# Baldwin Universal Tester Modernization

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## Abstract

This project continued the modernization and relocation of the control system for a 1942 Baldwin Locomotive Works Universal Tensile Tester. The purpose of the tester is to obtain material properties through either compression or tensile testing, where a given specimen is either elongated or compressed with properties being collected until failure. Previous control of the machine was done via hand dials and wheels giving an output on a paper roll. The new control mechanism allows an operator to completely control the machine via a computer, including test data output to the computer. Students modified the existing hydraulic control system and relocated it to an enclosure that saves laboratory floor space and is suitable for classroom demonstrations. The entire machine was updated to operate through software controls rather than physical dials that would be continuously adjusted by a skilled operator. This new solution will enable students, faculty, and Trine's Innovation One to conduct material testing for both classroom and business consulting purposes with the click of a couple buttons on a computer. Extensive laboratory tests were conducted to verify the new system can output material test results like stress strain curves, elastic moduli, yield and ultimate strengths in a manner that is compliant with standards set by the American Society for Testing of Materials (ASTM).

## Design Solution – Controls Relocation

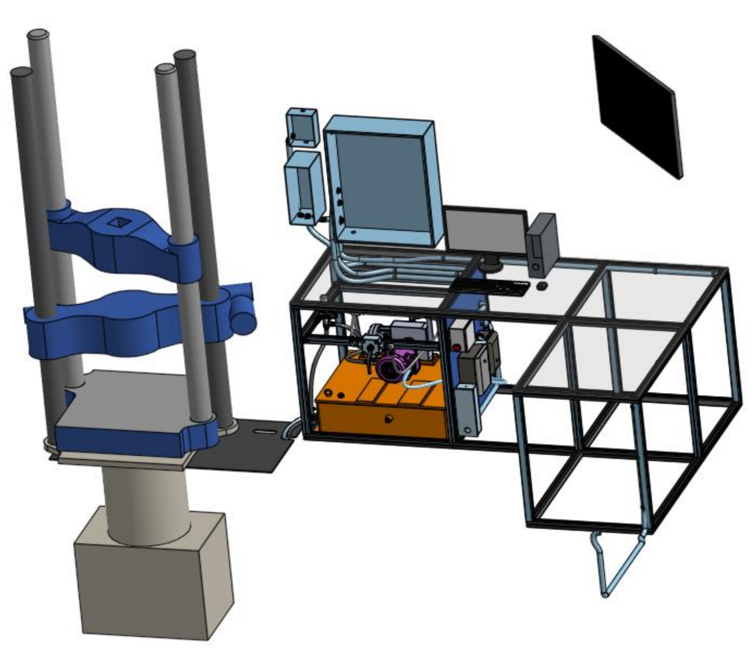


Figure 2: CAD Model of Control Head Revision

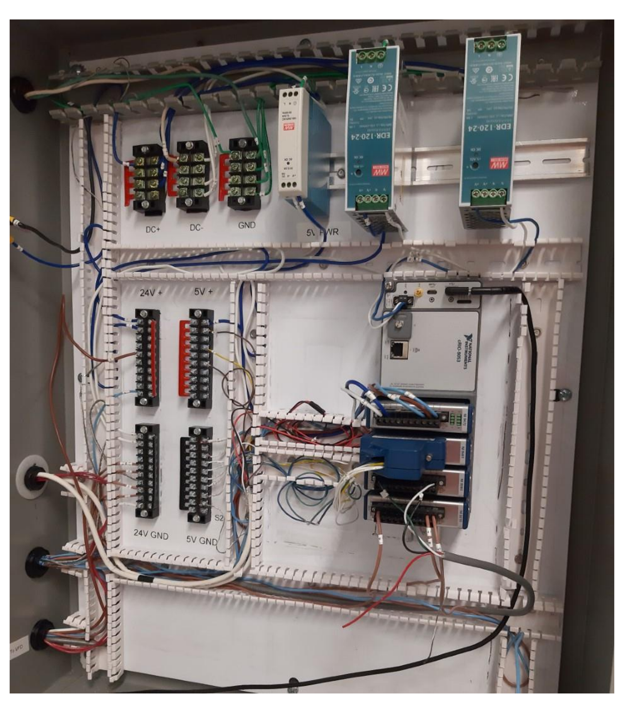


Figure 3: Completed Main Electrical Panel

- CAD modeling and wiring reorganization were used extensively to test component fitment and to determine optimum hydraulic hose and electrical conduit routes while better organizing the back end of the machine.

## Customer Needs and Requirements

- Control head must be relocated to new location, creating space for classroom demonstrations.
- Data output from the system must achieve level of accuracy suitable for classroom demonstrations.
- Control head pump and valve system must be relocated.
- Three control methods (strain rate, stress rate, cross-head displacement rate) must be implemented to adhere to ASTM testing standards.

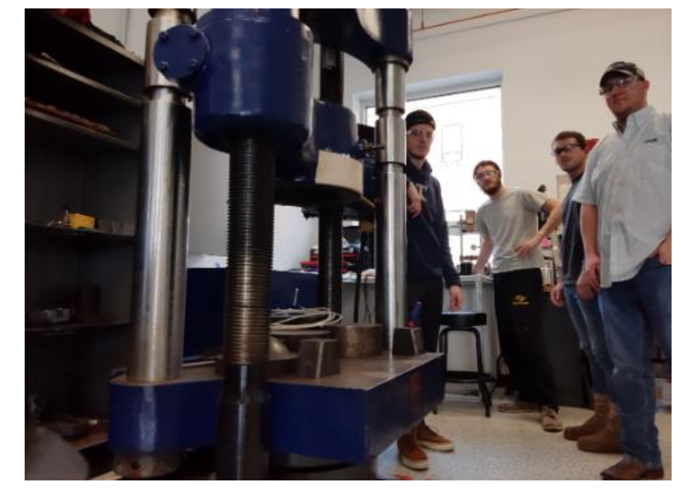


Figure 1: The Baldwin Boys

## Design Solution – Computer Control Methods

- Control Method implementation per ASTM E8/E8M
  - Strain Rate dictated by pressure transducer signal
  - Stress Rate dictated by elongation measured at the specimen by the extensometer
  - Cross-head Displacement rate dictated by linear encoder response signal as platens lift
- Control Method troubleshooting involved verifying rate of testing, accommodation for machine self-weight, and accommodating the effect of friction in initializing the machine's movement.
- A new streamlined LabVIEW user interface was created to accommodate the new user defined control methods and display key parameters.
- Extensometer grips were designed to provide a single point of contact on the test specimen.
- A 3/2 directional control valve was implemented as the only required manual input to the machine.

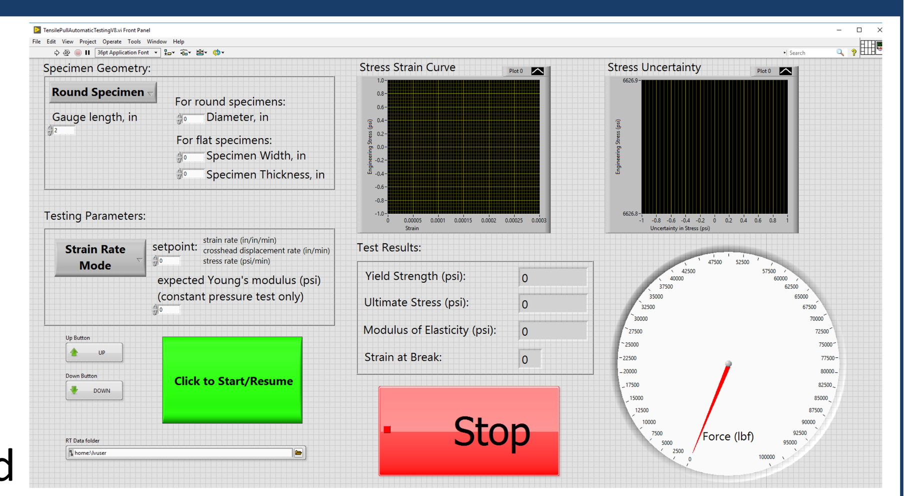


Figure 4: Lab View User Interface


Figure 5: Linear Magnetic Strip Encoder


Figure 6: Pressure Transducer

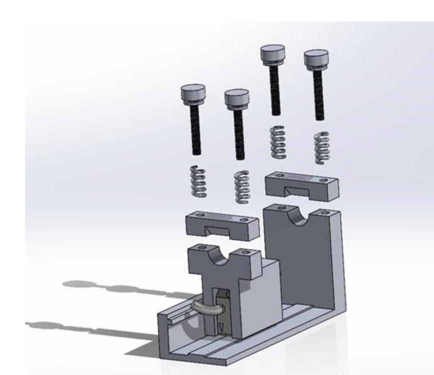
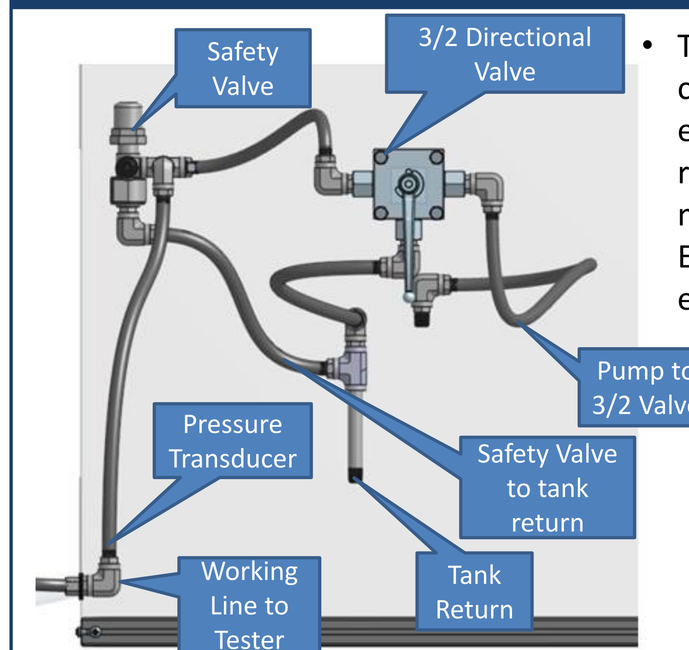
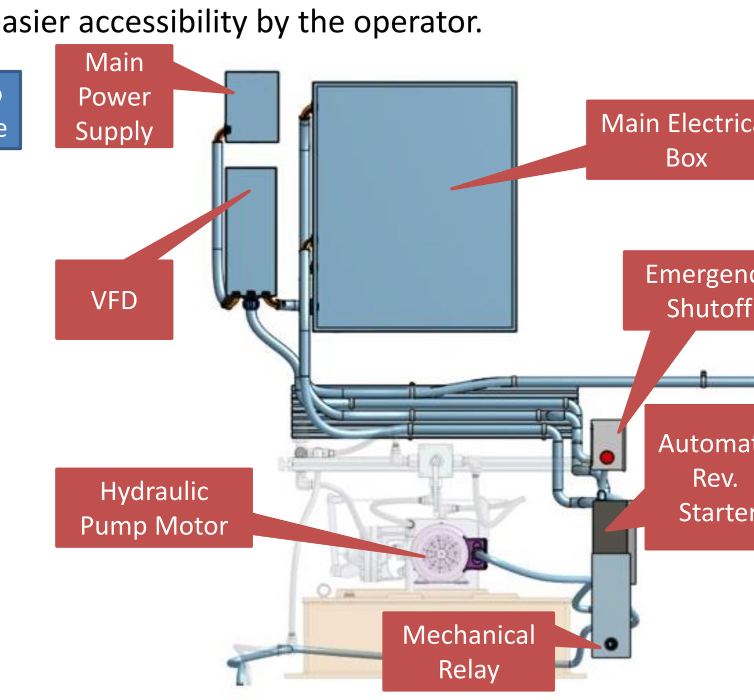


Figure 7: Extensometer

## Hydraulic & Electrical Assemblies




- The image below shows the conduit routing and critical electrical component locations on the new enclosure. The critical electrical components that were relocated include the automatic reversing starter and mechanical relays which control the middle platen. The Emergency Stop switch was also relocated to allow for easier accessibility by the operator.




- The hydraulic system pictured above was designed to utilize the existing pump, tank and motor from the Universal Tester in the new control head location with the addition of a popoff safety valve and 3/2 directional valve to allow for safer and easier user control during tests.

## Manufacturing


Figure 8: Baldwin Universal Tester pre-modernization.


Figure 9: Final Assembly

- In the new configuration the operator works safely at the computer, with the control head integrated into the wrap-around workbench.

## Error Troubleshooting

- **Pressure Transducer Uncertainty**
  - The error in the pressure transducer used in our system had previously not been accounted for and was found by our group to be a fixed ±10 [psi].
- **Extensometer Slippage**
  - The design of the extensometer grips inherited from the previous design group did not account for the change in specimen diameter during testing. Our group modified the extensometer grips through the addition of springs to maintain pressure on the specimen and eliminate slipping. Modified grips were also machined to incorporate a defined knife edge in order to precisely measure specimen elongation.
- **Failed Snubber**
  - A failed hydraulic snubber that prevented pressure from returning to atmosphere when load was taken off the cylinder was found using a calibrated load cell.
- **Weight of the Machine**
  - The weight of the machine itself during testing had not previously been accounted for and was found to be causing a significant error in acquired data. Our group was able to offset this weight in the LabVIEW code to eliminate the error.

## Testing and Validation

- Extensive testing occurred to quantify the change in data collection caused by the relocation of the control head and hydraulic system
- Several tensile tests were conducted to ensure if the material testing was both accurate and compliant with national testing standards.
- Using multiple material types and specimen sizes, the operator can collect properties for many different materials from the same program
- Testing under standard-driven parameters for rate and specimen selection allows for comparable data between tests.
- The two stress-strain curves on the right show comparative testing for two different materials between our group and Purdue Fort Wayne's ME Testing Laboratory. Also, on the right is shown a comparative breakdown of errors for Ultimate Strength, Yield Stress and Elastic Modulus between the two data sets.

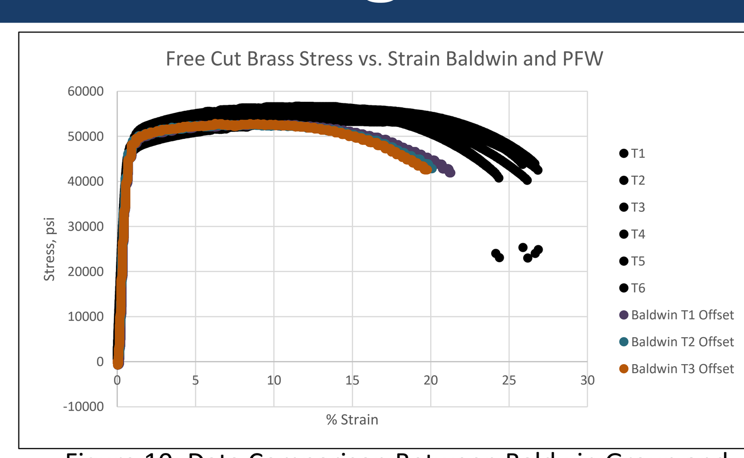


Figure 10: Data Comparison Between Baldwin Group and Purdue Fort Wayne Mechanical Testing Labs for Free Cut Brass

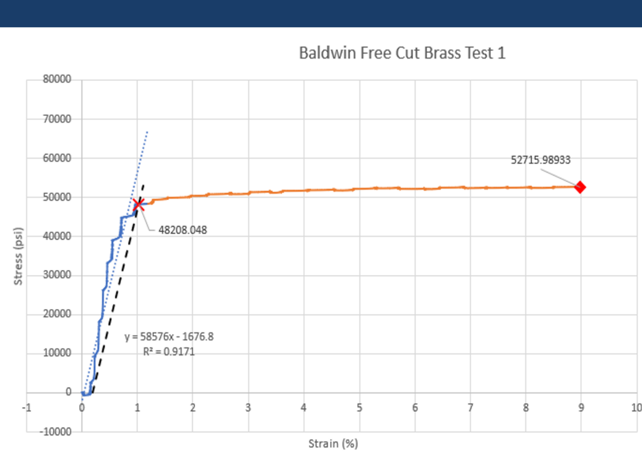


Figure 12: Critical Values Free Cut Brass

| Purdue - Brass | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 | Test 6 | Average |
|---|---|---|---|---|---|---|---|
| Elastic Modulus | 72559 | 69818 | 67480 | 66520 | 68103 | 71563 | 69340.5 |
| Yield Strength | 47649 | 47322 | 48184 | 46127 | 48702 | 48842 | 47804.33 |
| Ultimate Strength | 55201 | 54773 | 56005 | 53299 | 56102 | 56699 | 55346.5 |

| Baldwin - Brass | Test 1 | Test 2 | Test 3 | | Average | % Error |
|---|---|---|---|---|---|---|
| Elastic Modulus | 58576 | 60045 | 59396 | | 59339 | 14.4% |
| Yield Strength | 48208 | 48922 | 48132 | | 48420.667 | 1.3% |
| Ultimate Strength | 52715 | 52638 | 52810 | | 52721 | 4.7% |

Figure 14: Error Analysis for Free Cut Brass

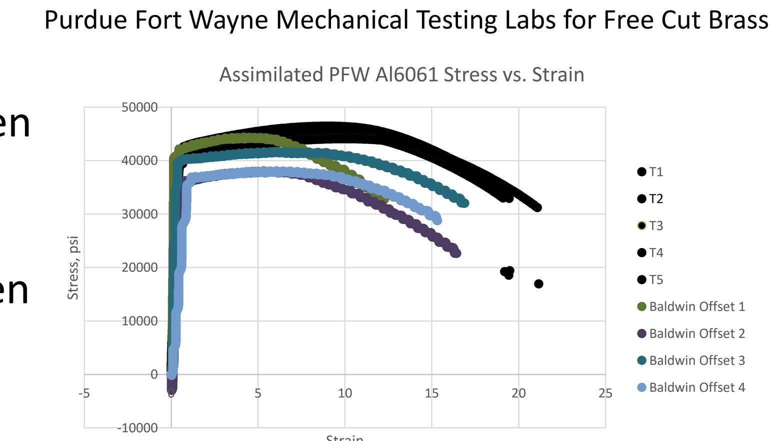


Figure 11: Data Comparison Between Baldwin Group and Purdue Fort Wayne Mechanical Testing Labs for 6061 Aluminum

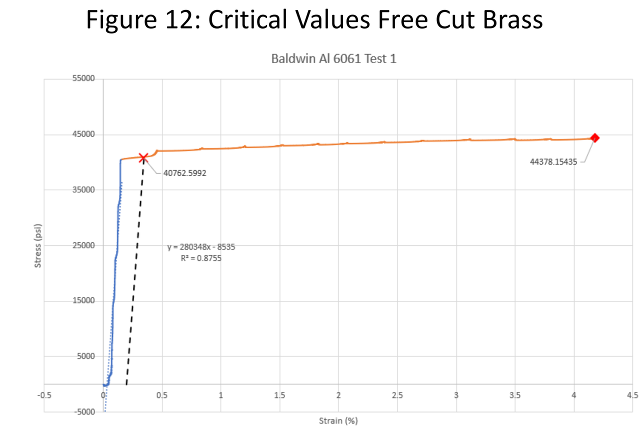


Figure 13: Critical Values 6061 Aluminum

| Purdue - Aluminum | Test 1 | Test 2 | Test 3 | Test 4 | Test 5 | Average |
|---|---|---|---|---|---|---|
| Elastic Modulus | 88335 | 85859 | 83677 | 85005 | 80712 | 84717.6 |
| Yield Strength | 42167 | 41294 | 40014 | 42060 | 40226 | 41152.2 |
| Ultimate Strength | 46389 | 45654 | 44092 | 46447 | 44840 | 45484.4 |

| Baldwin - Aluminum | Test 1* | Test 2 | Test 3 | Test 4 | Average | % Error |
|---|---|---|---|---|---|---|
| Elastic Modulus | 199000 | 68771 | 114943 | 45822 | 107134 | 26.5% |
| Yield Strength | 40762 | 35519 | 39734 | 38536 | 38637.75 | 6.1% |
| Ultimate Strength | 44378 | 38063 | 41684 | 40501 | 41156.5 | 9.5% |

Figure 15: Error Analysis for 6061 Aluminum

## Acknowledgments

Dr. Pavan Karra - Assisted in hardware and software diagnostics
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