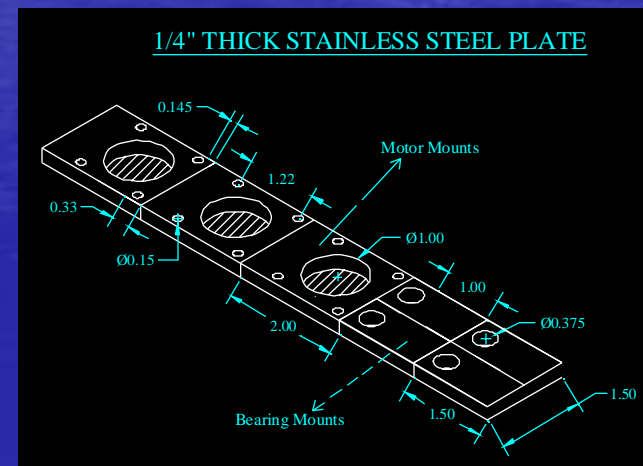
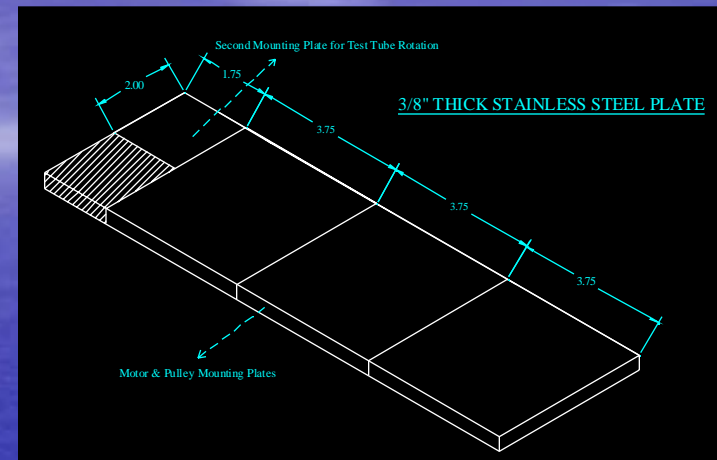
- Submersible Pump
 - Plastic housings can release contaminants
 - Lubricants can seep into water

Solution

- Peristaltic pump
 - No contamination
 - Positive displacement with no backflow
- Hosing will run from a container for de-ionized water through the pump and be positioned directly under the cell
- The pressure will be high enough to rinse the entire cell

Miscellaneous Components

- Mounting plates
 - Bearing holders
 - Motor front mounts
 - Motor and pulley mounts
 - Mounting plate for test tube rotation
- Adjustable legs
 - Account for height of test tube
 - Added to all components and spectrophotometer
- Indication Light
 - Inform user when cell is in testing area
- Start Button
 - Unpause system

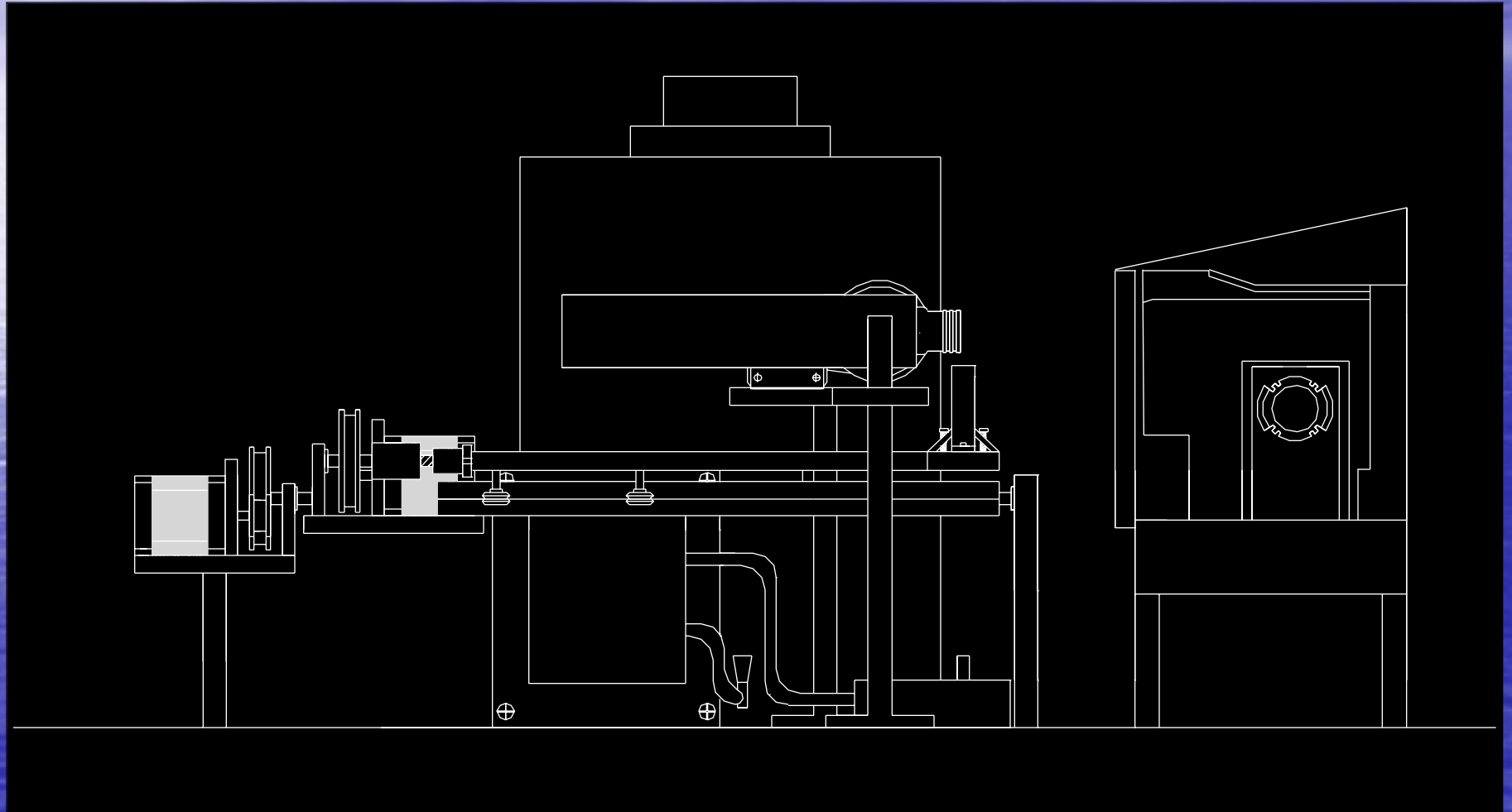


Automation and Power Supply

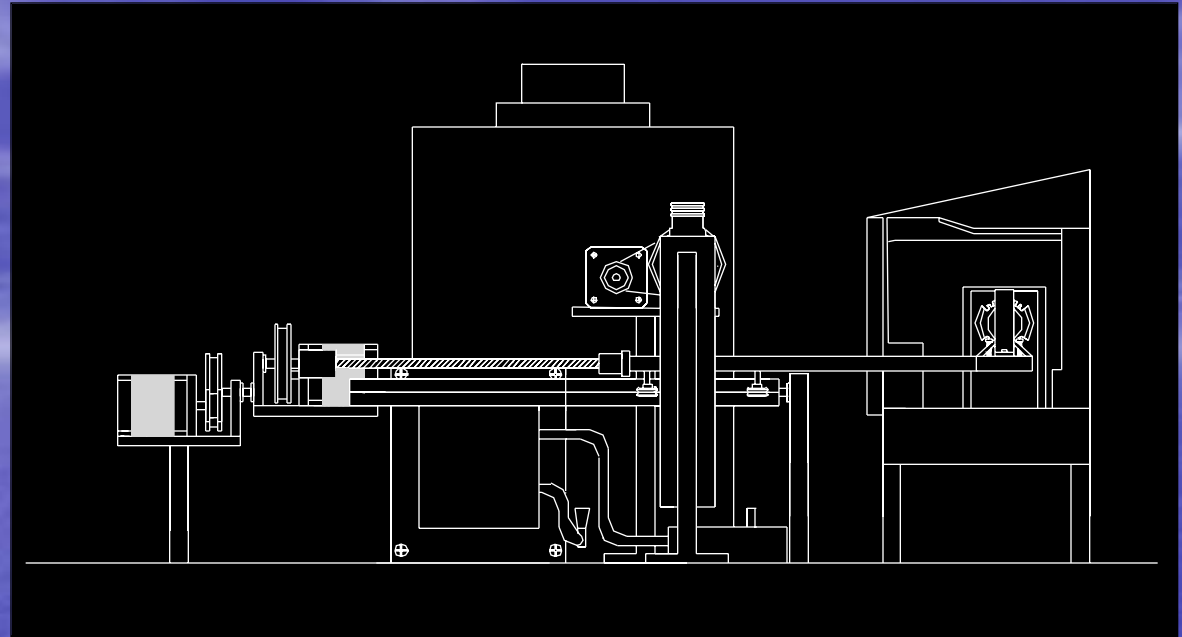
- A PLC was needed to automate the system.
- A solid state relay was required to allow the pump to run off the PLC's power.
- A single power supply was needed to run all three motors.
- Each motor required a drive.
- Two interface modules were needed.

Final Design

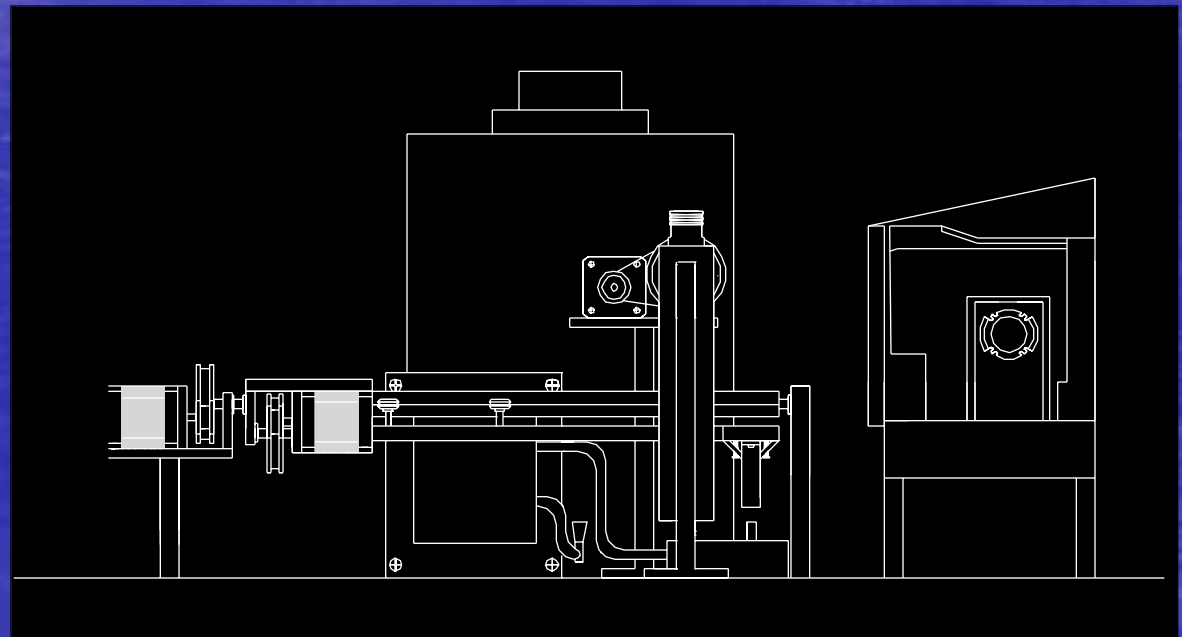
Side View-pouring of sample



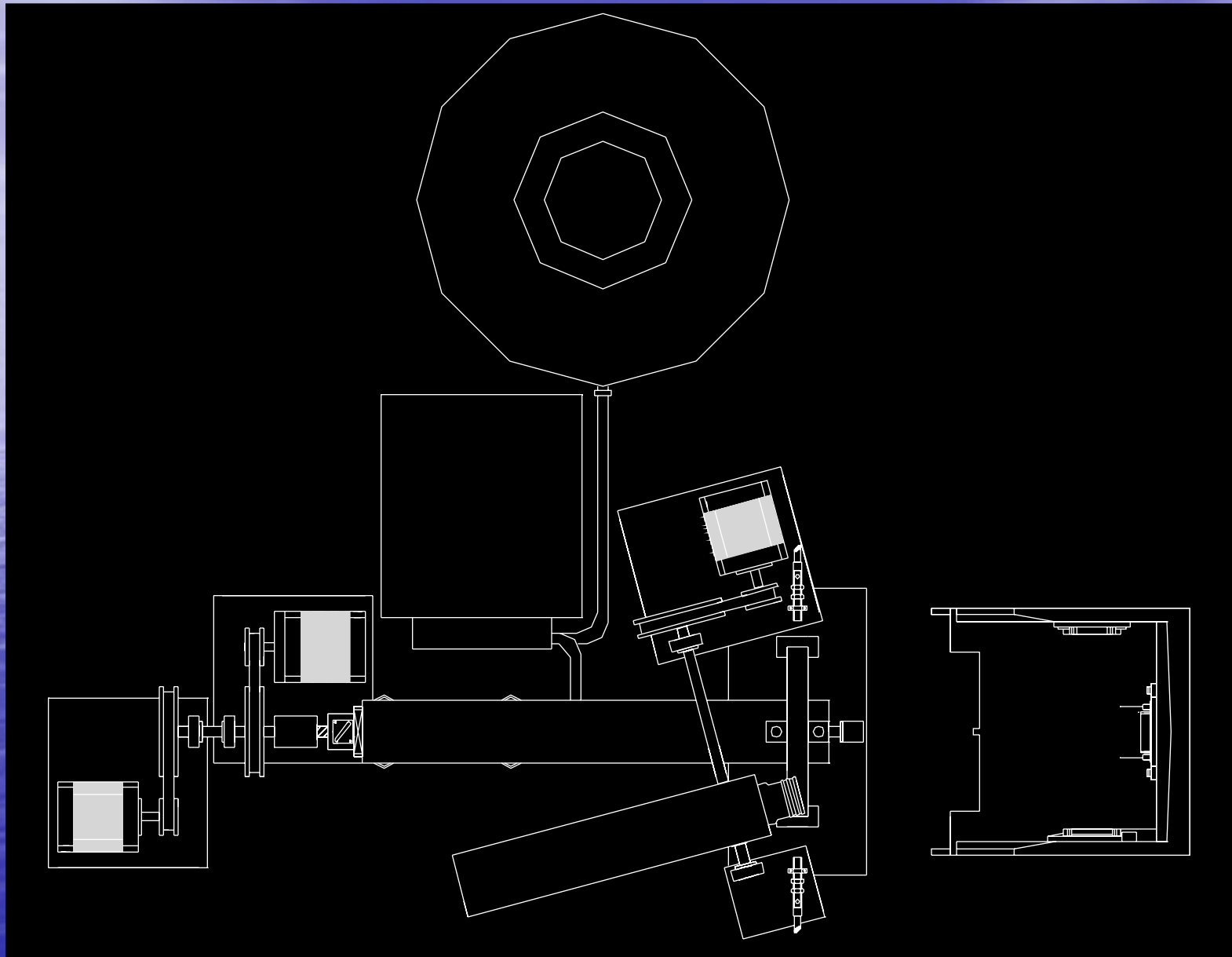
*Side View-cell
in testing area*



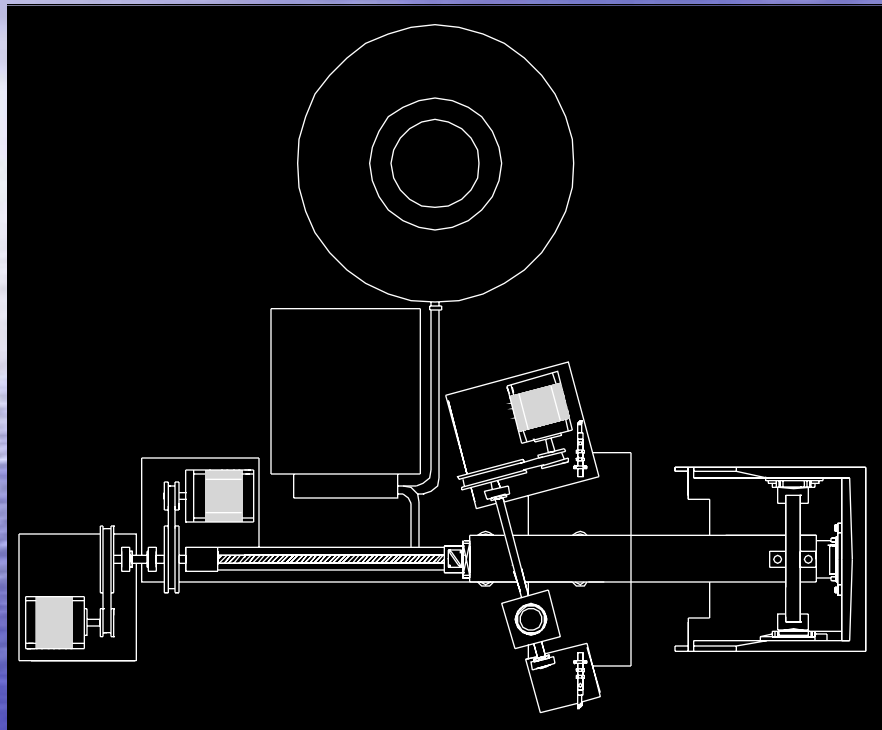
*Side View-
discarding of
waste and
rinsing*



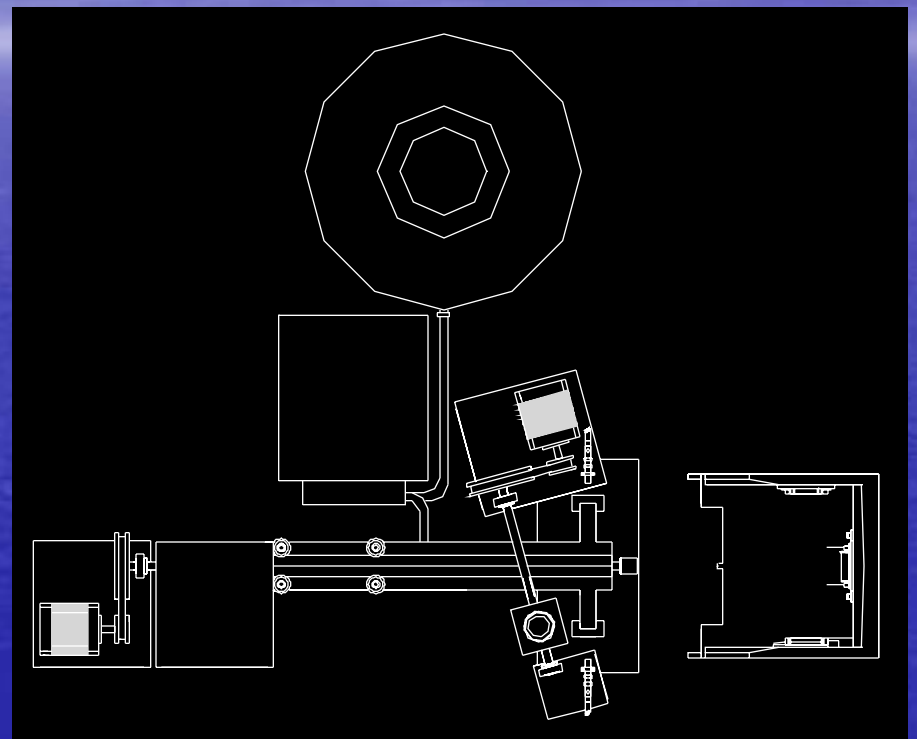
Top View-pouring of sample



Top View-cell in testing area



Top View-discarding of waste and rinsing

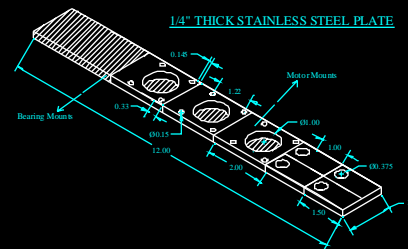
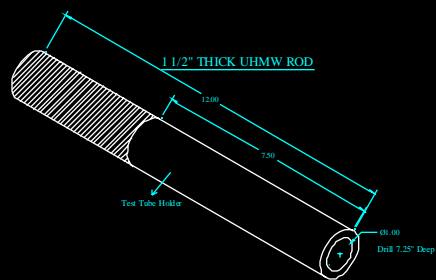
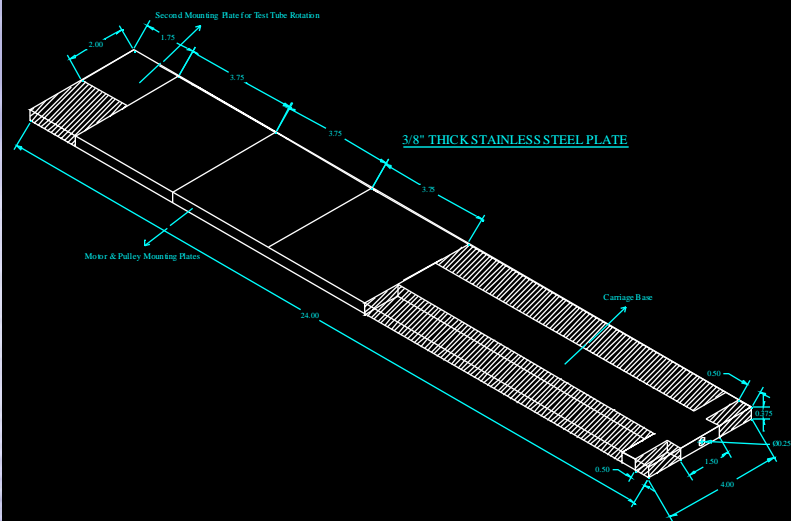


Process Steps for Automation

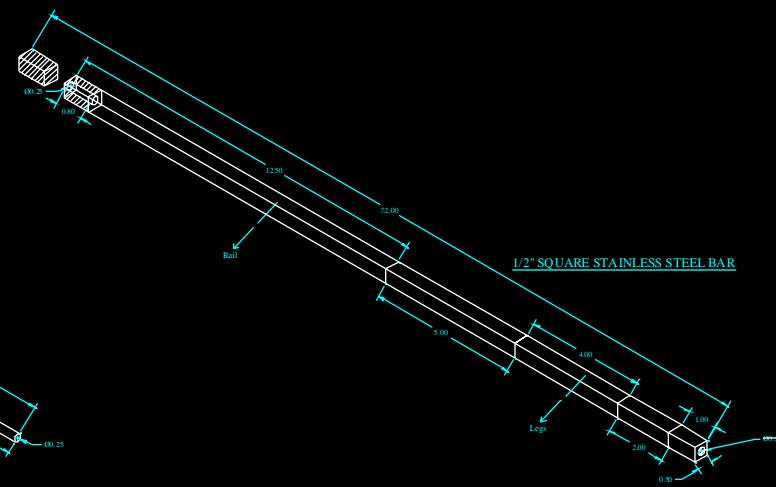
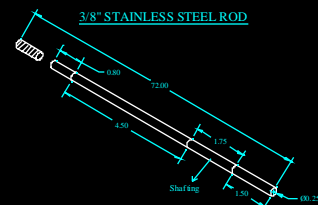
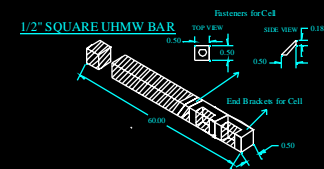
1. Turn spectrophotometer and automation device on if necessary
2. Place test tube in holder
3. Test tube hits limit switch
4. Test tube rotation motor turns on and cell slowly fills
5. Fiber optic sensor detects fill level
6. Motor for test tube rotation runs in reverse and shuts off when test tube returns to start position
7. Motor for linear motion turns on then shuts off at 7 inches of travel
8. System pause and indication light turns on
9. Manual start of spectrophotometer testing process to take reading
10. Manual recording of test result
11. Hit button to unpause automation system
12. Motor for linear motion runs in reverse and shuts off at 7 inches of travel
13. Motor for cell rotation turns on then shuts off at 180 degrees of rotation
14. Peristaltic pump turns on for x seconds
15. Cell drips for y seconds
16. Repeat steps 14-15 as necessary
17. Motor for cell rotation runs in reverse and turns off at 180 degrees of rotation
18. Remove test tube

Machining

MACHINING



PULLEY



Machining, Assembly, Wiring and Programming

- The University of Maine Advanced Manufacturing Center will perform all necessary machining, assembly, wiring and programming.
- They were selected due to experience as well as convenience and low cost.
- The estimated cost for this service is \$3000.

Cost Breakdown

Parts & Material	\$2480.87
Machining, Assembly, Wiring, & Programming	\$3000.00
TOTAL PROJECT COST	\$5480.87

Possible Design Problems and/or Improvements

- Stated parts may not be available at a later date.
- Might want to add limit switches.
 - Provide precise stopping
 - Could be placed for positioning of the cell during linear and rotational motion and positioning of the test tube.
 - Available in several sizes and styles from suppliers such as Automation Direct and MSC Industrial Supply.
- Might want to add emergency stop button.
- System should be enclosed.
 - Could use black poly panels from a supplier such as US Plastics

Conclusions

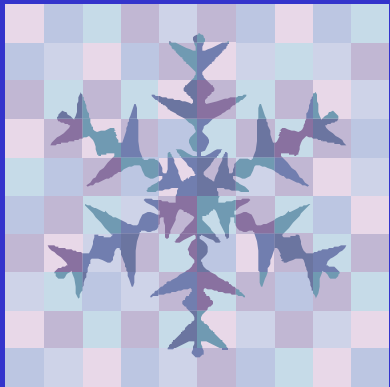
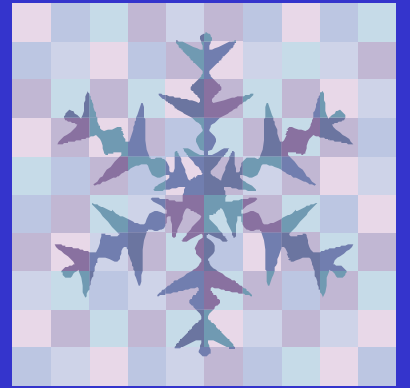
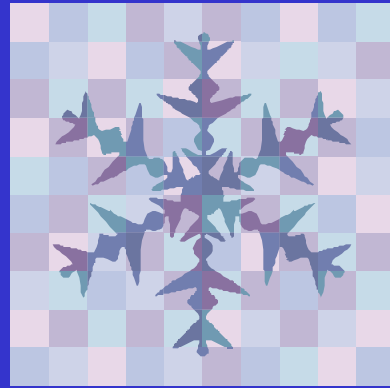
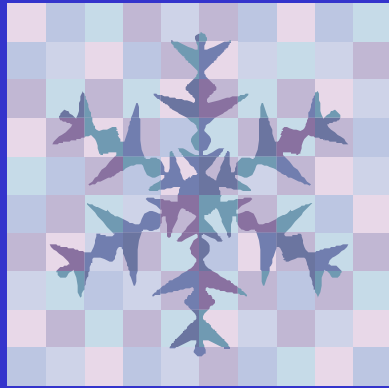
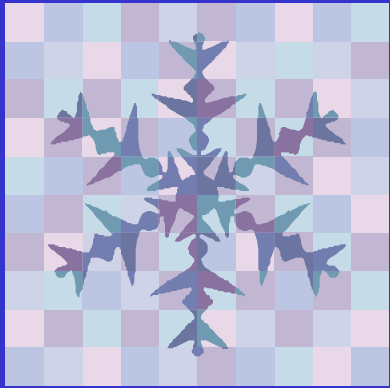
- Proposed system fulfills all design criteria.
- The system will aid in analysis of surface water samples.
- All handling of the cell itself will be eliminated.
- Stainless steel will provide long life of the system and corrosion resistance.
- Stepper motors and PLC will allow precise positioning.
- The system is within budget costing approximately \$5481.
- Minor adjustments may be needed to account for product availability and design improvements.

Special Thanks

Professor Tom Christensen

Mr. Brian Barker

Mr. Ken Johnson.



Thank you for listening.
HAPPY HOLIDAYS!

