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Process Bench for Engineering Technology Laboratory

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This paper is a report on work in progress. It describes student involvement in designing a process bench. The Texas A & M University - Corpus Christi has recently established four year degree programs in Mechanical Engineering Technology and Control Systems Engineering Technology. Laboratory equipment are being purchased and laboratory exercises are being developed. Many courses e.g. Fluid Mechanics, Principles of Measurements, Control Systems, Digital Logic, Microprocessors and Microcontrollers have laboratory exercises as integral part of the course. Some other courses, such as heat transfer and thermodynamics, would benefit from a laboratory where key principles can be demonstrated. We plan to build a process bench where many of the above mentioned experiments may be conducted and principles demonstrated. Additionally, the program as a whole would benefit from an installation where a series of equipment are interconnected as one sees in an industrial situation. An integrated set up would also provide the students an opportunity to combine a variety of lessons they learn in seemingly unconnected courses. Engineering Technology students in various courses are helping in design and construction of parts of the process bench as project work in these courses.

The Brazosport Community College[1], Lake Jackson, Texas and Victoria College[2], Victoria, Texas have many similar process benches. Each process bench at these locations highlights one specific process encountered in chemical plants. The main purpose of these process benches is to educate and train new hires in plant operations. The TAMU-CC Process Bench is mainly designed for demonstrations and conducting experiments. It incorporates the essential features of two or three benches at these Colleges in one single unit. It also differs from the benches at the other two facilities in that it does not contain any hazardous chemical e.g. ethylene glycol, acids or alkali in the process circuit. Yet, it is a very versatile facility where experiments in control systems, fluid dynamics, heat transfer and thermodynamics can be conducted. Because of its versatility and ease of modification, it is readily adaptable to research oriented efforts.

Overview of the Process Bench at TAMU-CC

The TAMU-CC Process Bench is designed to utilize water and water – glycerin mixture in a closed loop recycle system to demonstrate many simple but important operations routinely carried out in chemical / refining industries. The two fluids from their respective storage tanks are first mixed into a feed tank, and later separated as overhead and bottom products in a distillation column. The separated streams are recycled back to their respective storage tanks.

The choice of fluids was driven by safety and following considerations:

i.) Value added to the Mechanical / Control System Engineering Technology courses – no significant value from a chemically reactive system.
ii.) Location of the Process Bench - indoors and in the center of the campus.
iii.) Quantities of fluids involved - significantly more than those found in a typical chemistry laboratory.
iv.) Time available for training students in the handling of hazardous materials - very limited.
v.) Regulatory requirements for handling and storage of hazardous chemicals - complex, expensive and time consuming.

The Process Bench is a scaled-down version of a chemical plant. Many of the commonly seen equipment, operations and features in chemical and refining plants are included in the flow circuit. Some examples are:

a. Vessels: storage tanks, feed tanks, overhead tanks, distillation column
b. Equipment: pumps, valves and fittings, heat exchangers, agitators, manual and automatic control valves.
c. Instrumentation: Temperature, pressure, level, mass and volumetric flow measurement and control instrumentation. Instruments that measure the same property but operate on different principles.
d. Data acquisition and control schemes: distributed control system, Fieldbus technology, Labview data acquisition system etc.

Description of the Process Bench

Figures 1 through 3 show Process Bench in various details. There are three essential features of the Process Bench.

1. A Fluid Dynamics Section
2. A Process Operations Section and
3. A Process Instrumentation, Controls and Data Acquisition Section

I) Fluid Dynamics Section

This section has two storage tanks, pumps, connecting piping and fittings and measurement devices. The two fluids can be moved – one at time to avoid cross-contamination - through the pipes and recycled back into their respective tanks. The pipes are of different diameters and have various fittings and flow and pressure indicating instrumentation. Typical examples of flow indicating devices in this section are rotameter and orifice meters. The pipes are configured such that the fluid flow can be directed in series flow and parallel flow combinations. Experiments relating to pump performance, pressure drop as a function of flow rate, pipe diameter, fluid viscosity, laminar and turbulent flow regimes, Reynolds number, hydraulic pressure, pump cavitation etc. can be conducted in this section of the Process Bench.

The pumps in this section can also be used to pump water and water-glycerin mixture from the storage tanks to the feed tank in the Process Operations Section. The run of the pipe between the storage tank and the feed tank is equipped with various types of flow measurement instrument that are common in the chemical industries. By installing these devices in series on the same line, one can directly compare these instruments in terms of their steady state and dynamic response characteristics, and the range of reliable operation.

The students encounter these instruments and concepts in the fluids mechanics[3] course in the program.

ii) Process Operation Section

The desired concentration / viscosity of water and glycerin mixture is prepared in a feed tank in this section. The trims on the valves controlling the feed rate from each storage tank can be chosen to demonstrate different flow control characteristics e.g. equal percentage, linear control valve, and quick opening. The mixture is fed to a distillation column via a feed preheater. In the distillation column, the mixture is separated back into pure water as the overhead stream and water –glycerin mixture as the bottom stream of the original composition. These streams are recycled back to the appropriate storage tanks in the Fluid Dynamics Section. The entire Process Bench unit is thus engaged when operating in total recycle mode. The distillation column reboiler is supplied with steam generated by an electric steam generator. The overhead reflux condenser is operated with cooling water. The water storage tank in the Fluid Dynamics Section is also equipped with a steam heater and chilled water cooler so that temperature control experiments can be conducted in this tank. Additional heat transfer experiments may be conducted on the reboiler, condenser and feed preheater with temperature and flow indicators installed at appropriate locations. The piping on the pre-heater is configured such that the flow of the fluids through the heat exchanger can be in either countercurrent or co-current mode. The three tanks have agitators for conducting experiments on mixing of the fluids. The students in the heat transfer course[4] encounter these concepts.

The tanks have level gages that operate on different principles, so that the gages can be compared directly for their operating characteristics: e.g. static and dynamic response, range of operation, drift, linearity in response over the range etc.

Residence time and lag time related experiments in temperature, level or compositions control can also be conducted with the three tanks in the two areas.

iii) Process Instrumentation, Controls and Data Acquisition Section

a. Process Instrumentation: As described above, the Process Bench is heavily instrumented. Typical examples are:

Flow Meters: Orifice meter, Coriolis mass flow meter (for mass and density measurements), thermal mass flow meter, turbine flow meter, vortex flow meter, ultrasonic flow meter, venturi flow meter, rotameter etc. The rotameter and the orifice meter are the flow meters commonly used.

Pressure Indicators: Water column manometers, dial gages (Bourdon, magnehelic) and digital gages (LVDT, strain gage types).

Level Gages: Ultrasonic level gage, capacitance level gage, conductivity level gage, differential pressure gage, magnetic level gage, sight glass, float level sensor etc.

Students in Principles of Measurements[5] encounter these instruments and the related concepts.

b. Process Control: Various control strategies can be used on the operation of distillation column and in the process of preparing the feed to the distillation column. The control instrumentation scattered throughout the Process Bench include the following types: manual and automatic flow and level controllers, local controllers, PLC (programmable logic controllers) and SLCs (smart logic controllers), electric and pneumatic actuators, wireless data transmitters and controllers etc. Various control strategies e.g. cascade, feed forward, can be implemented on the three tanks and the distillation column. Both DCS (distributed control system) and Fieldbus control strategies may be implemented on portions of the Process Bench. Steady state and dynamic response characteristics of various transducers, actuators and control schemes can be studied.

c. Data Acquisition System: Programs developed in Labview[6] and / or Matlab[7] will be used to acquire and manipulate data from the Process Bench. As mentioned above, the data transmission and acquisition will be accomplished via a combination of hard wire and wireless communication. The data can then be manipulated in the control room to control the operation of the Process Bench. The data can also be archived for further analysis and research activities.

Students in Control Systems I and Control Systems II[5] encounter these instruments and concepts.

Student Involvement in the Process Bench

Student are involved in the design of the Process Bench. Students enrolled in the Fluid Mechanics course (ENTC 3406), a sophomore level course, completed a project in the Fluids Dynamics Section. The project assignment was:

1. Calculate and compare pressure drops for the two fluids flowing through the pipes and fittings in the process bench. The two fluids are water and a 50/50 mixture of water and glycerin. The fluids flow through the pipes and fittings arranged in series and parallel flow combinations. The flow rates are 1 gpm, 3 gpm and 5 gpm.
2. Size and select an appropriate centrifugal pump to accomplish the above objective.

The students enrolled in Engineering Design Graphics II (ENTC 2305) drew 3-D drawings of the whole Process Bench on Mechanical Desktop as their project. One such lay-out of the Process Bench is given in Figure –3.

Plans are to continue to engage students in the appropriate Mechanical Engineering Technology and Control Systems Engineering Technology courses in designing and specifying equipment and instruments as part of their project assignments. They may also help in the assembly and building of the portions of the Process Bench under the supervision of a skilled technician. The Process Bench is also amenable to modifications and demonstrations by students as part of their

Capstone projects. Future reports would include further involvement and accomplishment of the students.

Current Status

The author is currently sizing and generating specifications for the various equipment and instrument in the Process Bench. We are seeking donations of equipment / instrument and funding from industrial sponsors and other outside agencies. Presentations have been made to industry representatives and at professional society meetings. We are also seeking volunteer technician help from area industries to build the unit.

Conclusion

The integral features of the Process Bench make it a valuable installation for both Mechanical Engineering Technology and Control Systems Engineering Technology programs. Instructors and students in both programs can demonstrate key engineering and technical principles and conduct laboratory exercises on the Process Bench. It has sufficient simplicity, flexibility and versatility so that it can be redesigned or modified quickly to accommodate project work in various courses including Capstone projects.

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Biography

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Currently an assistant professor in the Mechanical Engineering Technology Program at Texas A & M University - Corpus Christi, Satyajit Verma received his Ph.D. in Chemical Engineering from Louisiana State University, Baton Rouge. He has more than 20 years of experience as product development and process development engineer in the plastics industry.

Figure 1. Schematic of the Process Bench at TAMU-CC

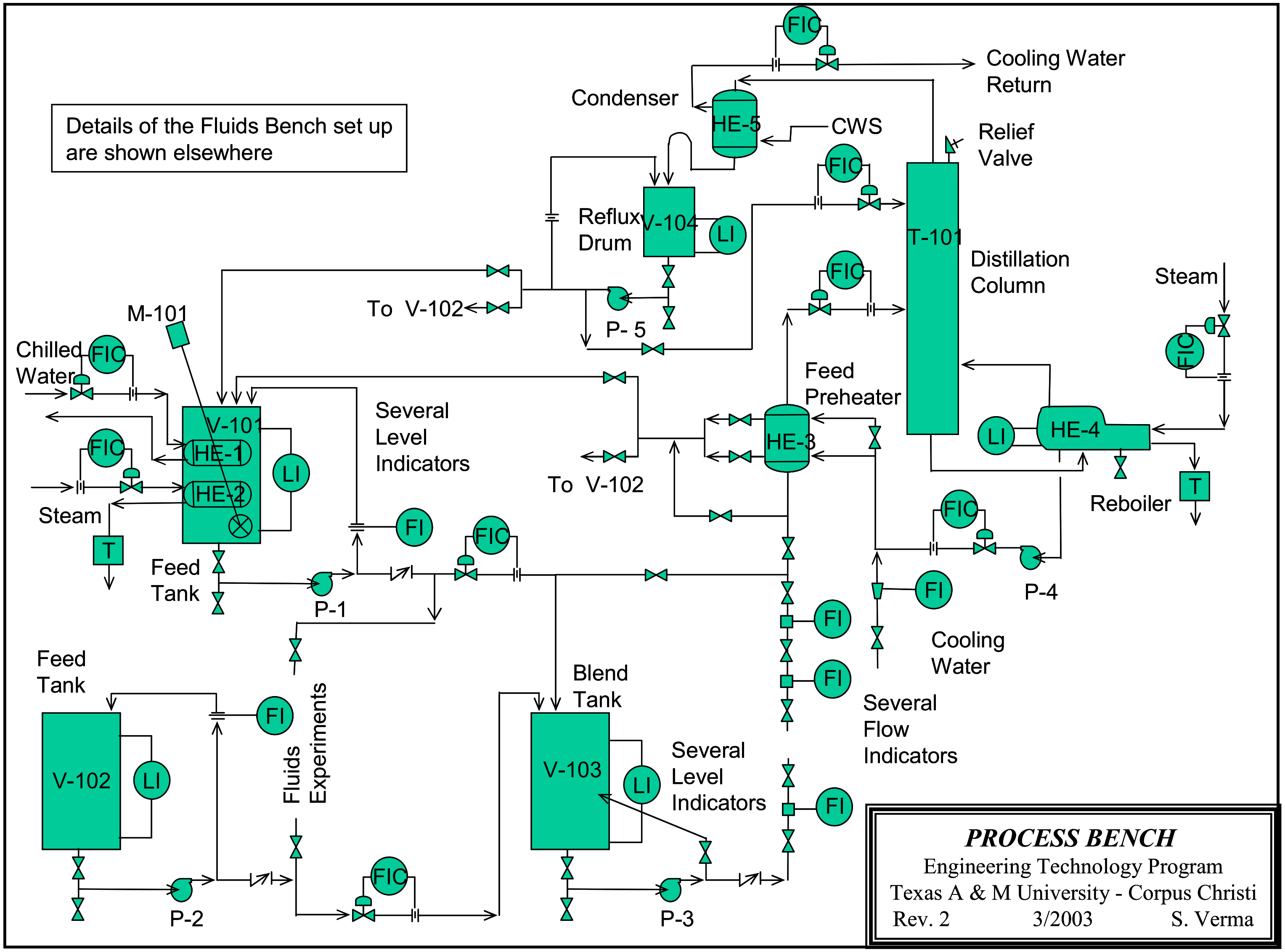
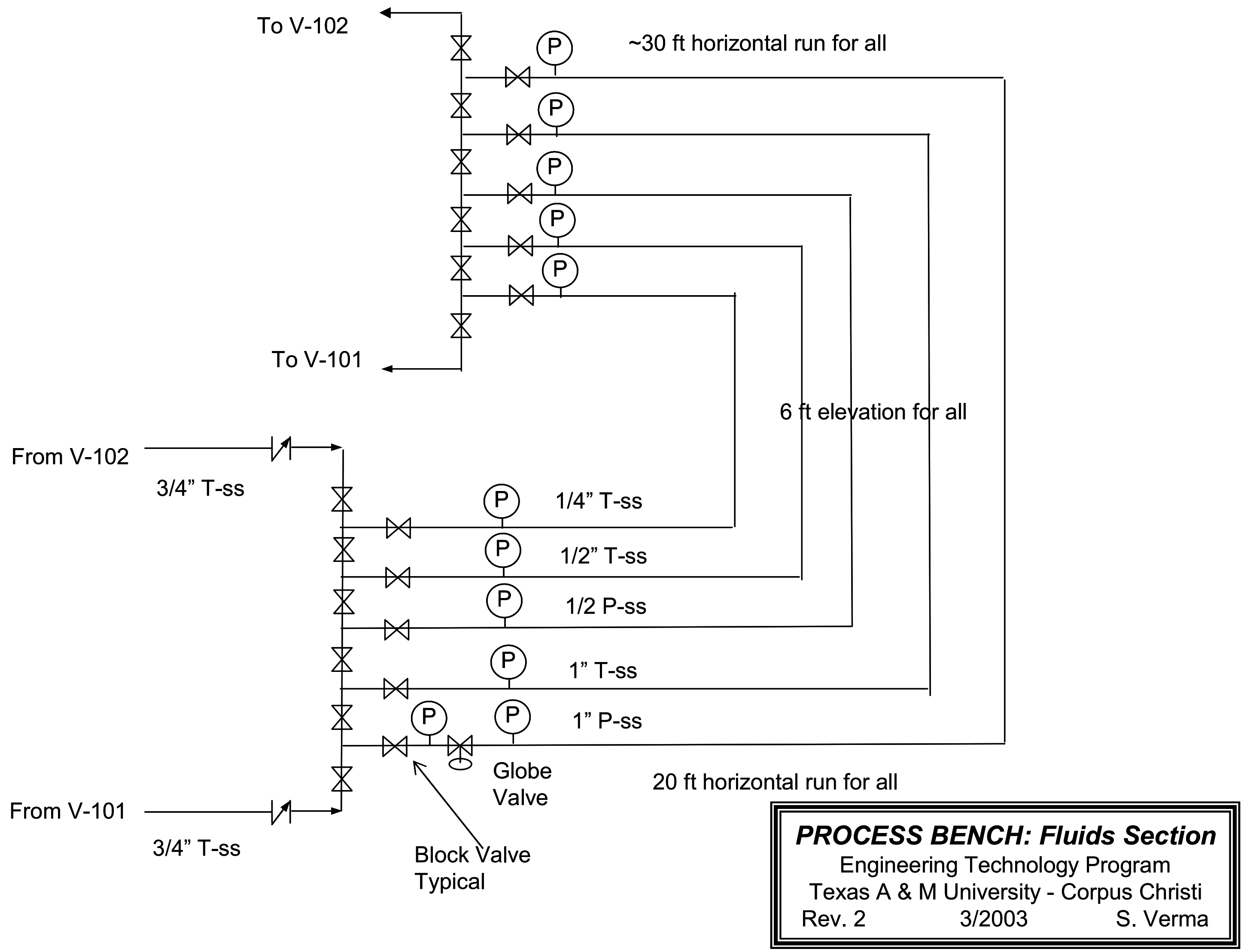


Figure 2. Details of the Fluids Section of the Process Bench



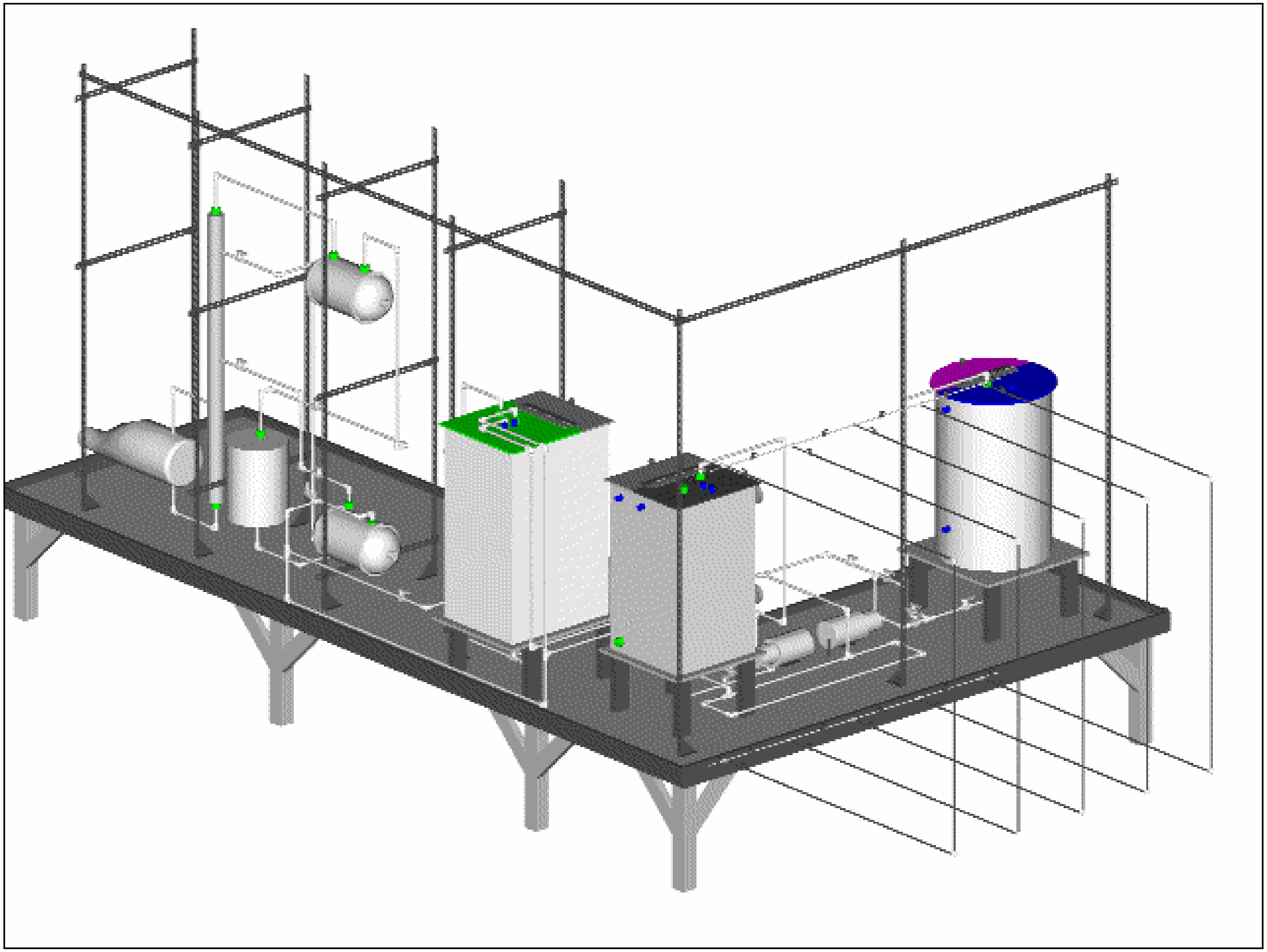


Figure 3. Lay-out of the Process Bench Drawn on AutoCAD by Students