THERMODYNAMICS—STEAM P7690 AND STEAM BENCHES
CUSSONS TECHNOLOGY LABORATORY RECOMMENDATION

Thermodynamics is a branch of physical science concerned with the inter-relationship and inter-conversion of different forms of energy. The student can observe the laws of thermodynamics by conducting experimental work on a wide range of our products.

A good practical understanding of air conditioning, refrigeration, work and heat transfer can be achieved with the use of various types of heat engines. An essential subject area concerns steam properties and steam turbine technology and Cussons offers a range of bench mounted steam property teaching products along with a range of complete working steam power plant up to 20 kW with features representing current industrial practice.

Please see www.cussons.co.uk for additional information on any product, or contact sales@cussons.co.uk

Steam Power Plant

P7690 Steam Power Plant—1KW

Cussons Mini Steam Power Plant has been specifically designed to allow institutes of education to study the principles and operations of an industrial steam power plant without the large capital investment normally required. The plant can operate as a steam boiler, turbo-generator or complete power plant. Available tests include:

- thermal and total efficiency consumption,
- boiler capacity,
- efficiency,
- heat balance,
- turbine power and
- specific steam consumption.

Cussons P7690 Mini Steam Power Plant is designed as a comprehensive self contained unit with all relevant items of equipment factory mounted on a common steel bedplate. This modular construction and assembly greatly reduces space and installation requirements. The plant is designed to operate at pressures up to 7 bar g and is complete with all pipework, insulation, electric cabling and trunking. All services terminate on the base allowing easy installation.

P7692 Cooling Tower for use With P7690

sized to suit Condenser, including cooling water supply and return pipework. Instrumentation enclosure with mimic diagram, temperature and relative humidity of ambient air and tower exit air, and air flow prediction from fan motor current.

N.B. This unit is designed to be located externally from the laboratory.

P7693 Installation and Commissioning by Cussons Engineers

P7694 Data Acquisition

to take conditioned signals to PDAQ ( USB based DataLogger) c/w compatible Personnal Computer. Supplied with software to display and store all parameters for use in the clients’ programs.
**P7669 Miniature Steam Power Plant**

- **GAS FIRED MODEL STEAM BOILER** – with a design pressure of 4 bar g and an equivalent evaporation of 24.5 kg steam per m³ gas consumed from and at 100ºC.

- BOILER FEED PUMP (hand operated) and FEEDWATER TANK.

- **P7669R STEAM ENGINE** – single cylinder double acting reciprocating model steam engine. Bore 19.05 mm, Stroke 19.05 mm. Nominal power output 3.3 watts at 1200 rpm.

- **P7669T STEAM ENGINE** – single rotor stage model steam turbine. Diameter 75 mm

- **DC GENERATOR** – coupled to the engine by a driving belt, with resistive load bank of 4 lamp bulbs each with nominal rating of 6V 0.03A (i.e. 20 ohms giving a power of 1.8 watts).

- **CONDENSER UNIT** – shell and tube atmospheric type condenser. Condensate collection by metal beaker. Minimum cooling water flow rate 0.5 litres/min.

- **INSTRUMENTATION** – comprehensive instrumentation is supplied comprising:

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>Boiler steam via 0-6 bar pressure gauge</td>
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<tr>
<td>Temperatures</td>
<td>Ambient air</td>
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<tr>
<td></td>
<td>Boiler feed water</td>
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<tr>
<td></td>
<td>Boiler steam</td>
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<td></td>
<td>Engine steam inlet</td>
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<td></td>
<td>Engine steam exhaust</td>
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<tr>
<td></td>
<td>Condenser cooling water inlet</td>
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<tr>
<td></td>
<td>Condenser cooling water outlet</td>
</tr>
<tr>
<td>Flowmeters</td>
<td>Fuel (gas)</td>
</tr>
<tr>
<td></td>
<td>Cooling water (50-800cc/mm)</td>
</tr>
<tr>
<td>Voltmeter</td>
<td>0-10V DC</td>
</tr>
<tr>
<td>Ammeter</td>
<td>0-1A DC</td>
</tr>
</tbody>
</table>

- All necessary interconnecting pipework, valves and fittings, together with electrical cabling, are included.

- All above equipment is supplied on a fabricated steel frame with components and instrumentation mounted at working height.

- Operating and instruction manual available in English but can be translated into other languages as an optional extra.
Steam is widely used in industry for power generation, heating and many other processes requiring high temperatures. Consequently, the topic of vapour power systems is a major part of the thermodynamics syllabus.

Cussons steam equipment has been carefully designed and manufactured from the highest quality materials to meet the needs of the educational establishments throughout the world in teaching the technology of steam in thermodynamics courses.

All the various experiments detailed here reflect modern manufacturing practice and their design incorporates the safety features necessary to minimise any risk in operation.

Cussons steam benches have been designed to allow experiments to be carried out on one piece of equipment by a small group of students.

Experience has shown that the modular form of construction is the most versatile and the benches can generally be supplied as “stand alone” units or where more than one bench has been ordered, simply interlinked to form a continuous system (see Fig. 1).

The general construction of benches comprises of welded steel frames fitted with adjustable feet together with steel front and back panels. To enable customers to test with one bench, then at a later date take on additional units linked together to form a complete system utilising a common steam supply and service system, each bench comes complete with the following standard features:

- An interconnecting back panel and student work surface.
- A set of four stainless steel flexible hoses complete with aluminium-clad lagging for steam, blowdown, drain and water services.
- Steam for conducting all experiments may be supplied by a Cussons Steam Boiler Bench, a Cussons Steam Plant or the clients own steam line, but in each case a maximum working pressure and temperature of 10.34 bar and 235°C is recommended.

THE STEAM BENCH SYSTEM CONSISTS OF:

P7670 Steam Boiler bench

A steam boiler bench is a service unit designed to provide a steam supply to a series of Cussons steam benches. When used in conjunction with the Separating and Throttling Steam Bench (P7672) and the Condenser Bench (P7675), experiments maybe conducted in:

- Boiler operation and behaviour
- Boiler evaporation capacity
- Boiler heat loss and efficiency
P7671 Pressure/Temperature Steam Bench

This bench includes a 2-pen continuous chart recorder tracing the variations in pressure and temperature. It allows students to become familiar with the presentation of such data on a typical process recorder used in industry. Students can then:

- Investigate the relationship between temperature and pressure of saturated steam
- Compare the experimental observations with data published in recognised steam tables

P7672 Separating and Throttling Calorimeter Steam Bench

Separating and throttling calorimeters are used to determine the dryness fraction or quality of steam passing through the steam main. Using this bench students can:

- Measure the dryness fraction of the steam supply by:
  - using the separating calorimeter
  - using the throttling calorimeter
  - using both separating and throttling calorimeters together

P7673 Lagging Efficiency Steam Bench

Lagging is applied to pipes carrying hot fluids as a means of reducing heat loss to the surrounding environment by both radiation and convection, and to protect personnel from contact with high surface temperatures. On this bench students can:

- Investigate the efficiency of two types of lagging widely used in industry
- Compare the heat loss from these lagged pipes with that from two unlagged pipes with different surface finish
P7674 Ejector Steam Bench

A common use for steam ejectors is as simple vacuum pumps where they have the advantage of being inexpensive and small, and with no moving parts are much more economical to operate than mechanical pumps. On this apparatus students are able to:-

- Investigate the efficiency of an ejector as a water pump
- Measure the heat transfer of steam to cooling water

P7675 Condenser Bench

Condensers are heat exchanging devices commonly used in industry to convert exhaust steam to water for subsequent re-use. This apparatus enables student to:-

- Demonstrate the operation of the condenser
- Investigate the heat transfer coefficient of condenser tubes under varying conditions of inlet and outlet pressures and rate of cooling water flow
- Demonstrate that condensing steam in a closed system will produce a vacuum

7676 Steam Engine Steam Bench

A steam engine utilises the energy contained in steam under pressure. The energy released when steam expands in an engine cylinder is made to produce rotary motion suitable for driving machinery. On this bench the students can:-

- Demonstrate the method of testing a steam engine
- Measure brake horse power, steam consumption, and various efficiencies for a single cylinder engine with a variable load at constant speed
**P7677 Water Treatment Studies Bench**

Raw water supplied for steam raising plant contains impurities which are harmful to the equipment and it therefore requires treatment to minimise these detrimental effects. This bench has a dual function, it can be used either as:-

- An experimental bench to demonstrate the basic principles of water treatment by filtration and chemical means and enable students to carry out individual experiments and analysis of sample on varying types of water
- OR
- A service module to supply treated water to a steam boiler bench

**P7678 Process Control Steam Bench**

Steam has many uses in process engineering. The steam heating circuit on this bench supplies steam to a process fluid circuit designed so that the various processes can be clearly observed. Students can therefore:-

- Demonstrate, visually the use of steam in a natural circulation (thermosyphon) reboiler for the heating of other fluids and the distillation process
- Verify the change of rate of recirculation with increase in boiling temperature
- Verify the choice of process steam pressure to suit the required process temperature

**P7681 Nozzle Steam Bench**

The purpose of a nozzle in steam applications is to convert the internal energy of the steam into kinetic energy and this is achieved by expanding it from higher to a lower pressure. The ultimate efficiency of this conversion process depends upon the shape (or profile) of the nozzle. With four different nozzles the experiments which can be carried out are:-

- The variation of pressure along a nozzle profile as a function of back pressure
- The effect of back pressure on the mass rate of flow
- A comparison of theoretical and actual throat pressures and rates of flow
- Determination of critical pressure ratio for choked flow
- Calculation of velocity through length of nozzles of various forms
- Study of the effects of friction in a parallel nozzle
- Study of shock wave formation with nozzle divergence and at nozzle outlet
- Measurement of state of entry to the nozzle and subsequent calculation.

**P7682 PIPE CLOSURE KIT (ESSENTIAL ITEM)**

The pipe closure unit is designed to close the open ends of the service pipes on the steam bench and provide a means of blowing down the system and automatically discharging condensate from the steam main. It comprises pipework connecting the steam main to the blowdown, a steam trap and isolating valve, a direct bypass line with isolating valve and drain plug, together with blanking plugs for water supply and drainage lines.
Steam Power Plant

P7665 Boiler control Demonstration And Fault Simulation Unit

An arrangement of up to date integrated circuits is used to simulate boiler pressure and burner control together with the sensing and control systems associated with modern boiler systems. The simulated boiler itself is constructed from a clear acrylic tank and thus the demonstration unit provides a clear visual appreciation of the operating characteristics of the various level controls i.e. float operated magnetic, reed or mercury switch or electronic system using electrode sensors. The operation of these level sensing devices can readily be investigated since they may be removed from the Demonstration Unit, dismantled and re-assembled, without the attendant problems which would occur on an operational boiler. These systems would not normally all be fitted in the same boiler but are included in this unit to give the student an appreciation of the characteristics of each system. Conversion of water from the boiler into steam is simulated so that the level sensors need to operate as in a true Boiler system.

P7667 Boiler Simulation Software

Cussons P7667 boiler simulation software allows students to investigate the operation of a steam generation plant. Altering the system properties allows the user to simulate a wide range of boiler systems for periods up to 24 hours and adjustments to the operating parameters may be made whilst the simulation is running to allow the investigation of transients on the system.

Results from the simulation may be saved manually or automatically to allow subsequent viewing and printing. The results are saved in ‘tabbed text’ format to allow importing into spreadsheet programs that the student may be familiar with, such as Microsoft Excel, which will allow further analysis and production of graphs.

The software may be used in conjunction with Cussons P7665 Boiler Control Demonstration and Fault Simulation unit, which will interact with the simulation software and enables the introduction of faults into the operation of the system. This requires that interface cards be fitted to the P7665 and the PC to allow their interconnection.

Sectioned Steam Equipment

P2295 Sectioned Steam Trap
P2296 Sectioned Steam Separator
P2297 Sectioned Steam Ejector
P2298 Sectioned Pressure Relief Valve (steam)
P2299 Sectioned Condenser
P2300 Sectioned Steam Engine
P2301 Sectioned Steam Injector