11 Thermodynamics and Heat Transfer

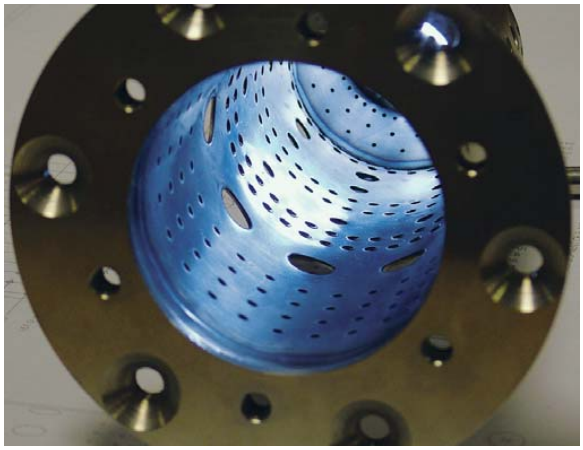
“ BAE Systems Defence Information, Training and Services have recently used TecQuipment to support training activities in the Kingdom of Saudi Arabia through the procurement of two gas turbine trainers. Throughout the procurement, manufacturing and installation period TecQuipment have performed well and supported extra requirements such as product safety justification reports. The experience and expertise of their commissioning engineer was first class and in-country activities went well. ”

N Cherry, Training Procurement Warton, BAE Systems (Operations) Limited

Thermodynamics and Heat Transfer

Safe, practical and realistic

Guided by educational experts and students, TecQuipment has developed and expanded this range to include an extensive selection of high-quality robust products. Our experience has shown that thermodynamics experiments can take many hours, so our designs reduce the experiment time to a practical and realistic level, with safety as the key aspect.



KEY FEATURES AND BENEFITS:

- **Safe and practical design: reduced experiment times.**
- **Broad range of products: covers from basic principles to gas turbines.**
- **Automatic data acquisition: thermodynamics experiments need several minutes of constant monitoring to achieve thermal equilibrium, making automatic data acquisition a useful tool.**

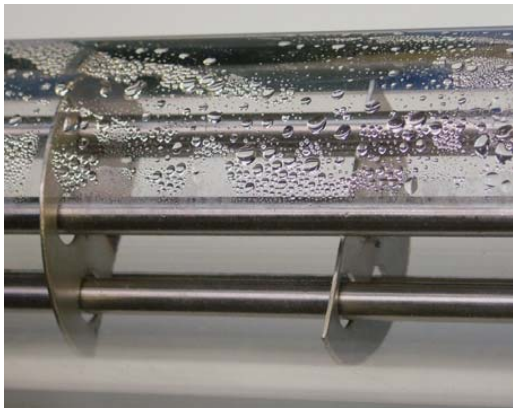
Modular fluid power

Our Modular Fluid Power range includes products that can be analysed in terms of thermodynamic performance, such as compressors.

See **pages 137–152** for more details.

Broad range

Over the last decade, TecQuipment has improved and grown this range to include a broad range of products that now cover topics starting from thermodynamic principles up to complex systems such as gas turbines.



Automatic Data Acquisition

VDAS® Most of the Thermodynamic and Heat Transfer products work with TecQuipment's unique Versatile Data Acquisition System (VDAS®). See **Section 2** for more details.

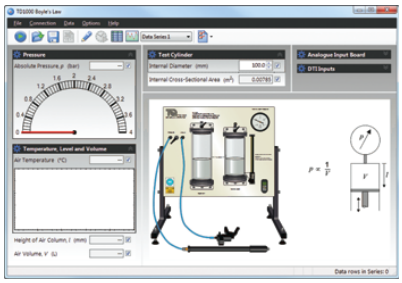
ADA TecQuipment's gas turbine products work with our unique Gas Turbine software.

VDAS®	ADA	Product	Page
●		**Boyle's Law** (TD1000)	251
●		**Gay Lussac's Law** (TD1001)	252
●		**Boiling and Condensing Heat Transfer** (TE78)	253
●		**Natural Convection and Radiation** (TE85)	254
●		**Thermal Conductivity Experiment** (TE19)	255
●		**Heat Transfer Experiments** (TD1002)	257
●		**Free and Forced Convection** (TD1005)	262
●		**Bench-top Heat Exchangers** (TD360)	263
●		**Cross-Flow Heat Exchanger** (TE93)	268
●		**Radiant Transfer Experiments** (TD1003)	269
●		**Water-to-Air Heat Exchanger** (TD1007)	270
●		**Thermoelectric Device Demonstrator** (TD1008)	272
●		**Temp Measurement and Calibration** (TD400)	274
●		**Marcet Boiler** (TD1006)	277
●		**Steam Motor and Energy Conversion** (TD1050)	278
●		**Small Engine Test Set** (TD200)	279
●		**Regenerative Engine Test Set** (TD300)	285
●		**Automatic Volumetric Fuel Gauge** (DVF1)	291
	●	**Turbojet Trainer** (GT100)	293
	●	**Turbojet Trainer with Reheat** (GT100RS)	294
	●	**Two-Shaft Gas Turbine** (GT185)	296

Boyle's Law Apparatus (TD1000)

Works with VDAS®

Shows the relationship between pressure and volume of an ideal gas at a fixed temperature



Screenshot of the optional VDAS® software

- A self-contained bench-top experiment – no power supply needed
- Highly visual experiment using a 'liquid piston' for reliability and accurate, repeatable results
- Includes a thermocouple and digital display to help maintain constant temperature and show how compression and decompression of a gas can affect its temperature
- Supplied with hand-operated pumps to compress or decompress the gas (air) above and below atmospheric pressure

EXPERIMENTS:

- **Demonstrations of gas temperature change during compression and decompression**
- **Proving Boyle's Law by experiment**

The bench-mounting equipment includes a backplate that holds two clear-walled cylinders containing oil (supplied). Students use hand-operated pumps (supplied) to increase or decrease the pressure in the left-hand cylinder (the reservoir) which moves a "liquid piston" of oil in the right-hand cylinder (the test cylinder). This piston compresses or decompresses a trapped column of air in the test cylinder.

The equipment uses normal, clean, dry air as it behaves as an ideal gas over the range of pressures used in this equipment.

A digital indicator measures the change in height of the trapped air column. When multiplied by the cross-sectional area of the column, this gives the change in volume. A mechanical pressure gauge measures the pressure of the trapped air.

A thermocouple and digital display measure the temperature of the trapped air to make sure that students maintain a constant air temperature during tests. They also help to demonstrate the change in air temperature during demonstrations.

Students maintain a constant temperature while recording the changes in volume with applied pressure. They then plot the results to prove Boyle's Law.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Recommended Ancillaries:

	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

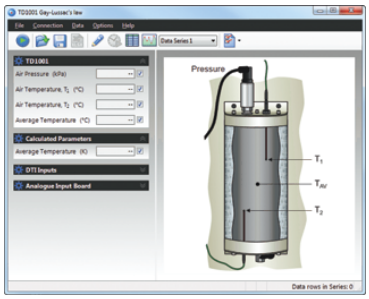
Alternative Product:

	Page
• Gay-Lussac's Law (TD1001)	252

Gay-Lussac's Law (TD1001)

Works with VDAS®

Shows the relationship between pressure and temperature of a fixed volume of ideal gas



Screenshot of the optional VDAS® software

- Demonstrates Gay-Lussac's Law relating pressure and temperature of an ideal gas (air)
- Simple and safe – needs no tools, uses low pressures and a thermally-insulated heater
- Includes thermocouples and a pressure sensor connected to a digital display
- Electronic controller to accurately regulate temperature

EXPERIMENTS :

- **Demonstrates change of pressure of a fixed volume of gas during heating**
- **Proving Gay-Lussac's Law by experiment**
- **The principle of a vapour pressure thermometer**

The bench-mounting equipment includes a backplate that holds a low-pressure vessel. The vessel holds a fixed volume of air surrounded by an insulated heater, controlled by an electronic temperature controller.

A hand-operated valve at the bottom of the vessel allows students to normalize the air in the vessel to ambient conditions.

The equipment uses normal, clean, dry air as it behaves as an ideal gas over the range of pressures used in this equipment.

A thermocouple measures the temperature of the heater surface for the controller. Two thermocouples measure the temperature of the air in the vessel. A pressure transducer measures the pressure of the heated air in the vessel. A digital display shows the absolute pressure, both temperatures and their average value.

Students set the controller for the range of temperatures needed during the experiment. They then record the changes in pressure as the temperature increases and plot the results to prove Gay-Lussac's Law.

The experiment can also work in reverse; students heat the vessel, open the valve to normalise the air in the vessel, then shut the valve. They then record the pressure and temperature drop as the vessel cools naturally. This gives a different starting point and results which will fall below local ambient. Due to the slow nature of natural cooling, the optional VDAS® is helpful in this test to log results automatically.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

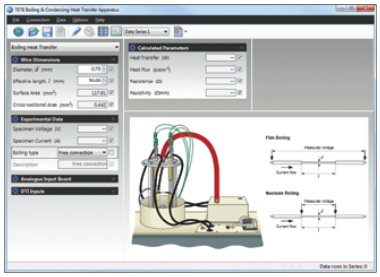
Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Product:	Page
• Boyle's Law Apparatus (TD1000)	251

Boiling and Condensing Heat Transfer (TE78)

Works with VDAS®

Shows heat transfer during different boiling and condensing processes



Screenshot of the optional VDAS® software

- Has a glass vessel so students can see what is happening
- Shows nucleate, film and sub-cooled boiling
- Shows condensation on different surface finishes
- Shows filmwise and dropwise condensation

EXPERIMENTS:

- **Boiling heat transfer**
- **Condensing heat transfer**

Gives students an understanding of heat transfer during boiling and condensing.

The equipment heats and condenses water, and includes a separate control module with a digital display. Heating and condensing takes place inside a partially filled glass vessel. A heater coil heats the water. For boiling heat transfer experiments, students adjust the current in a resistant wire heater element in the water. The temperature of the wire reaches significantly higher than 100°C.

Students watch the boiling process and note the different boiling processes. They note the free convection (before boiling) and the other stages (during boiling).

These include:

- Sub cooled boiling – small bubbles form and rise
- Nucleate boiling – large bubbles form and rise
- Film boiling – unstable and stable, where a vapour blanket forms and heat transfer by radiation becomes important

For condensing heat transfer experiments, water condenses on two water-cooled, vertical cylinder specimens. The cooling water flow rate and its temperature change at each cylinder helps students to find the heat transfer.

To show the effect of surface finish on heat transfer, one specimen has a gold plating and the other has an oxidised finish. They show clearly the difference between filmwise and dropwise condensation.

For quick and reliable tests, TecQuipment can supply its optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all important readings on a suitable computer (computer not included).

Recommended Ancillary:

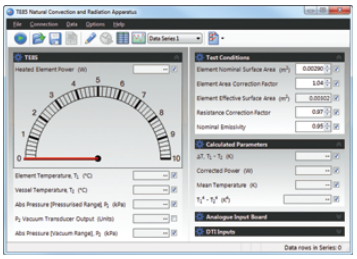
Page

- Versatile Data Acquisition System – Bench-mounted version (VDAS-B) 32

Natural Convection and Radiation (TE85)

Works with VDAS®

Shows students how different types of heat can transfer over a range of pressures



Screenshot of the optional VDAS® software

- Helps students to understand natural 'free' convection, radiation, emissivity and the Stefan-Boltzman equation
- Includes a pressure vessel to allow tests above and below atmospheric pressure
- All instruments and vacuum pump included
- Test results are accurate enough to allow extrapolation down to a complete vacuum

EXPERIMENTS:

- **Determination of emissivity**
- **Verification of the Stefan-Boltzmann constant**

The Natural Convection and Radiation equipment allows the study of heat transfer at different pressures and vacuum. It shows the differences between radiation and natural 'free' convection. It allows students to find the emissivity of a surface and verify the Stefan-Boltzman equation. It also gives students an understanding of the non-dimensional characteristics using Nusselt, Grasof, Prandtl and Knudsen numbers.

A small heated element hangs in the centre of a pressure vessel. The heater has a matt black surface. Attached to its surface is a thermocouple to measure the temperature.

The vessel's inside is also black, and it has a thermocouple fitted to its wall to measure the temperature in the vessel. The vessel may be charged with compressed air up to 1 bar (gauge) or evacuated down to about 5 Pa (absolute). Students can extrapolate the results down to a total vacuum (no convection). This allows them to isolate the heat transfer by radiation.

Instruments and a digital display measure and display the temperatures, pressures and power to the element. To give accurate measurements of pressure and vacuum, the equipment has two different pressure transducers – one for pressures above atmospheric and one for pressures below atmospheric.

The equipment also includes a socket for connection to TecQuipment's Versatile Data Acquisition System (VDAS®). Included is a vacuum pump, and a regulator for an external compressed air supply (up to 10 bar). The system includes a pressure-relief valve to protect the equipment and the user.

The equipment works with TecQuipment's Versatile Data Acquisition System (VDAS-B, not included). VDAS® allows accurate real-time data capture, monitoring, display, calculation and charting of all the important readings on a computer (computer not supplied).

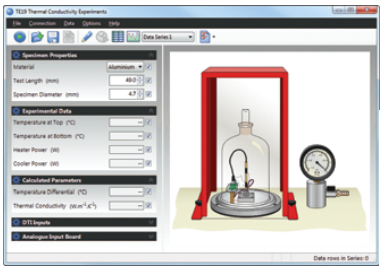
Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Products:	Page
• Free and Forced Convection (TD1005)	262
• Radiant Transfer Experiments (TD1003)	269

Thermal Conductivity Experiment (TE19)

Works with VDAS®

Shows heat conduction in different metals at ambient temperature



Screenshot of the optional VDAS® software

- Uses low temperatures to reduce heat losses for accurate results
- Test area pressure can be reduced to a vacuum for accurate results (needs optional vacuum pump)
- Supplied with selection of different metal specimens
- Specimens are reusable and easily changed

EXPERIMENTS:

- **Thermal conductivity of different metals**

The Thermal Conductivity Experiment is in two parts:

- Base unit with a Peltier cooler, a vacuum gauge and a moulded glass dome (vacuum vessel).
- Separate control module, with heater and cooler controls and a multi-line display. It also includes a connection for TecQuipment's optional VDAS® and a suitable computer (not supplied) for automatic data acquisition.

Included with the equipment are specimens of different metals. Each specimen has a small resistive heater at one end; the other end clamps to the cooler of the base unit. The heater at one end and the cooler at the other give a controlled heat flow along the specimen. Attached to the specimen are two thermocouples at a precise distance apart, near to each end. Students use the temperature difference between the thermocouples to find the thermal conductivity of the material. They then compare it with other materials and with given values.

The glass dome covers the area around the specimen. The students use a suitable vacuum pump (RE19, available separately) to remove the air inside the dome. This reduces heat loss due to convection to give more accurate results.

For quick and reliable tests, TecQuipment can supply its optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all important readings on a suitable computer (computer not included).

Essential Ancillary:	Page
• Laboratory Vacuum Pump (RE19)	299

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Product:	Page
• Linear Heat Conduction Experiment (TD1002a)	258

Forced Convection Heat Transfer (TD1)

Shows forced convection in pipes and heat transfer theory

- Constant-speed fan with variable flow-control valve for better flow control
- Heater interlock for safety
- Includes Pitot tube traverse for velocity profile measurements, and traversing thermocouple to measure temperature distribution across the test pipe
- Includes thermocouples along the test pipe to measure heat transfer

EXPERIMENTS:

- **Derivation of the value of Nusselt number (Nu) and comparison with empirical formula**
- **Calculation of the local heat transfer coefficient (h)**
- **Determination of the Stanton number (St)**
- **Calculation of the friction factor (f) and comparison with experimental value**
- **Determination of the validity of the Reynolds analogy for air**

A basic knowledge of forced convection heat transfer theory is valuable in many engineering fields, especially heat-exchanger design. TecQuipment's Forced Convection Heat Transfer apparatus allows students to examine the theory and associated formulae related to forced convection in pipes.

The TD1 is a frame holding a motor-driven fan, piping and instrumentation panel. It also has a large work surface for student convenience.

The fan runs at a constant speed and draws air through a control valve. The air then moves into a U-shaped pipe. An orifice plate in the pipe connects to a manometer on the instrumentation panel to measure the air flow rate. A larger manometer on the instrumentation panel measures the fan pressure drop.

The U-shaped pipe connects to a smaller diameter, insulated and electrically heated copper 'test pipe'. Students control the power input to the test pipe heater using a variable transformer, while noting the power using instrumentation on the panel. The test pipe discharges to atmosphere.

Pressure tappings at each end of the test pipe connect to a manometer on the instrument panel to measure test length pressure drop. A thermometer measures the air temperature at the inlet to the test pipe. Thermocouples measure the temperature at various points along the test pipe wall. Further thermocouples measure temperature at various points within the test pipe insulation. Students use a digital indicator on the instrumentation panel to display thermocouple temperature readings.

To avoid overheating, a motor starter, isolator and safety interlock prevent the heater working unless there is a suitable flow of air.

The instrument panel also includes a manometer which connects to a Pitot tube traverse assembly to measure the velocity profile across the test pipe.

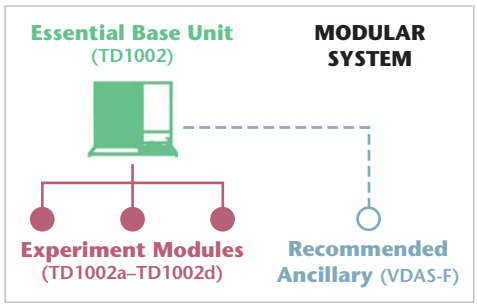
Alternative Products:

- Cross-Flow Heat Exchanger (TE93) 268
- Free and Forced Convection (TD1005) 262
- Water-to-Air Heat Exchanger (TD1007) 270

Heat Transfer Experiments Base Unit (TD1002)

Works with VDAS®

Base unit for a range of optional experiments that study different methods of heat transfer



FEATURES:		BENEFITS:
A self-contained bench-top base unit with four optional experiments	→	**Modular approach reduces total laboratory costs**
Fool-proof fittings allow students to change and connect the optional experiments quickly and easily (needs no tools)	→	Simple and safe to use – self-sealing connectors prevents spillage of water
Clear digital displays of all readings	→	**No computer needed to work it or take readings – simplified approach enhances student learning**
The experiments each have a bedplate with a clear schematic diagram to show students how they connect, and the measuring point positions	→	Maximises teaching effectiveness – simple to set up and students can easily understand the experiment

The Heat Transfer Experiments Base Unit (TD1002) is the core of the TD1002 range. It provides cold water and heater power to the optional experiments and all the instruments needed to measure their performance.

The base unit's water system connects to a suitable cold water supply and drain. It includes a hand-operated valve to help give a controllable water flow and a simple return pipe, both colour-coded.

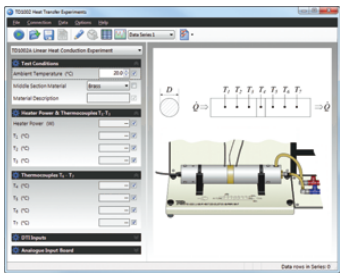
The water connections to the optional experiments are self-sealing quick connectors – for safety and simplicity. The inlet and outlet fluid streams have different colours to reduce errors. Changing an experiment takes less than a minute.

The base unit provides a variable and measured electrical current to the heater in each experiment and works with a safety switch to stop the heater from becoming too hot. It also includes sockets for the thermocouples built into each optional experiment.

Clear, multi-line digital displays on the base unit show the temperatures and heater power of each experiment.

A spare area to the right of the base unit frame allows you to fit the optional VDAS-F hardware.

Each optional experiment is on a bedplate that has a clear schematic diagram showing the connections and measuring point positions. The bedplate fixes to the base unit with thumbscrews (students need no tools).



Screenshot of the optional VDAS® software

Note: You need at least one of the optional experiments. You cannot do experiments with just the base unit.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Continued on next page

Heat Transfer Experiments Base Unit (TD1002)
Continued from previous page

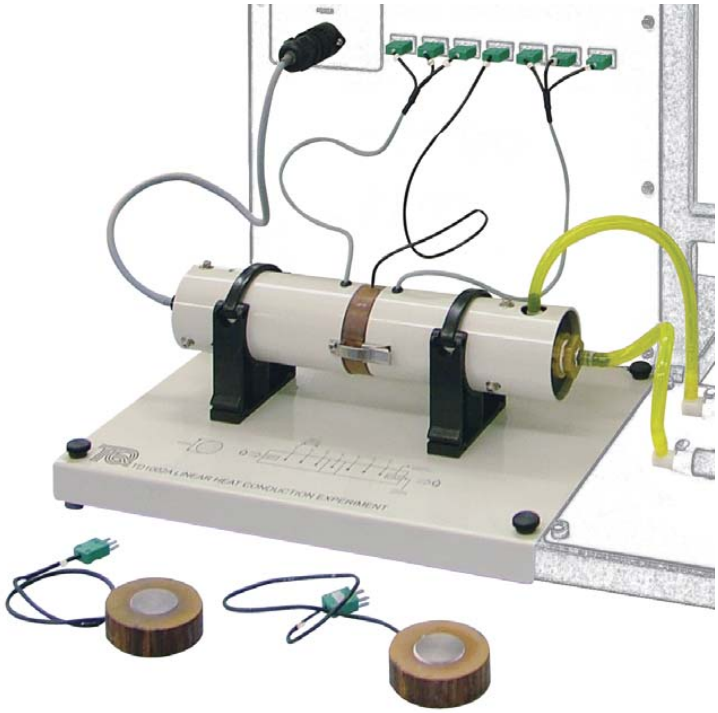
Available Experiment Modules:	Page
• Linear Heat Conduction Experiment (TD1002a)	258
• Radial Heat Conduction Experiment (TD1002b)	259
• Extended Surface Heat Transfer Experiment (TD1002c)	260
• Conductivity of Liquids and Gasses Experiment (TD1002d)	261

Recommended Ancillary:	Page
• VDAS-F (frame-mounted version of the Versatile Data Acquisition System)	32

Alternative Products:	Page
• Free and Forced Convection (TD1005)	262
• Radiant Transfer Experiments (TD1003)	269

Linear Heat Conduction Experiment (TD1002a)

Introduces students to the principles of linear heat conduction and thermal conductivity

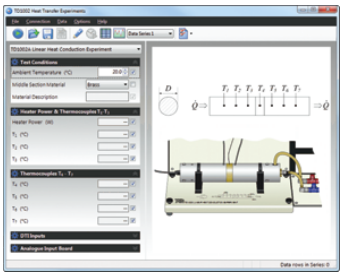


- One of four optional experiments for the Heat Transfer Experiments Base Unit (TD1002)
- Fits quickly and easily onto the Heat Transfer Experiments Base Unit and water connections have self-sealing quick connectors – needs no tools
- Shows the principles of linear heat conduction along a rod of uniform diameter
- Clear schematic printed on the baseplate aids student understanding

EXPERIMENTS:

- **Demonstration and calculations of linear heat conduction**
- **Calculation of the thermal conductivity (*k* value)**
- **Demonstration of the effectiveness of thermal paste**
- **Demonstration and calculations of thermal resistances (*R* value) in series**
- **Demonstration of 'thermal lag'**

This experiment has a solid brass bar of circular cross-section, made in two sections with an interchangeable middle section. It mounts on a base plate with a clear schematic of the experiment layout. The first brass section includes three thermocouples and the electric heater (heat source). The second brass section includes a small water-cooled chamber (heat sink) and three more thermocouples. The interchangeable middle sections (supplied) are of different metals:



Screenshot of the optional VDAS® software

- Brass – so the bar becomes one length of brass
- Aluminium
- Stainless steel
- Copper

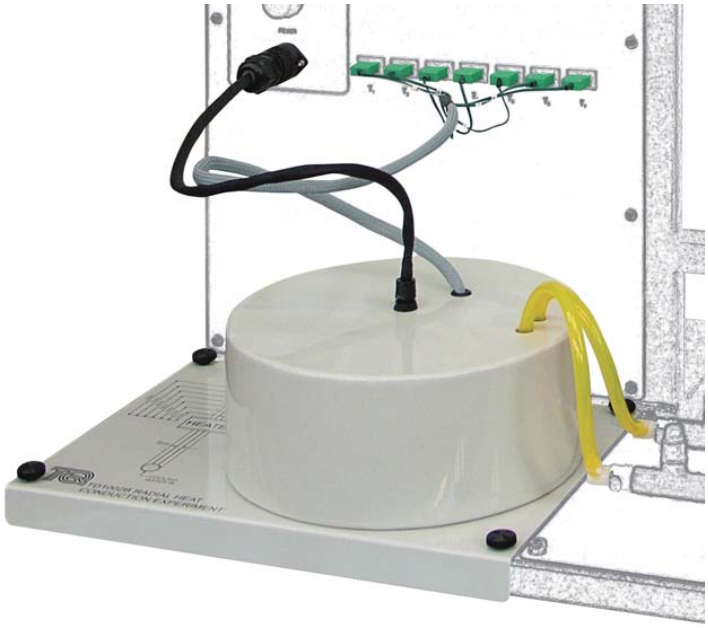
Each middle section has a thermocouple. The electric heater and thermocouples connect to sockets on the Heat Transfer Experiments Base Unit, which also supplies the cold water feed and drain for the heat sink. Students turn on the cooling water flow and adjust the heater power until the experiment reaches equilibrium and then record the temperatures as the heat conducts along the bar. Insulation around the bar reduces heat loss by convection and radiation, so that the results should match the theory for simple linear conduction only.

Essential Base Unit:	Page
• Heat Transfer Experiments Base Unit (TD1002)	257

Alternative Product:	Page
• Thermal Conductivity Experiment (TE19)	255

Radial Heat Conduction Experiment (TD1002b)

Introduces students to the principle of radial heat conduction and thermal conductivity



- One of four optional experiments for the Heat Transfer Experiments Base Unit (TD1002)
- Fits quickly and easily onto the base of the Heat Transfer Experiments Base Unit and water connections have self-sealing quick connectors – needs no tools
- Shows the principles of radial heat conduction radially around a disc of uniform diameter
- Clear schematic printed on the baseplate aids student understanding

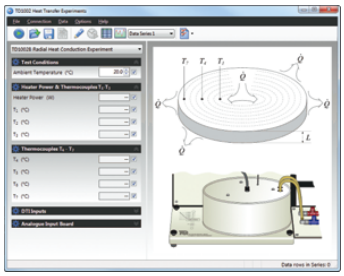
EXPERIMENTS:

- **Demonstration and calculations of radial heat conduction**
- **Calculation of the thermal conductivity (k value)**

This experiment has a solid brass disc with an electric heater (heat source) at its centre and a circular cross-section cooling tube (heat sink) around its circumference. It mounts on a base plate with a clear schematic of the experiment layout.

The electric heater and thermocouples connect to sockets on the Heat Transfer Experiments Base Unit, which also supplies the cold water feed and drain for the heat sink

Students turn on the cooling water flow and adjust the heater power until the experiment reaches equilibrium. At equally spaced radii on the disc, seven thermocouples measure the temperature as the heat conducts radially



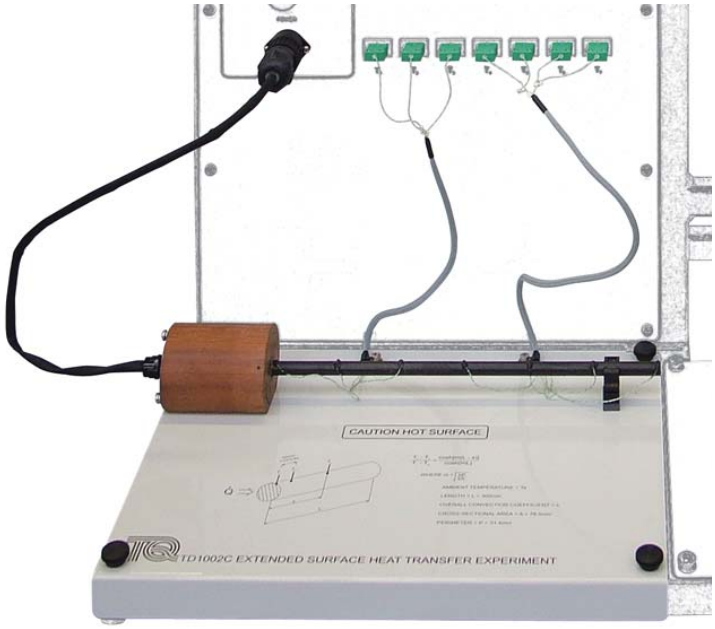
Screenshot of the optional VDAS® software

outwards from the heater. Insulation around the disc reduces heat loss by convection and radiation, so that the results should match the theory for simple radial conduction only.

Essential Base Unit:	Page
• Heat Transfer Experiments Base Unit (TD1002)	257

Extended Surface Heat Conduction Experiment (TD1002c)

Shows students an example of conduction combined with losses due to radiation and convection



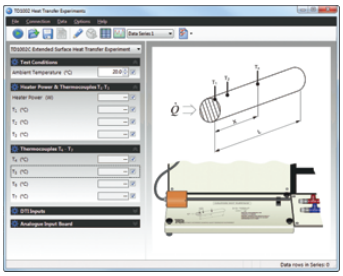
- One of four optional experiments for the Heat Transfer Experiments base unit (TD1002)
- Fits quickly and easily onto the Heat Transfer Experiments Base Unit and water connections have self-sealing quick connectors – needs no tools
- Shows how a long thin rod conducts heat along it and how heat is lost due to radiation and convection
- Clear schematic printed on the baseplate aids student understanding

EXPERIMENTS:

- **To show how heat transfers from the surface of a solid bar or rod.**
- **To show the temperatures on, and heat flow through, the solid bar to its surroundings.**

This experiment has a thin solid bar with an electric heater (heat source) at one end. It mounts on a base plate with a clear schematic of the experiment layout. The bar has a matt black coating for a consistent and predictable emissivity value. Thermocouples measure the temperature along the surface of the bar at equally spaced intervals. The electric heater and thermocouples connect to sockets on the Heat Transfer Experiments Base Unit.

Heat conducts along the bar and transfers to the local surroundings by natural convection and radiation. Students use initial test results to predict the temperatures and heat flow along the bar.



Screenshot of the optional VDAS® software

Essential Base Unit:	Page
• Heat Transfer Experiments Base Unit (TD1002)	257

Need more information?

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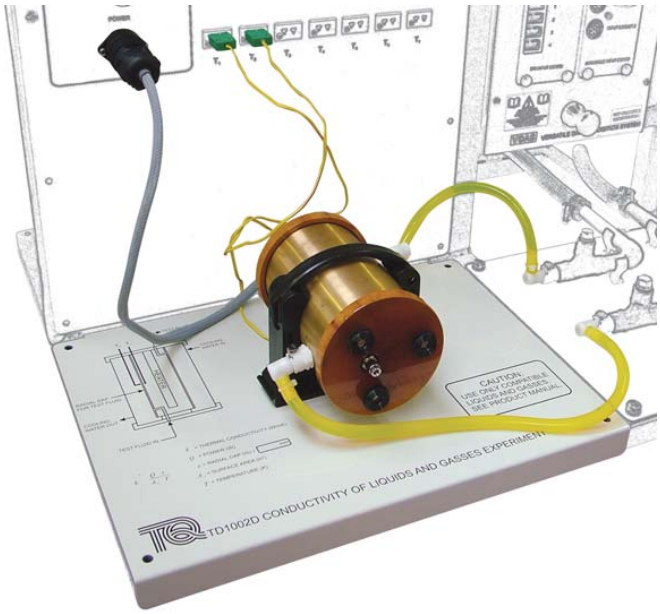
www.tecquipment.com

Conductivity of Liquids and Gasses Experiment (TD1002d)

Allows students to test various fluids to find their thermal conductivity



- One of four optional experiments for the Heat Transfer Experiments base unit (TD1002)
- Fits quickly and easily onto the Heat Transfer Experiments Base Unit and water connections have self-sealing quick connectors – needs no tools
- Allows students to measure the thermal conductivity of various compatible liquids and gasses
- Clear schematic printed on the baseplate aids student understanding

EXPERIMENTS:

- **Calibration of the unit using air as the known medium.**
- **Finding the thermal conductivity (k) of various liquids and gasses and comparing them to typical published values .**

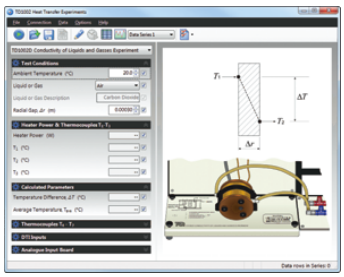
This experiment has three concentric cylinders. The inner cylinder contains an electric heater (the heat source). The test liquid or gas forms a second, thin cylinder around the heat source. The third cylinder, cooled by water, surrounds them both to make a heat sink. The whole assembly is mounted on a base plate with a clear schematic of the experiment layout.

Heat passes by conduction from the heat source, through the test liquid or gas, to the heat sink. Thermocouples measure the temperature on the inside and outside edges of the cylinder of test liquid or gas.

The electric heater and thermocouples connect to sockets on the Heat Transfer Experiments Base Unit, which also supplies the cold water feed and drain for the heat sink

Caps of thermally-insulating material at the ends of the cylinders reduce heat loss, but students do an initial experiment to calibrate the equipment to allow for heat losses and improve experiment accuracy. One end cap is removable to allow the unit to be easily cleaned when changing from one fluid to another.

Students turn on the cooling water and the heater and measure the temperatures at each side of the test gas or liquid. They then compare their results with those predicted from theory for conduction in liquids and gasses.



Screenshot of the optional VDAS® software

Note: The TD1002d equipment is made of brass, aluminium, tufnol, nylon and nickel-plated parts. For safety reasons and to avoid damage to the equipment, only use test fluids that will not damage or react with the materials used to make the TD1002d. TecQuipment does not supply and cannot be held responsible for the test fluids that you use.

Suitable test fluids include:

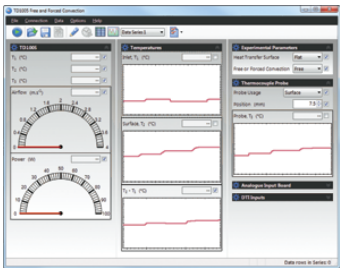
- Normal, dry air
- Carbon dioxide
- Castor oil

Essential Base Unit:	Page
• Heat Transfer Experiments Base Unit (TD1002)	257

Free and Forced Convection (TD1005)

Works with VDAS®

Shows free and forced convection from different heat transfer surfaces



Screenshot of the optional VDAS® software

- Includes three of the most common heat transfer surfaces – flat plate, pinned and finned
- Thermocouples and a sensitive anemometer measure temperatures and air velocity – shown on a digital display
- Additional hand-held thermocouple probe included – to measure temperatures along the length of the pins and fins of two heat transfer surfaces
- Variable-speed fan and variable-power heat source for a range of tests

EXPERIMENTS:

- **Comparing free and forced convection for different surfaces**
- **Comparison of free convection from vertical and horizontal (finned) surfaces**
- **Comparison of heat transfer surface efficiency**
- **Comparing the coefficient of heat transfer and Nusselt Number for forced and free convection**
- **Temperature distribution along finned and pinned surfaces**

The bench-top equipment includes a vertical duct that holds the chosen heat transfer surface and all instruments needed.

TecQuipment include three different common heat transfer surfaces with the equipment:

- A flat plate
- A pinned surface – similar to a tubular heat exchanger
- A finned surface – similar to the fins on air-cooled engines or electrical heat sinks

Each surface has its own built-in variable-power electric heater. Students choose which surface they need to test and fit it to the duct using simple fixings.

For free convection tests, the heated air rises from the surface and up the duct. For forced convection tests, a variable-speed fan draws air up through the duct and across the surface. Thermocouples measure the air temperature upstream and downstream of the surface and the temperature at the heat transfer surface. The downstream probe moves in a traverse mechanism to measure the temperature distribution across the duct, allowing calculation of the bulk outlet temperature. An additional probe allows students to measure the temperature distribution along the extended surfaces of the pinned and finned heater transfer surfaces. A sensitive anemometer measures the air velocity.

Two controls allow students to set different air velocities and heater power for a full range of tests.

A digital display shows the heater power, air velocity and the temperatures measured by the thermocouples.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

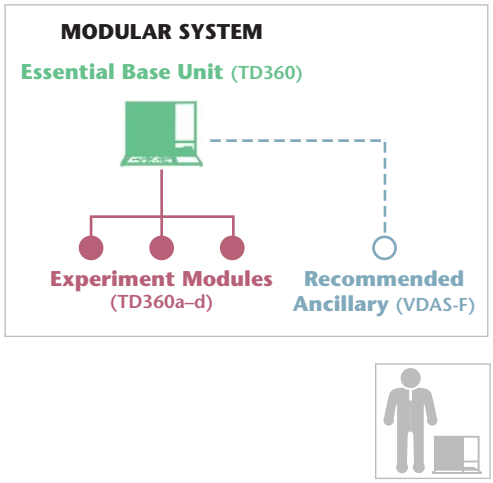
Recommended Ancillary:	Page
• Bench-mounted version of the Versatile Data Acquisition System (VDAS-B)	32

Alternative Products:	Page
• Forced Convection Heat Transfer (TD1)	256
• Heat Transfer Experiments (TD1002)	257
• Natural Convection and Radiation (TE85)	254
• Cross-Flow Heat Exchanger (TE93)	268
• Water-to-Air Heat Exchanger (TD1007)	270

Bench-top Heat Exchangers Service Module (TD360)

Works with VDAS®

Examines and compares small-scale heat exchangers to help students understand how they work



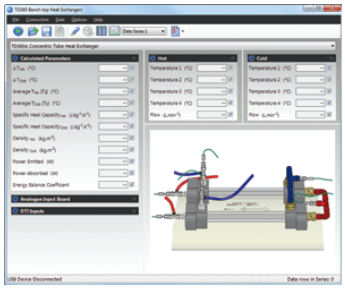
FEATURES:		BENEFITS:
A bench-top service module with optional small-scale demonstration heat exchangers – designed for teaching	→	**Efficient use of valuable laboratory space**
Optional heat exchangers include most common types used in industry (tubular, plate, shell and tube, and a jacketed vessel with coil and stirrer)	→	Qualitative and quantitative comparison of main heat exchanger designs
Fool-proof fittings allow students to change and connect the optional experiments quickly and easily (needs no tools)	→	**Simple and safe to use – self-sealing connectors prevents spillage of water**
Heat-exchangers each have a bedplate with a clear schematic diagram to help students understand how to connect it	→	Easy to set up and operate – maximises students' practical time

The Bench-top Heat Exchangers Service Module (TD360) is the core of the bench-top heat exchangers range. It provides hot and cold water to the heat exchangers and all the instruments needed to measure their performance.

All fluid connections to the optional heat exchangers are self-sealing quick connectors – for safety and simplicity. The hot and cold fluid streams have different connectors to reduce errors. Changing a heat exchanger takes less than one minute.

The service module's hot water system includes a tank with a PID-controlled electric heater, a pump and tank level indicators. An electrically operated valve opens to let water in to fill the tank. The tank has protection in case of over-temperature, low water level and over-filling.

The hot water system gives stable flow rates and temperatures. The service module's cold water circuit has a flow regulator and connection for an external mains water supply. Both the cold and hot water system have precision



Screenshot of the optional VDAS® software

Continued on next page

Bench-top Heat Exchangers Service Module (TD360)
Continued from previous page

needle valves and turbine flow meters to control and measure the flow rates. Thermocouples at the connectors measure hot and cold inlet and outlet fluid stream temperatures. Some of the heat exchangers also have built-in thermocouples for extra temperature measurements.

Clear, multi-line digital displays show the temperatures and flow rates of the fluid streams.

All optional heat exchangers have the same nominal heat transfer area and wall thickness, so students can compare them directly. Each heat exchanger is on a bedplate that has a clear schematic diagram showing the connections. The bedplate fixes to the service module with thumbscrews (students need no tools).

Note: You need at least one of the optional heat exchangers to do experiments. TecQuipment recommends that you buy the Concentric Tube Heat Exchanger (TD360a) first, because it has extra temperature measuring points. You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

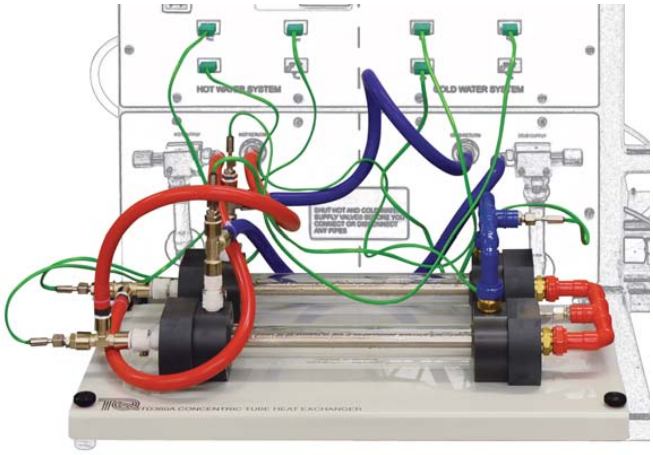
Available Experiment Modules:	Page
• Concentric Tube Heat Exchanger (TD360a)	264
• Plate Heat Exchanger (TD360b)	265
• Shell and Tube Heat Exchanger (TD360c)	266
• Jacketed Vessel with Coil and Stirrer (TD360d)	267

Recommended Ancillary:	Page
• Frame-mounted version of the Versatile Data Acquisition System (VDAS-F)	32

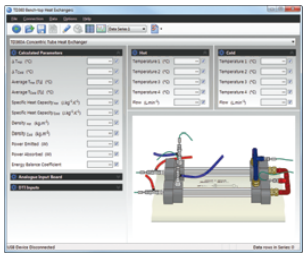
Alternative Products:	Page
• Cross-Flow Heat Exchanger (TE93)	268
• Water-to-Air Heat Exchanger (TD1007)	270

Concentric Tube Heat Exchanger (TD360a)

Shows how a simple concentric shell and tube heat exchanger works



- One of a set of optional heat exchangers for use with TecQuipment's TD360 Service Module
- Simple and safe to use – foolproof fittings allow students to change and connect the heat exchanger quickly and easily (needs no tools)
- Clear outside casing, so students can see its construction
- Bedplate with a clear schematic diagram to help students understand how to connect the heat exchanger



Screenshot of the optional VDAS® software

EXPERIMENTS:

- **Demonstration of heat transfer from one fluid to another through a solid wall.**
- **Energy balance and efficiency calculations.**
- **Demonstration of parallel-flow and counter-flow operation of heat exchangers.**
- **Measurement of the heat transfer coefficient, and the effect of fluid flow rates and the driving force (temperature differential) upon it.**
- **Introduction to the logarithmic mean temperature difference in heat exchangers.**
- **Comparison of different types of heat exchanger in terms of performance, size and relative cost (only if you have two or more optional heat exchangers).**

This is the simplest of the optional heat exchangers. It has two tubes, one inside the other. One tube carries hot fluid, the other carries cold fluid. Heat transfers between them. TecQuipment's heat exchanger is in two equal parts joined by intermediate pipes. This allows two extra measurement points at the midpoint (plus the standard four points at the connectors). This gives more useful experiment results, to show more clearly how the fluid temperatures change during heat transfer.

The Service Module (TD360) provides hot and cold water to the heat exchanger and all the instruments needed to measure its performance. All fluid connections to the heat exchanger are self-sealing quick connectors – for safety and simplicity. The hot and cold fluid streams have different connectors to reduce errors. Connecting the heat exchanger takes less than one minute.

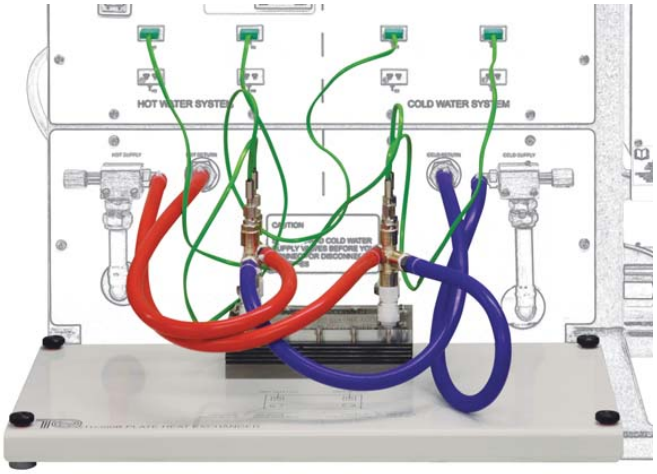
The heat exchanger is on a bedplate that has a clear schematic diagram showing the connections. The bedplate fixes to the service module with thumbscrews (students need no tools).

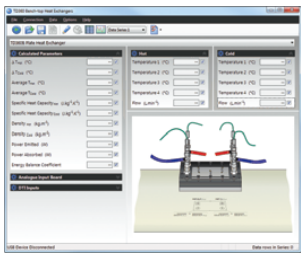
Essential Base Unit:	Page
• Service Module (TD360)	263

Plate Heat Exchanger (TD360b)

Shows how a compact plate heat exchanger works

- One of a set of optional heat exchangers for use with TecQuipment's TD360 Service Module
- Simple and safe to use – foolproof fittings allow students to change and connect the heat exchanger quickly and easily (needs no tools)
- Clear outside casing, so students can see its construction
- Bedplate with a clear schematic diagram to help students understand how to connect the heat exchanger





Screenshot of the optional VDAS® software

EXPERIMENTS:

- **Demonstration of heat transfer from one fluid to another through a solid wall.**
- **Energy balance and efficiency calculations.**
- **Demonstration of parallel-flow and counter-flow operation of heat exchangers.**
- **Measurement of the heat transfer coefficient, and the effect of fluid flow rates and the driving force (temperature differential) upon it.**
- **Introduction to the logarithmic mean temperature difference in heat exchangers.**
- **Comparison of different types of heat exchanger in terms of performance, size and relative cost (only if you have two or more optional heat exchangers).**

This heat exchanger is a set of metal plates separated by spacers (gaskets). The plates and gaskets have holes that make the hot and cold flow run on alternate sides of the plates, therefore transferring heat. The metal plates have flow disturbers on their sides to help improve the heat transfer. Plate heat exchangers are compact and therefore good for applications with limited space. It is also easy to alter their design to change their capacity – you simply add or remove plates and spacers.

The Service Module (TD360) provides hot and cold water to the heat exchanger and all the instruments needed to measure its performance. All fluid connections to the heat exchanger are self-sealing quick connectors – for safety and simplicity. The hot and cold fluid streams have different connectors to reduce errors. Connecting the heat exchanger takes less than one minute.

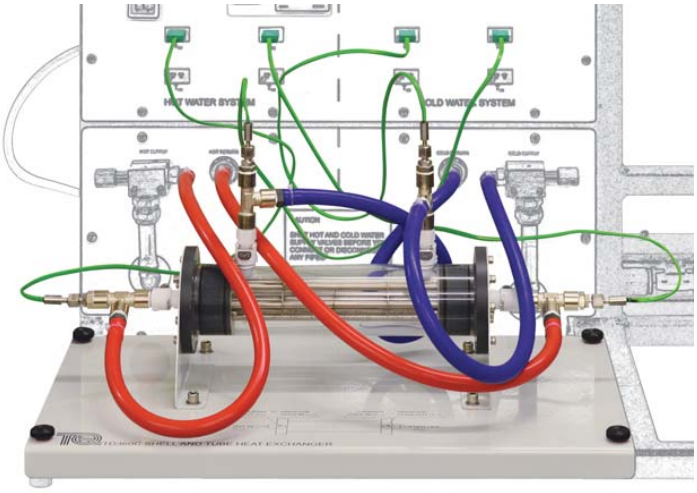
The heat exchanger is on a bedplate that has a clear schematic diagram showing the connections. The bedplate fixes to the Service Module with thumbscrews (students need no tools).

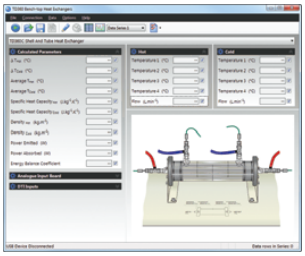
Essential Base Unit:	Page
• Service Module (TD360)	263

Shell and Tube Heat Exchanger (TD360c)

Shows how a compact shell and tube bundle heat exchanger works

- One of a set of optional heat exchangers for use with TecQuipment's TD360 Service Module
- Simple and safe to use – foolproof fittings allow students to change and connect the heat exchanger quickly and easily (needs no tools)
- Clear outside casing, so students can see its construction
- Bedplate with a clear schematic diagram to help students understand how to connect the heat exchanger





Screenshot of the optional VDAS® software

EXPERIMENTS:

- **Demonstration of heat transfer from one fluid to another through a solid wall.**
- **Energy balance and efficiency calculations.**
- **Demonstration of parallel-flow and counter-flow operation of heat exchangers.**
- **Measurement of the heat transfer coefficient, and the effect of fluid flow rates and the driving force (temperature differential) upon it.**
- **Introduction to the logarithmic mean temperature difference in heat exchangers.**
- **Comparison of different types of heat exchanger in terms of performance, size and relative cost (only if you have two or more optional heat exchangers).**

This heat exchanger is one of the most common types used in industry. This is because it is compact, but can work at higher pressures than other designs. It is a large tube (shell) which surrounds several smaller tubes (a bundle). One fluid passes through the shell, and the other fluid passes through the tube bundle, therefore transferring heat. Baffles around the bundle help to create a turbulent mixed flow.

The Service Module (TD360) provides hot and cold water to the heat exchanger and all the instruments needed to measure its performance. All fluid connections to the heat exchanger are self-sealing quick connectors – for safety and simplicity. The hot and cold fluid streams have different connectors to reduce errors. Connecting the heat exchanger takes less than one minute.

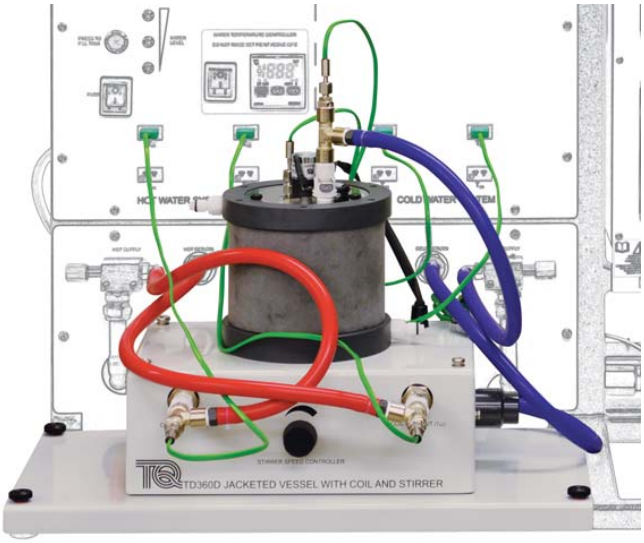
The heat exchanger is on a bedplate that has a clear schematic diagram showing the connections. The bedplate fixes to the Service Module with thumbscrews (students need no tools).

Essential Base Unit:	Page
• Service Module (TD360)	263

Jacketed Vessel with Coil and Stirrer (TD360d)

Shows how a 'jacketed vessel' heat exchanger works and how stirring affects heat transfer

- One of a set of optional heat exchangers for use with TecQuipment's TD360 Service Module
- Simple and safe to use – foolproof fittings allow students to change and connect the heat exchanger quickly and easily (needs no tools)
- Clear top cover, so students can see its construction
- Jacketed vessel with internal coil and stirrer for batch or continuous heating tests



EXPERIMENTS:

- **Demonstration of heat transfer from one fluid to another through a solid wall.**
- **Introduction to the logarithmic mean temperature difference in heat exchangers.**
- **Comparison of different types of heat exchanger in terms of performance, size and relative cost (only if you have two or more optional heat exchangers).**
- **Flow-through and batch heating, with or without stirring, using a heating jacket or a coil.**

Screenshot of the optional VDAS® software

This heat exchanger mimics those used in the process industry. It can show heat transfer by using the outer skin (or 'jacket') of the vessel, or by a coil inside the vessel. You can set a continuous feed to the vessel for heating, or you set a fixed batch for heating. The unit has an extra thermocouple to measure the batch temperature. It also has a motorised stirrer to show how stirring affects heat transfer.

The Service Module (TD360) provides hot and cold water to the heat exchanger and all the instruments needed to measure its performance. All fluid connections between the Service Module and the heat exchanger are self-sealing quick connectors – for safety and simplicity. The hot and cold fluid streams have different connectors to reduce errors.

The bedplate fixes to the Service Module with thumbscrews (students need no tools).

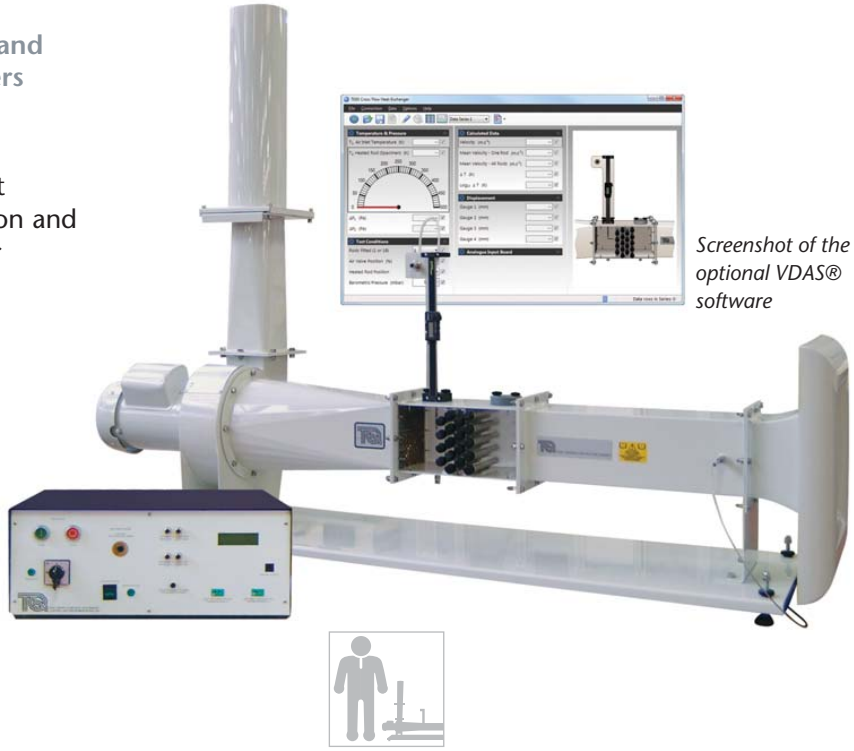
Essential Base Unit:	Page
• Service Module (TD360)	263

Cross-Flow Heat Exchanger (TE93)

Works with VDAS®

For studies into the principles and performance of heat exchangers

- For full understanding of heat exchange by forced convection and measurement of heat transfer
- Consists of wind tunnel with fully controllable air flow and heat-exchanger rod matrix
- Separate pre-heated element with built-in thermocouple can take the place of any heat exchanger rod
- Instrumentation unit also includes controlled heat source to pre-heat element



Screenshot of the optional VDAS® software

EXPERIMENTS:

Typical experiments include:

- **Determining the pressure losses created by the heat exchange rods and creating a chart of pressure drop against upstream pressure.**
- **Calculating the inlet velocity and the mean velocity through the rods.**
- **Determining the rate at which the heated rod cools down, within a bank of rods and by itself.**
- **Plotting 'cooling curves' and using them to find the coefficient of heat transfer (h) for the heated rod at various positions in the heat exchanger.**
- **Determining the velocity distribution (profile) downstream of the rods.**
- **Converting results into dimensionless values (typically using Nusselt, Prandtl and Reynolds equations).**
- **Comparing results and producing heat transfer coefficient curves.**

For comprehensive studies into the principles and performance of heat exchangers. The equipment allows students to quickly assess heat transfer rates by forced convection. They monitor the rate of cooling of a body of known thermal capacity in an air flow.

The apparatus is bench mounting. It is a horizontal wind tunnel with a contraction cone, a working section, a diffuser, a constant speed fan, and an exhaust with silencer. A variable slide valve controls the air flow.

The working section includes a series of rods arranged in a matrix and at right-angles to the direction of air flow. To do experiments, students can remove any one of these rods and replace it with a cylindrical copper element. The copper element is of known thermal capacity and includes a built-in thermocouple. Students insert the element, which has been pre-heated to a specific temperature, into the working section at a known air velocity. They measure the time taken for the temperature to drop and determine the heat transfer rate.

A second thermocouple at the inlet to the wind tunnel measures the temperature of air entering the heat exchanger. The base of the working section includes two static pressure tappings: one before the rods and one afterwards. These enable students to measure the static pressure difference across the rods. A Pitot traverse can measure air velocity at any vertical point in the working section, either before or after the rods.

The equipment includes a separate instrumentation unit. The instrumentation unit has two inputs for the thermocouples, and two pairs of quick-release couplings for connection to the pressure tappings. It also includes a controlled heat source for the copper element.

A digital display on the front of the instrumentation unit allows students to view all experimental data. In addition, the equipment is fully compatible with our Versatile Data Acquisition System (VDAS®), and can quickly and conveniently connect to a bench-mounting interface unit (VDAS-B, not included). Using VDAS® enables accurate real-time data capture, monitoring, display, calculation and charting of all relevant parameters on a computer (PC available separately).

Recommended Ancillary:

	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Products:

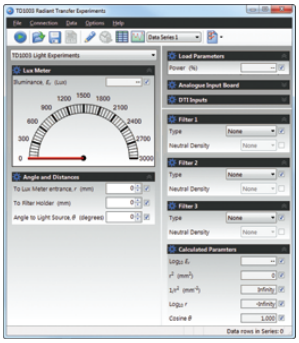
	Page
• Forced Convection Heat Transfer (TD1)	256
• Bench-top Heat Exchangers (TD360)	263
• Free and Forced Convection (TD1005)	262
• Water-to-Air Heat Exchanger (TD1007)	270

Radiant Transfer Experiments (TD1003)

Works with VDAS®

Shows the laws of radiant transfer from heat and light sources

- Uses a safe, low-voltage heat source and thermopile (heat flux sensor) for radiant heat transfer experiments
- Includes plates of different heat absorption properties and apertures for extra experiments in heat transfer
- Uses a safe, low-voltage 'integrating sphere' light source and lux meter (light meter) for light transfer experiments
- Includes different optical filters for extra experiments in light transfer



Screenshot of the optional VDAS® software

EXPERIMENTS:

Heat:

- **Inverse Square Law (or Lambert's Distance Law/Area Law) – showing radiation is inversely proportional to distance squared.**
- **Stefan-Boltzmann Law – showing the relationship between radiation and source temperature.**
- **Kirchhoff's Law – showing that a body with good emissivity also has good absorptivity.**
- **Area Factor – showing that radiation transfer depends on the exposed area of the radiant source.**

Light:

- **Inverse Square Law (or Lambert's Distance Law/Area Law) – showing radiation is inversely proportional to distance squared.**
- **Lambert's Direction Law (or Cosine Law) – showing that radiation is proportional to the cosine of the angle between the emitter and the receiver.**
- **Transmittance and Absorbance – showing that optical filters can reduce light intensity.**

The equipment has two parts: an aluminium experiment frame and a control box. The frame holds all the experiment parts and allows the user to slide the parts along easily for experiments of transfer over distances. The control box contains the electrical controls and displays of the measured readings.

The user fits different parts to the frame to measure the radiant transfer from light and heat sources.

The heat source uses a variable low-voltage electric heater on a flat plate, creating a black body heat source of variable temperature. A thermocouple measures the heat source temperature. A moveable thermopile measures the heat radiation from the heat source at varying distances. TecQuipment includes plates with different apertures, surface finishes and thermocouples. They allow extra experiments that show how surface finish affects emissivity and absorptivity, and the area factor for heat transfer.

The light source uses a low-voltage lamp inside an integrating sphere to create a diffuse light. Students can rotate the light source through a range of angles (shown on a protractor scale) for experiments in light direction. A moveable lux meter measures the light radiation from the light source at varying distances. TecQuipment includes different optical filters (coloured, neutral density and infra-red block). They allow extra experiments that show how optical filters affect light transfer.

A clear, multi-line digital display on the control box shows temperatures and light or heat radiation.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

Alternative Products:	Page
• Heat Transfer Experiments (TD1002)	257
• Natural Convection and Radiation (TE85)	254

Water-to-Air Heat Exchangers (TD1007)

Works with VDAS®

Shows how cross-flow water-to-air heat exchangers work

16-Tube Heat Exchanger (TD1007a)

16-Tube Finned Heat Exchanger (TD1007b)

Screenshot of the optional VDAS® software

FEATURES:		BENEFITS:
Includes one heat exchanger as standard	→	**Complete experiment 'out of the box'**
Two additional heat exchangers available for extended experiments	→	Allows quantitative comparison of different designs of heat exchanger
Heat exchangers have transparent sides and schematic diagrams	→	**Enhanced learning capabilities – helps students understand how they work and how to connect them**
Fool-proof fittings allow students to change and connect the optional experiments quickly and easily (needs no tools)	→	Simple and safe to use – self-sealing connectors prevents spillage of water

EXPERIMENTS:

- **Heat transfer between fluids through a solid wall**
- **Energy balance and efficiency**
- **Finding the heat transfer coefficient and Log Mean Temperature Difference (LMTD)**
- **Effect of water temperature (the 'driving force')**
- **Comparison of heat exchangers of different construction and heat transfer area (needs optional TD1007a and TD1007b)**

Many thermodynamic applications use water-to-air heat exchangers. Examples include using circulated water to heat or cool air in a HVAC installation, or to cool hot water using a flow of air, as in the radiator of a combustion engine.

The TecQuipment Water-to-Air Heat Exchanger mirrors air heating and water cooling applications. It fits on a bench top and includes a hot water supply, a cooling air duct and all instruments needed for tests on cross-flow heat exchangers. The heat output of the design produces good results without greatly affecting the temperature of a reasonable size classroom or laboratory.

It's hot water system includes a tank with a PID-controlled electric heater for stable temperatures, a pump and tank level indicators. An electrically operated valve opens to let water in to fill the tank. The tank has protection in case of over temperature, low water level and overfilling. A precision needle valve and flow meter control and measure the water flow rate.

The cooling air passes down a vertical duct containing an orifice plate which connects to a differential pressure transducer. The air then passes through a fixed speed centrifugal fan and along a horizontal duct containing the heat exchanger. The air exits the duct through a hand-operated slide-valve. Students use the orifice and valve to measure and control the air flow.

Thermocouples at the water connectors and in the air duct measure hot and cold inlet and outlet fluid stream temperatures. Clear, multiline digital displays show the temperatures, water flow rate and orifice pressure (to calculate air flow).

For safety and simplicity, the heat exchangers have self-sealing quick connectors for their water supply. Quick-release clamps and locating dowels hold the heat exchanger in the air duct. Students need no tools to fit and change the heat exchangers.

Each heat exchanger includes a mimic diagram that attaches to a space on the main unit panel. The diagram gives useful information to the student, including how to connect the heat exchanger. Each heat exchanger has transparent sides so students can easily see their construction and understand how they work.

The equipment includes one heat exchanger as standard. It has 32 tubes in two banks of 16, allowing the addition of a thermocouple at the mid point. TecQuipment supplies two different heat exchangers as optional extras. One (TD1007a) has a single bank of 16 tubes, giving half the heat transfer area of the standard heat exchanger. The other (TD1007b) also has a single bank of 16 tubes, but includes fins to increase the heat transfer area to equal that of the standard 32 tube heat exchanger.

The different heat exchanger options give students a better understanding of how they work and how size and construction may affect practical applications.

The equipment includes a space for TecQuipment's optional VDAS-F. You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

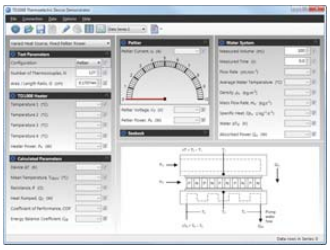
Recommended Ancillaries:	Page
• 16-Tube Heat Exchanger (TD1007a)	
• 16-Tube Finned Heat Exchanger (TD1007b)	
• VDAS-F (frame-mounted version of the Versatile Data Acquisition System)	32

Alternative Products:	Page
• Bench-Top Heat Exchangers (TD360)	263
• Cross-Flow Heat Exchanger (TE93)	268
• Free and Forced Convection (TD1005)	262
• Forced Convection Heat Transfer (TD1)	256

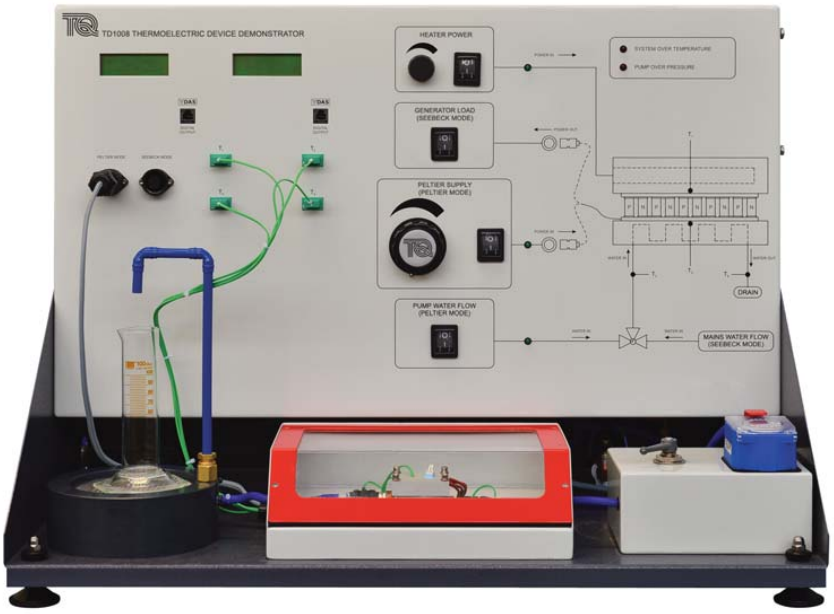
Thermoelectric Device Demonstrator NEW!
(TD1008)

Works with VDAS®

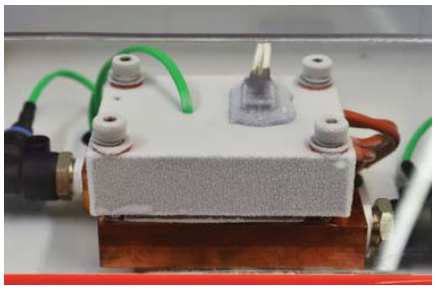
Examines the performance of a thermoelectric device when connected for Peltier or Seebeck tests as a heat pump or generator



Screenshot of the optional VDAS® software



- Connects for both Peltier or Seebeck tests – giving a full set of experiments
- Schematic diagram and transparent guard to help students understand the device construction and allow simple demonstrations
- A switchable load, variable heat source and device power supply for multiple test conditions
- Clear, multiline digital displays of all readings – you do not need a computer to work it or collect data



Ice crystals forming on the module

EXPERIMENTS:

- **Seebeck coefficient and the performance of a thermoelectric generator (TEG)**
- **Peltier heat pump tests and the performance of a thermoelectric cooler (TEC)**
- **Coefficient of performance (COP) and energy balance**
- **Comparisons of manufacturers data, theoretical performance and results from experiments**
- **Observation of the Lenz and Thompson effects**
- **Simple cooling demonstrations (determined by local conditions)**

The increasing need for smaller and more portable electrically powered equipment has produced a need for low maintenance, smaller and more portable cooling. To satisfy this need, manufacturers now use solid-state thermoelectric devices in computers, portable refrigerators and cool boxes.

The TecQuipment Thermoelectric Device Demonstrator shows how one of these devices work and tests its performance when connected in a choice of two modes:

- Heat to electricity for power generation when used in Seebeck mode – often used for thermoelectric generation and given the acronym 'TEG'.
- As an electrically powered heat pump when used in Peltier mode. Often used in thermoelectric cooling and given the acronym 'TEC'.

Students then learn to analyse its performance in both modes, analysing several factors including coefficient of performance (COP) and energy balance.

For the Seebeck tests, the equipment uses an external cold water source and variable power electric heater to create a temperature difference across the device. The device then converts this into an electrical potential difference (voltage). A switch allows tests with and without an electrical load. The load allows generated power to flow and be measured for a range of applied temperature gradients.

For the Peltier tests it also uses the electric heater, but with a small water storage tank and water pump, creating a stable, fixed-flow water supply. A variable voltage supply controls the electrical power into the device. A calibrated vessel allows students to measure the fixed water flow accurately, for calculation of the heat pumped at the 'cold' side of the device. This allows assessment of the device performance over a range of temperature gradients and electrical power inputs.

A hand-operated valve allows the user to change the water source without the need to reconnect pipes. Students need no tools to do the experiments.

Thermocouples measure temperatures near to the surface of the device and at the inlet and outlet of the water circuit.

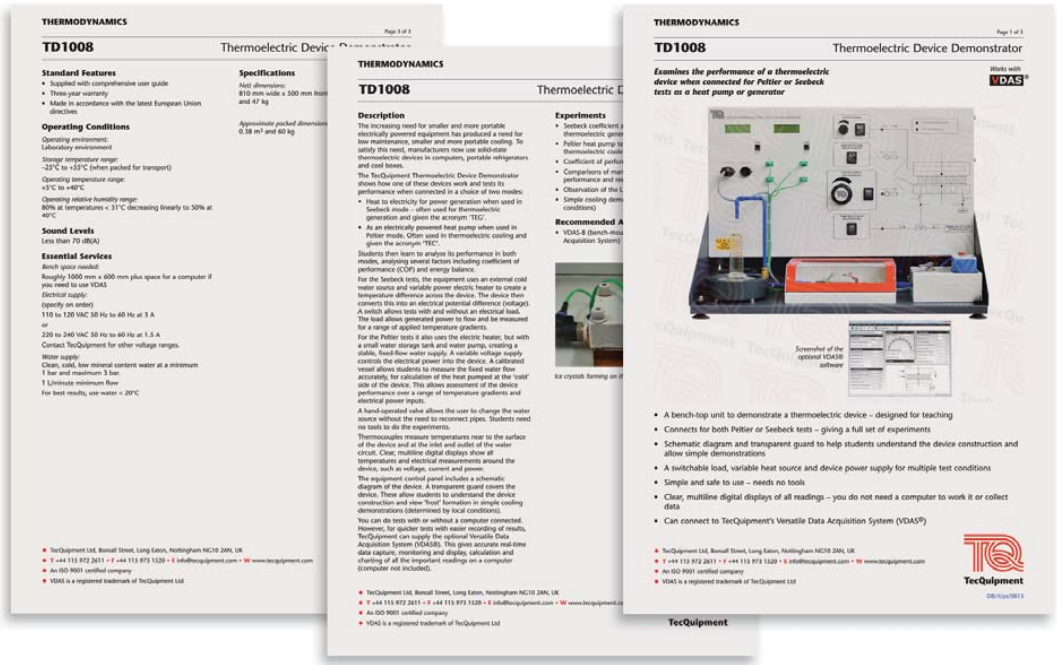
Clear, multiline digital displays show all temperatures and electrical measurements around the device, such as voltage, current and power.

The equipment control panel includes a schematic diagram of the device. A transparent guard covers the device. These allow students to understand the device construction and view 'frost' formation in simple cooling demonstrations (determined by local conditions).

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Recommended Ancillary:	Page
• VDAS-B (bench-mounted version of the Versatile Data Acquisition System)	32

For more information download our datasheets

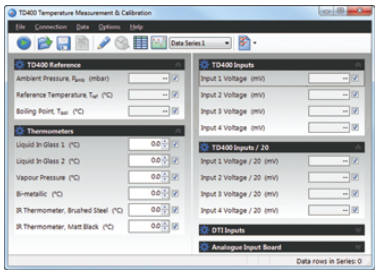


www.tecquipment.com

Temperature Measurement and Calibration (TD400)

Works with VDAS®

Studies the accuracy, linearity and important characteristics of popular temperature measuring devices



Screenshot of the optional VDAS® software

- Uses a platinum resistance thermometer as a reference to accurately calibrate the other devices
- Shows how electrical resistance devices and thermocouples work, their characteristics and how to connect them correctly to reduce measurement errors
- Hand-held digital thermometer for thermal infrared measurements
- Built-in water heater tank with protective guard and drain tap for safe experiments
- Built-in pressure sensor (barometer) with display of local water boiling temperature

EXPERIMENTS:

- **Simulation of two, three and four wire connection of a platinum resistance thermometer (PRT)**
- **Constant current and voltage sources**
- **Calibration and linearity of temperature measurement devices and temperature lag**
- **Thermal infrared temperature measurement on surfaces of different emissivity**
- **Thermocouples in series, parallel and the Seebeck effect**
- **Resistance in thermocouple circuits**

The Temperature Measurement and Calibration apparatus (TD400) fits on a desk or bench top. It includes eight different temperature measurement devices and shows their characteristics and how to calibrate them against a standard. The built-in precision reference sensor works as an accurate temperature reference. A display shows the temperature from the reference sensor and the local (barometric) pressure from the built-in pressure sensor. The display also calculates the local boiling point of water based on the barometric pressure.

Students add crushed ice (not supplied) to the insulated icebox and clean water to the fully guarded water heater tank. A carefully rated immersion heater in the tank heats the water steadily up to boiling, giving time to take accurate results. The water heater tank includes a water level float switch and a safety temperature cut-out switch to turn off the heater in case of low water level. The water heater tank has a drain tap for connection to a suitable container or local water drain. This helps students to change the heated water safely and quickly, reducing experiment time. As an extra reference, a liquid crystal temperature indicator strip on the front of the heater tank shows its temperature during experiments.

To the right of the temperature indicator strip, a window allows students to test the thermal infrared thermometer on a matt black or brushed steel surface of the heater tank. This shows limitations of infrared measurements caused by surfaces of different emissivity.

The equipment includes a thermowell that works with the gas (vapour) thermometer to show temperature lag.

Sockets on the front panel connect to electronic circuits and a multiline display that work with the electrical resistance and thermocouple devices. The sockets include resistances to simulate a resistance device and show the problems of adding resistances (for example, long wires) to your measuring circuits.

The electronic circuits also include:

- an amplifier to increase the output of the thermocouples for more useful voltage measurement.
- constant current and voltage sources, and a resistive bridge. These show the problems with different measurement circuits and power sources for electrical temperature measurement devices.

This equipment connects to TecQuipment's Versatile Data Acquisition System (VDAS®).

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Bench-mounted version (VDAS-B)	32

TecQuipment Document Packs

Making it clear for the customer

We send document packs with all TecQuipment products* which contain:

- **Packing contents list** (PCL) – shows you what parts we pack with the product.
- **Test certificate** – shows you that we've thoroughly tested the product before we send it to you.
- **User guides*** and **safety information** – show you how to use the product safely and learn how it works.

Some packs also include **compact discs** (CD-ROMs) with TecQuipment software (e.g. VDAS®).

At TecQuipment we continually improve our user guides so they include pictures of the products, clear diagrams and plain English text. This helps you to understand the product more clearly. Where necessary, the guides include theory, suggested experiments and typical results to help students understand what the product teaches.

*Some products may not need user guides, as their details are already shown in their parent product, for example the optional pumps on the MFP103.

Humidity Measurement (TE6)

Shows the principles of humidity measurement and compares different methods of measurement

- Allows students to compare different humidity-measuring instruments
- Includes air filter to reduce effects of air particles
- Includes mechanical and electronic instruments to measure temperature and humidity
- Variable flow-rate fan to show the effect of air flow on humidity measurement

EXPERIMENTS:

- **Measurement of air flow rate in a duct**
- **Measurement of relative humidity using different types of instrumentation**
- **Comparison of measurement methods for accuracy and ease of use**

The Humidity Measurement unit allows students to compare different methods of humidity measurement. It shows the differences in accuracy between instruments and their ease of use. It also includes a blower unit with a valve to show how air flow affects the different instruments.

A square cross-section duct supports a blower unit. The duct contains a selection of instruments to measure humidity and temperature. A clear window in the duct allows students to see the instruments. A removeable outlet grill gives access to the instruments. A fan in the blower unit above the duct supplies a flow of air and a hand-operated valve varies the air flow rate. This allows students to study the effect of air flow on the instruments. An orifice plate and manometer measure the flow rate. An air filter in the air flow path stops dirt or other particles affecting the instruments. The instruments include a whirling hygrometer that students use near the outlet of the duct, providing an extra method of measuring temperature and humidity.

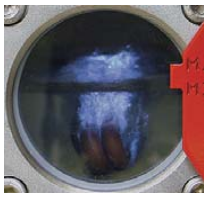
The back of the duct includes an extra port. It allows students to introduce low-pressure steam into the duct, to increase the range of experiments (steam generator not included).

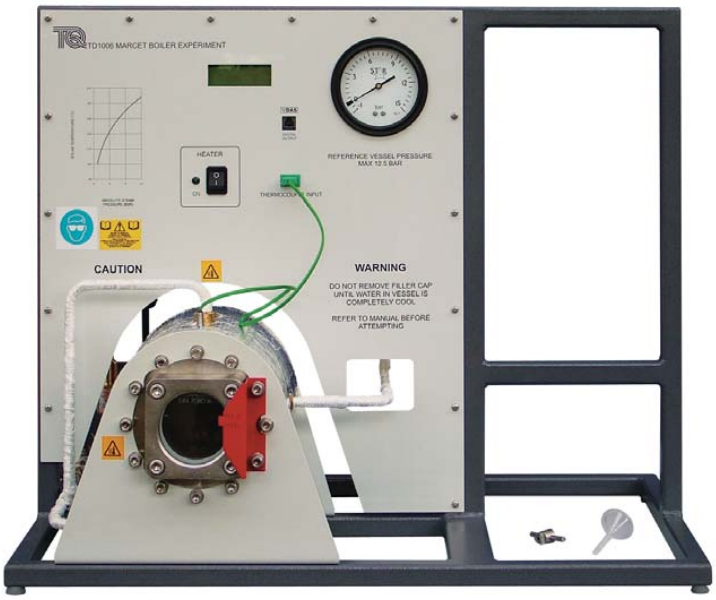
Marcet Boiler (TD1006)

Works with VDAS®

Shows the pressure and temperature relationship for saturated steam

Screenshot of the optional VDAS® software





- Proves the Antoine Equation for saturated steam
- Vessel (boiler) has viewing window to see the boiling process and the water level
- Simple and safe to use – includes temperature cut-out switches and a pressure-relief valve
- Electronic sensors measure boiler temperature and pressure – shown on a digital display in both SI and traditional units (including absolute values)

EXPERIMENTS:

- **Variation of saturated steam pressure with temperature**
- **Confirmation of the Antoine Equation**

The Marcet Boiler is a simple experiment to show the relationship between pressure and temperature for saturated (wet) steam for comparison with published results.

The apparatus consists of a rigid frame containing an insulated pressure vessel (boiler) and an instrumentation and control unit. The frame also has extra space for the optional VDAS® interface.

The electrically-heated boiler holds water. As the water temperature increases, so does the pressure in the boiler. A transducer and a thermocouple measure the boiler pressure and temperature. A digital display shows the values in both SI and traditional units (including absolute values).

The boiler includes a special-purpose glass window. It allows students to see the internal construction of the vessel, to see the boiling process and to check the water level.

For sound engineering practice, a mechanical Bourdon-type gauge also displays the pressure. It works independent of the electrical supply so the user can always see the pressure in the vessel.

The electrical heater has a thermostat to limit the maximum heater temperature. A pressure-relief valve limits the maximum boiler pressure. For safety, the equipment includes high-temperature pipe to direct any vented steam away from the working area to a suitable drain.

The design includes all possible safety and low-maintenance features, specially for educational use. TecQuipment has checked the corrosion-resistant, high-grade stainless steel boiler against the latest European safety standards.

You can do tests with or without a computer connected. However, for quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Frame-mounted version (VDAS-F)	32

Alternative Product:	Page
• Steam Motor and Energy Conversion Test Set (TD1050)	278

Steam Motor and Energy Conversion Test Set (TD1050)

Works with VDAS®

A laboratory-scale steam plant that shows fundamental thermodynamic principles of energy conversion and mechanical power measurement

Screenshot of the optional VDAS® software

- Introduces students to industry-standard methods of analysing steam plant performance, including Rankine cycle analysis and using the Willans line
- Uses a simple two-cylinder steam motor and an electrically heated boiler for easy understanding of the main parts of a steam plant
- Self-contained in a mobile frame that includes all instruments needed for experiments
- Allows students to copy the Marcet boiler experiment to prove the pressure-temperature relationship for saturated steam

EXPERIMENTS:

- **Steam plant performance, including the Rankine cycle analysis and the Willans line**
- **Marcet boiler experiment on saturated steam (pressure temperature relationship)**

A mobile laboratory-scale steam plant for experiments in thermodynamic principles. It helps students to understand:

- Thermodynamic laws of energy conservation
- Steady flow energy equation
- Thermal efficiency and the control surface
- Rankine cycle analysis
- The Willans line

A mobile frame contains all the parts of the test set. An electric pump draws from a reservoir (included) to deliver water to an electrically heated boiler. The boiler includes a safety valve, water level gauge and 'blow-down cock'. The boiler produces steam to turn a two-cylinder steam motor. The used steam from the motor outlet passes through a mains water-cooled condenser, then down to a waste tank or to a measuring vessel (supplied). TecQuipment supplies a stopwatch and thermometer to allow accurate measurement of the flow and temperature of the condensate (steam flow).

The equipment includes all instruments needed for the experiments. These include a band-brake dynamometer with a digital torque and speed display, to measure and display motor speed, torque and power. Thermocouples connect to a digital temperature display to measure and display temperatures at key points in the test set. A throttling calorimeter allows students to measure the dryness fraction of the steam.

Two mechanical gauges show the boiler and engine inlet pressures. A meter shows the electrical power supplied to the heaters in the boiler.

For quicker tests with easier recording of results, TecQuipment can supply the optional Versatile Data Acquisition System (VDAS®). This gives accurate real-time data capture, monitoring and display, calculation and charting of all the important readings on a computer (computer not included).

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Frame-mounted version (VDAS-F)	32

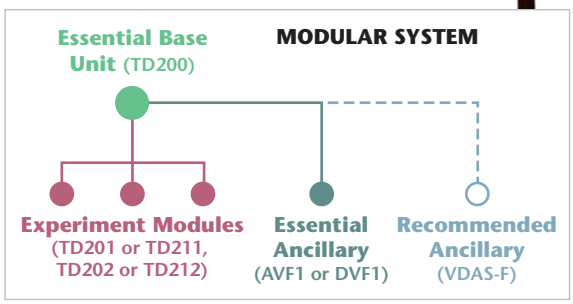
Alternative Product:	Page
• Marcet Boiler (TD1006)	277

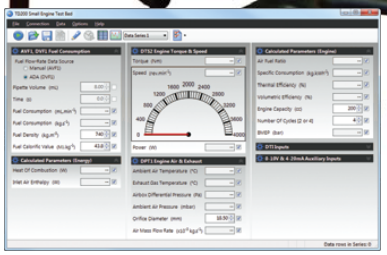
Small Engine Test Set (TD200)

Works with VDAS®

Versatile engine test bed and instrumentation for investigations into the fundamental features of internal combustion engines

Shown fitted with one of the optional engines





Screenshot of the optional VDAS® software

FEATURES:		BENEFITS:
Enables wide range of investigations into the characteristics of four-stroke, single-cylinder petrol and diesel engines	→	**Practical analysis of internal combustion engines**
Four-stroke diesel and four-stroke petrol engines available separately	→	Modular approach – separate test bed not required
Optional ancillaries available to extend range of study even further	→	**Flexible system allows for first, second and third-year studies**
Quick, convenient and accurate engine mounting and changeover	→	Saves time and ensures accurate results and repeatability
Robust, simple hydraulic dynamometer	→	**Eliminates need for large power supplies**
Instrumentation and test bed are separate to avoid vibration being transmitted to measuring devices	→	Ensures accuracy and repeatability of test results

Continued on next page

Small Engine Test Set (TD200)
Continued from previous page

EXPERIMENTS:

A comprehensive range of investigations into the features of single-cylinder, four-stroke petrol and diesel engines including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**
- **Willans line for a diesel engine**

By using the recommended ancillaries and engine choices students can investigate more features including:

- **Plotting p-θ and p-V diagrams**
- **Engine cycle analysis**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

A versatile hydraulic engine test bed with comprehensive instrumentation. The equipment requires minimum services, installation and outlay. When used with one of TecQuipment's optional single-cylinder engines, it safely and effectively enables study and demonstrations of the most important features of the engine. In addition, optional ancillaries are available to extend the range of study, demonstrations and investigations even further.

The equipment is fully compatible with TecQuipment's optional Versatile Data Acquisition System (VDAS®). This enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a suitable computer (computer not included) making tests quick and reliable.

The main components of the test set are a:

- heavy fabricated portable bed, and
- a bench-mounted instrumentation frame.

The bed sits on a trolley for portability. It includes a robust, precision-machined, trunnion-mounted hydraulic dynamometer. A significant advantage of using a hydraulic dynamometer is that no large electrical supplies are required as the engine power is dissipated into the water used to load the dynamometer.

The dynamometer applies load according to the flow rate and level of water in the casing. An accurate needle valve controls the flow rate and level. An electronic load cell measures torque. The engines (available separately) are supplied pre-mounted on a sturdy precision base plate. When the engine is initially mounted onto the test bed or exchanged with an alternative engine, dowels and slots locate the engine quickly, accurately and reliably. To enable students to measure air flow, an air box and orifice plate are located underneath the engine bed on the trolley.

The instrumentation is mounted in a sturdy frame. The frame has a single power inlet and several power outlets to supply the various display units (either those provided as standard or those provided as optional extras). The instrumentation and test bed are separate in order to avoid vibration being transmitted from the engine to the measuring devices.

The engines (available separately) include an exhaust thermocouple, dynamometer coupling, hoses and fittings. TecQuipment can also supply the engines with pre-modified cylinder heads and cranks for connection to TecQuipment's Engine Cycle Analyser (ECA100, available separately). Each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engines can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

Available Experiment Modules:	Page
• Four-Stoke Petrol Engine (TD201 or TD211)	281 /283
• Four-Stroke Diesel Engine (TD202 or TD212)	282 /284

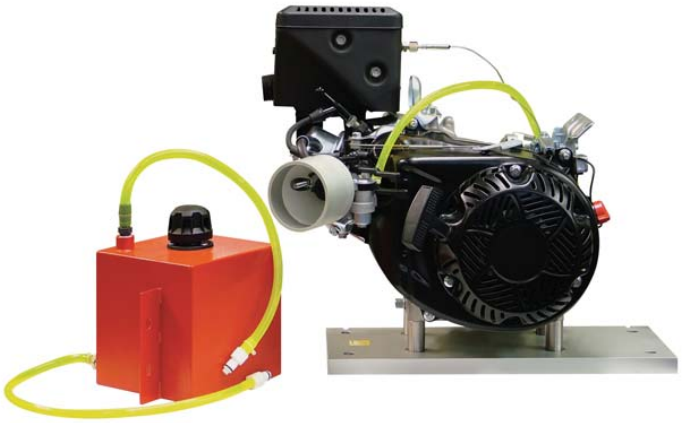
Essential Ancillaries:	Page
• Manual Volumetric Fuel Gauge (AVF1) **or**	290
• Automatic Volumetric Fuel Gauge with Digital Read-Out (DVF1)	291

Recommended Ancillary:	Page
• Versatile Data Acquisition System – Frame-mounted version (VDAS-F)	32

Alternative Product:	Page
• Regenerative Engine Test Set (TD300)	285

Four-Stroke Petrol Engine (TD201)

A four-stroke, single-cylinder petrol engine for use with TecQuipment's Small Engine Test Set (TD200)



- High-quality yet cost-effective engine specially modified for educational use
- Wide range of investigations possible
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Small Engine Test Set (TD200), investigations into the performance and characteristics of a four-stroke petrol engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**

High-quality and cost-effective four-stroke, single-cylinder petrol engine for use with TecQuipment's Small Engine Test Set (TD200). Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test set dynamometer and all essential hoses and fittings. In addition, each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engine can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine is mounted on a sturdy precision bed plate. The bed plate has dowels and slots which align and locate it accurately with the dynamometer test set. This minimises the time spent replacing one engine with another.

Essential Base Unit:	Page
• Small Engine Test Set (TD200)	279

Alternative Products:	Page
• Four-Stroke Diesel Engine (TD202)	282
• Modified Four-Stroke Petrol Engine (TD211)	283
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Petrol Engine (TD301)	287
• Four-Stroke Diesel Engine (TD302)	288

Installation and commissioning

TecQuipment is pleased to offer a world-class installation and commissioning service for all of our equipment. Our skilled engineers can professionally and safely install your new equipment to the highest standard.

Four-Stroke Diesel Engine (TD202)

A four-stroke, single-cylinder diesel engine for use with TecQuipment's Small Engine Test Set (TD200)

- High-quality yet cost-effective engine specially modified for educational use
- Wide range of investigations possible
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Small Engine Test Set (TD200), investigations into the performance and characteristics of a four-stroke diesel engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**
- **Willans line**

High-quality, cost-effective four-stroke, single-cylinder diesel engine for use with TecQuipment's Small Engine Test Set (TD200). Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test bed dynamometer and all essential hoses and fittings.

In addition, each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engine can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine is mounted on a sturdy precision bed plate. The bed plate has dowels and slots which align and locate it accurately with the dynamometer test set. This minimises the time spent replacing one engine with another.

Essential Base Unit:	Page
• Small Engine Test Set (TD200)	279

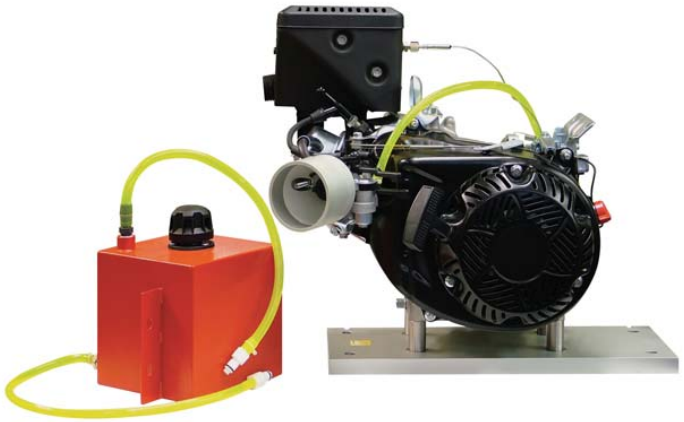
Alternative Products:	Page
• Four-Stroke Petrol Engine (TD201)	281
• Modified Four-Stroke Petrol Engine (TD211)	283
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Petrol Engine (TD301)	287
• Four-Stroke Diesel Engine (TD302)	288

Talk to our experts

Our dedicated Sales team can help you choose the equipment best suited for your needs, answer your questions and progress your order.

Modified Four-Stroke Petrol Engine (TD211)

A four-stroke, single-cylinder petrol engine with modified cylinder head and crank, for use with TecQuipment's Small Engine Test Set (TD200)



- Modified for use with optional Pressure (ECA101) and Crank Angle (ECA102) Transducers and Engine Cycle Analyser (ECA100)
- Wide range of investigations possible
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Small Engine Test Set (TD200), investigations into the performance and characteristics of a four-stroke petrol engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**

When used with TecQuipment's Small Engine Test Set (TD200), Cylinder Head Pressure Transducer (ECA101), Crank Angle Encoder (ECA102) and Engine Cycle Analyser (ECA100), students can investigate further features including:

- **Plotting p-θ and p-V diagrams**
- **Engine cycle analysis**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

High-quality and cost-effective four-stroke, single-cylinder petrol engine for use with TecQuipment's Small Engine Test Set (TD200). Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test set dynamometer and all essential hoses and fittings. In addition, each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engines can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine has a modified cylinder head and crank. These allow use with the Cylinder Head Pressure Transducer (ECA101 available separately) and the Crank Angle Encoder (EA102 available separately). These can then connect to the Engine Cycle Analyser (ECA100 available separately) to extend the range of experiments possible.

The engine is mounted on a sturdy precision bedplate. The bedplate has dowels and slots which align and locate it accurately with the dynamometer test set. This minimises the time spent replacing one engine with another.

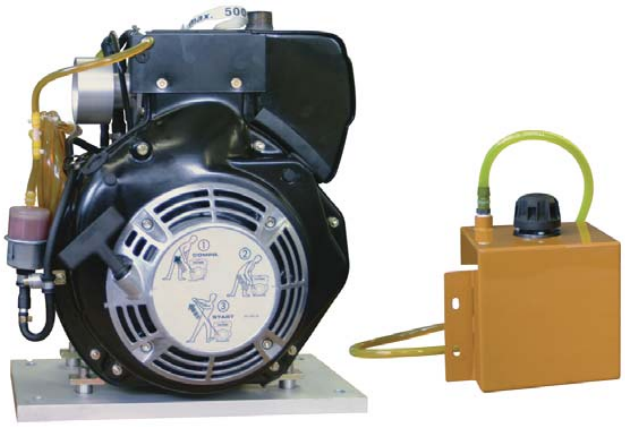
Essential Base Unit:	Page
• Small Engine Test Set (TD200)	279

Recommended Ancillaries:	Page
• Engine Cycle Analyser (ECA100)	292
• Cylinder Head Pressure Transducer (ECA101)	
• Crank Angle Encoder (ECA102)	

Alternative Products:	Page
• Four-Stroke Petrol Engine (TD201)	281
• Four-Stroke Diesel Engine (TD202)	282
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Petrol Engine (TD301)	287
• Four-Stroke Diesel Engine (TD302)	288

Modified Four-Stroke Diesel Engine (TD212)

A four-stroke, single-cylinder diesel engine with modified cylinder head and crank, for use with TecQuipment's Small Engine Test Set (TD200)



- Modified for use with optional Pressure (ECA101) and Crank Angle (ECA102) Transducers and Engine Cycle Analyser (ECA100)
- Wide range of investigations possible
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Small Engine Test Set (TD200), investigations into the performance and characteristics of a four-stroke diesel engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**
- **Willans line**

When used with TecQuipment's Small Engine Test Set (TD200), Cylinder Head Pressure Transducer (ECA101), Crank Angle Encoder (ECA102) and Engine Cycle Analyser (ECA100), students can investigate further features including:

- **Plotting p-θ and p-V diagrams**
- **Engine cycle analysis**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

High-quality and cost-effective four-stroke, single-cylinder diesel engine for use with TecQuipment's Small Engine Test Set (TD200). Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test bed dynamometer and all essential hoses and fittings. In addition, each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engine can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine has a modified cylinder head and crank. These allow use with the Cylinder Head Pressure Transducer (ECA101 available separately) and the Crank Angle Encoder (EA102 available separately). These can then connect to the Engine Cycle Analyser (ECA100 available separately) to extend the range of experiments possible.

The engine is mounted on a sturdy precision bed plate. The bed plate has dowels and slots which align and locate it accurately with the dynamometer test set. This minimises the time spent replacing one engine with another.

Essential Base Unit:	Page
• Small Engine Test Set (TD200)	279

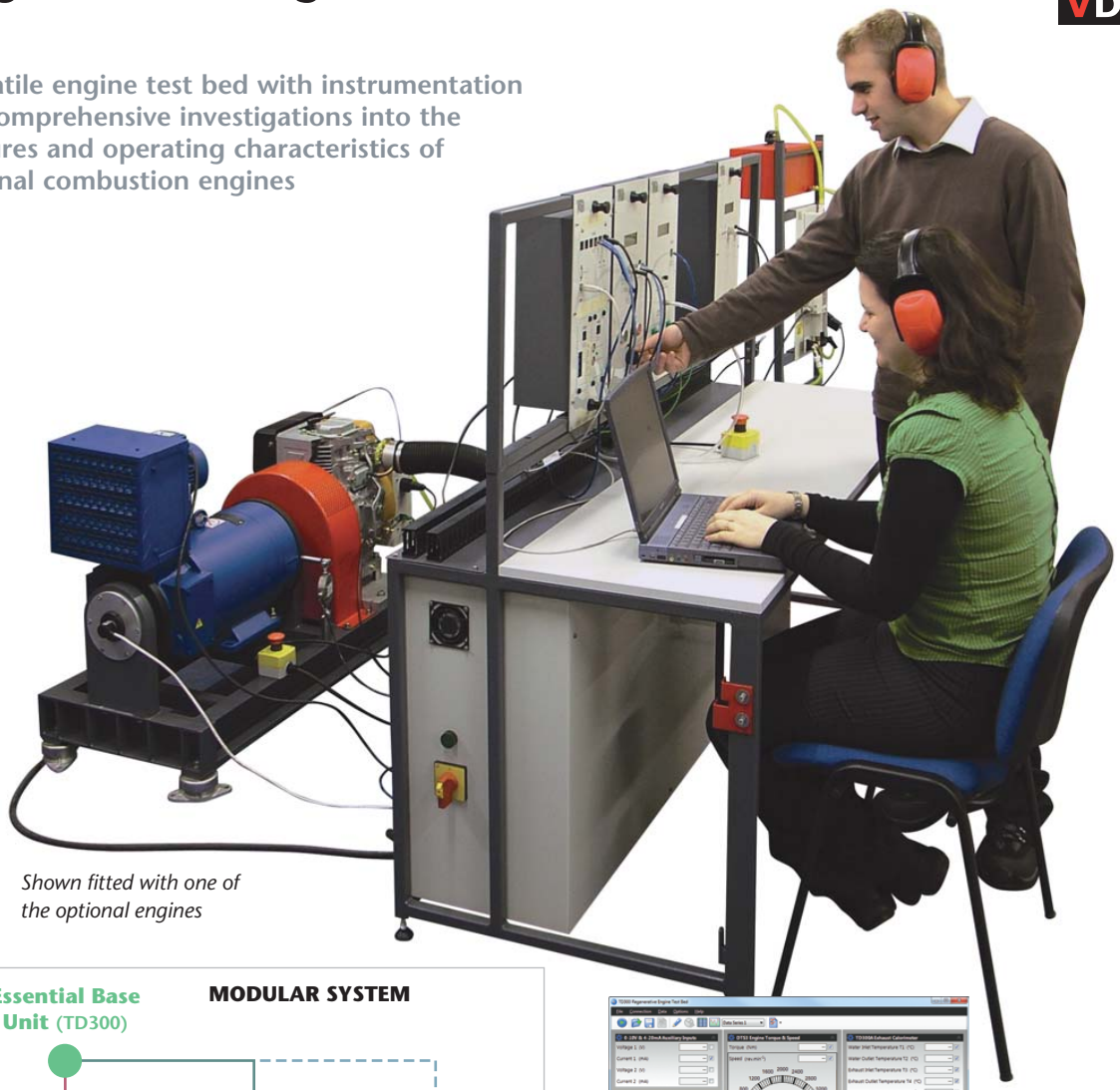
Recommended Ancillaries:	Page
• Engine Cycle Analyser (ECA100)	292
• Cylinder Head Pressure Transducer (ECA101)	
• Crank Angle Encoder (ECA102)	

Alternative Products:	Page
• Four-Stroke Petrol Engine (TD201)	281
• Four-Stroke Diesel Engine (TD202)	282
• Modified Four-Stroke Petrol Engine (TD211)	283
• Four-Stroke Petrol Engine (TD301)	287
• Four-Stroke Diesel Engine (TD302)	288

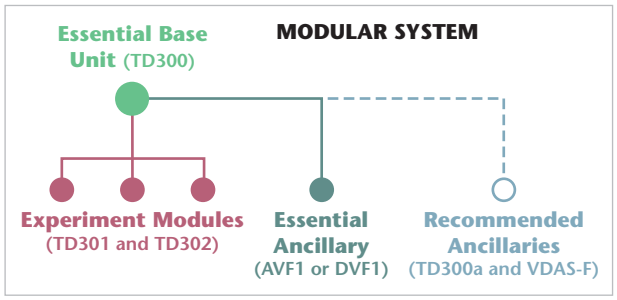
Regenerative Engine Test Set (TD300)

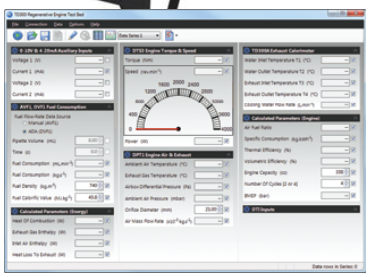
Works with VDAS®

Versatile engine test bed with instrumentation for comprehensive investigations into the features and operating characteristics of internal combustion engines



Shown fitted with one of the optional engines





Screenshot of the optional VDAS® software

FEATURES:		BENEFITS:
Enables wide range of investigations into the characteristics of four-stroke single-cylinder petrol and diesel engines	→	**Practical analysis of internal combustion engines**
For use with engines up to 10 kW: fourstroke diesel and four-stroke petrol engines (available separately)	→	Modular approach – separate test bed not required
Optional ancillaries available to extend range of study even further	→	**Flexible system allows for first, second and third-year studies**
Quick, convenient and accurate engine mounting and changeover	→	Saves time and ensures accurate results and repeatability
Uses four-quadrant drive to start and load the engine, giving excellent stability	→	**Increased safety and ease of operation**

Continued on the next page

Regenerative Engine Test Set (TD300)
Continued from previous page

EXPERIMENTS:

A comprehensive range of investigations into the features of single-cylinder, four-stroke petrol and diesel engines including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**

By using the recommended ancillaries and engine choices,students can investigate more features including:

- **Plotting p-θ and p-V diagrams**
- **Engine cycle analysis**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

A versatile regenerative engine test set with comprehensive controls and instrumentation. When used with one of TecQuipment's optional single-cylinder engines (rated up to 10 kW), it safely and effectively enables study and demonstrations of the features and characteristics of the engine. In addition, optional ancillaries are available to extend the range of study, demonstrations and investigations even further.

The equipment is fully compatible with TecQuipment's optional Versatile Data Acquisition System (VDAS®). This enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a suitable computer (computer not included) making tests quick and reliable.

The main components of the system are a:

- heavy fabricated floor-mounting bed,
- control console with instrumentation frame, and a
- frame which supports the fuel tank and fuel gauge.

The bed is held on anti-vibration mounts. It includes a robust trunnion-mounted d.c. machine. An electronic load cell connected to the machine measures the driving torque of the test engine. The engines (available separately) are supplied pre-mounted on a sturdy precision base plate. When the engine is initially mounted onto the test bed or exchanged with an alternative engine, dowels and slots locate the engine quickly, accurately and reliably.

Each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engines can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The control console has an electrical cabinet which houses a four-quadrant drive to start and load the engine. The motor can also be used to drive the engine while the fuel and ignition are off, so students can establish frictional losses. The control console includes an air box and orifice plate to enable students to measure air flow. The instrumentation and display units are mounted on a sturdy frame, which is part of the control console. The control console also includes a convenient work top for use as a writing desk, or for positioning other equipment such as a computer (computer not included).

The control console and test bed are separate in order to avoid vibration being transmitted from the engine to the measuring devices. In addition, it allows the instrumentation to be thermally and acoustically screened from the test bed, using suitable shielding or a wall. The engines (available separately) include an exhaust thermocouple, dynamometer coupling, colour-coded fuel tank, hoses and fittings. They also have modified cylinder heads and cranks for connection to TecQuipment's Engine Cycle Analyser (ECA100, available separately). An Exhaust Gas Calorimeter (TD300a) is also available separately to enable students to measure energy lost through exhaust gases and to determine the energy balance of the engine.

Available Experiment Modules:	Page
• Four-stroke petrol engine (TD301)	287
• Four-stroke diesel engine (TD302)	288

Essential Ancillary:	Page
• Manual Volumetric Fuel Gauge (AVF1)	290
or	
• Automatic Volumetric Fuel Gauge with Digital Read-out (DVF1)	291

Recommended Ancillaries:	Page
• Versatile Data Acquisition System – Frame-mounted version (VDAS-F)	32
• Exhaust Gas Calorimeter (TD300a)	289

Alternative Product:	Page
• Small Engine Test Set (TD200)	279

Four-Stroke Petrol Engine (TD301)

A four-stroke, single-cylinder petrol engine with modified cylinder head and crank, for use with TecQuipment's Regenerative Engine Test Set (TD300)

- Modified for use with optional Pressure (ECA101) and Crank Angle (ECA102) Transducers and Engine Cycle Analyser (ECA100)
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Regenerative Engine Test Set (TD300), investigations into the performance and characteristics of a four-stroke petrol engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**

When used with TecQuipment's Regenerative Engine Test Set (TD300), Cylinder Head Pressure Transducer (ECA101), Crank Angle Encoder (ECA102) and Engine Cycle Analyser (ECA100), students can investigate further features including:

- **Plotting p-θ and p-V diagrams**
- **The thermodynamic cycle of an internal combustion engine**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

High-quality, cost-effective four-stroke, single-cylinder petrol engine for use with TecQuipment's Regenerative Engine Test Set (TD300).

Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test set dynamometer and all essential hoses and fittings. In addition, each engine includes a colour-coded fuel tank with self-sealing couplings. The couplings ensure the engine can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine has a modified cylinder head and crank. These allow use with the Cylinder Head Pressure Transducer (ECA101 available separately) and the Crank Angle Encoder (ECA102 available separately). These can then connect to the Engine Cycle Analyser (ECA100 available separately) to extend the range of experiments possible.

The engine is mounted on a sturdy precision bed plate. The bed plate has dowels and slots which align and locate it accurately with the dynamometer. This minimises the time spent replacing one engine with another.

If a mains power failure or emergency stop occurs, interlocking relays on the engine immediately cut the ignition. In addition, to prevent transmission of accidentally ignited flames or explosions, the air inlet includes a flame arrestor.

Essential Base Unit:	Page
• Regenerative Engine Test Set (TD300)	285

Recommended Ancillaries:	Page
• Engine Cycle Analyser (ECA100)	292
• Cylinder Head Pressure Transducer (ECA101)	
• Crank Angle Encoder (ECA102)	

Alternative Products:	Page
• Four-Stroke Petrol Engine (TD201)	281
• Four-Stroke Diesel Engine (TD202)	282
• Modified Four-Stroke Petrol Engine (TD211)	283
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Diesel Engine (TD302)	288

Four-Stroke Diesel Engine (TD302)

A four-stroke, single-cylinder diesel engine with modified cylinder head and crank, for use with TecQuipment's Regenerative Engine Test Set (TD300)

- Modified for use with optional Pressure (ECA101) and Crank Angle (ECA102) Transducers and Engine Cycle Analyser (ECA100)
- Quickly and accurately mounts on the test bed
- Includes colour-coded fuel tank with quick-release couplings

EXPERIMENTS:

When used with TecQuipment's Regenerative Engine Test Set (TD300), investigations into the performance and characteristics of a four-stroke diesel engine, including:

- **Torque, speed and power relationship**
- **Brake mean effective pressure**
- **Engine performance curves**
- **Air and fuel consumption**
- **Volumetric and thermal efficiencies**

When used with TecQuipment's Regenerative Engine Test Set (TD300), Cylinder Head Pressure Transducer (ECA101), Crank Angle Encoder (ECA102) and Engine Cycle Analyser (ECA100) students can investigate further features including:

- **Plotting p-θ and p-V diagrams**
- **The thermodynamic cycle of an internal combustion engine**
- **Indicated mean effective pressure**
- **Indicated power**
- **Comparison of brake and indicated mean effective pressures**
- **Mechanical efficiency of the engine**

High-quality, cost-effective four-stroke, single-cylinder diesel engine for use with TecQuipment's Regenerative Engine Test Set (TD300). Adapted specially for education to enable effective laboratory testing and demonstrations, the engine includes an exhaust thermocouple, a half-coupling to link to the test bed dynamometer, and all essential hoses and fittings. In addition, each engine includes a colour-coded fuel tank with self-sealing couplings.

The couplings ensure the engine can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel. For convenience and safety, the fuel tank can be removed for filling or for storage in a fuel locker when not in use. Removing the fuel tank also prevents unauthorised use of the equipment.

The engine has a modified cylinder head and crank. These allow use with the Cylinder Head Pressure Transducer (ECA101 available separately) and the Crank Angle Encoder (ECA102 available separately). These can then connect to the Engine Cycle Analyser (ECA100 available separately) to extend the range of experiments possible.

The engine is mounted on a sturdy precision bed plate. The bed plate has dowels and slots which align and locate it accurately with the dynamometer test set. This minimises the time spent replacing one engine with another.

If a mains power failure or emergency stop occurs, interlocking relays on the engine immediately cut the fuel supply. In addition, to prevent transmission of accidentally ignited flames or explosions, the air inlet includes a flame arrestor.

Essential Base Unit:

	Page
• Regenerative Engine Test Set (TD300)	285

Recommended Ancillaries:

	Page
• Engine Cycle Analyser (ECA100)	292
• Cylinder Head Pressure Transducer (ECA101)	
• Crank Angle Encoder (ECA102)	

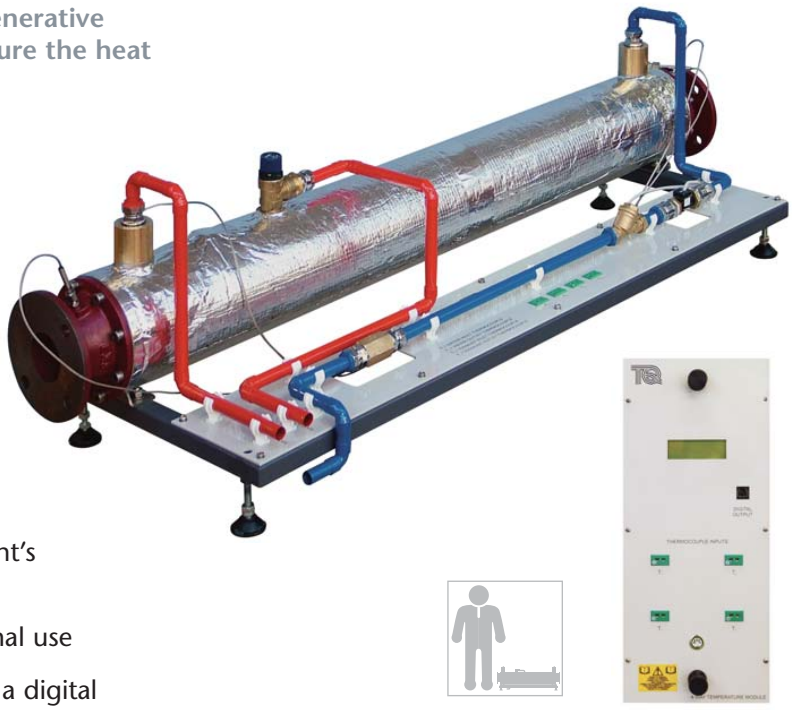
Alternative Products:

	Page
• Four-Stroke Petrol Engine (TD201)	281
• Four-Stroke Diesel Engine (TD202)	282
• Modified Four-Stroke Petrol Engine (TD211)	283
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Petrol Engine (TD301)	287

Exhaust Gas Calorimeter (TD300a)

Works with VDAS®

For use with TecQuipment's Regenerative Engine Test Set (TD300) to measure the heat content of engine exhaust gases



- Safely and effectively measures the heat content of TecQuipment's test engine exhaust gases
- Specially designed for educational use
- Uses electronic transducers and a digital display for ease of use and accuracy
- Separate instrumentation unit conveniently mounts on test set console frame

EXPERIMENTS:

When used with TecQuipment's Regenerative Engine Test Set (TD300), the Exhaust Gas Calorimeter enables students to assess the heat lost to exhaust in the energy balance for single-cylinder, four-stroke petrol (TD301) and diesel (TD302) engines.

An exhaust gas calorimeter for use with TecQuipment's Regenerative Engine Test Set (TD300). The equipment measures the heat content of exhaust gases and enables students to determine the energy lost to exhaust in the energy balance for single-cylinder, four-stroke petrol (TD301, available separately) and diesel (TD302, available separately) engines.

The main components of the Exhaust Gas Calorimeter are:

- Gas-to-water shell and multi-tube heat exchanger
- Control valve
- Instrumentation unit

The heat exchanger is mounted on a sturdy base plate. Exhaust gases from the test engine mounted on the test set flow through the tubes. A jacket of constantly flowing cooling water surrounds the tubes, and the heat content of the gases is assessed by measuring the cooling water flow rate and the inlet and outlet temperatures.

A hand-operated valve, which mounts on the control console of the test set, controls the flow of cooling water through the heat-exchanger jacket. Thermocouples measure the temperature of gas and water at the inlet and outlet. A turbine flow meter measures the flow rate. For safety, the heat exchanger also includes a pressure-relief valve in case insufficient cooling water is flowing.

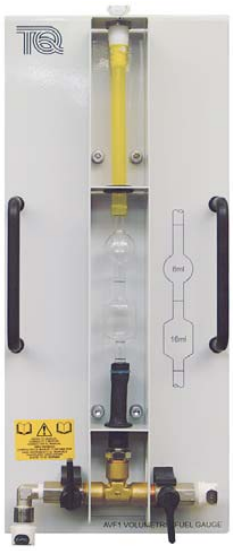
The instrumentation consists of a digital, four-channel temperature and flow display unit. This unit mounts on the instrumentation rail of the test set console frame and allows easy and accurate display and monitoring of data. In addition, the Exhaust Gas Calorimeter is fully compatible with TecQuipment's optional Versatile Data Acquisition System (VDAS®).

VDAS® enables accurate real-time data capture, monitoring and display, calculation and charting of all relevant parameters on a suitable computer (computer not included) making tests quick and reliable.

Ancillary for:	Page
• Regenerative Engine Test Set (TD300)	285

Manual Volumetric Fuel Gauge (AVF1)

Convenient and accurate fuel gauge for use with TecQuipment engine test sets



- Volumetric fuel gauge for use with TecQuipment's Small Engine Test Set (TD200) and Regenerative Engine Test Set (TD300) and engines
- Convenient and accurate measurement of fuel consumption
- Easy to install and use
- Self-sealing couplings enable quick and efficient connection and disconnection of fuel lines with minimum loss or spillage of fuel

An easy-to-use, accurate volumetric fuel gauge for use with TecQuipment's engine test sets and engines (TD200 and TD300 series).

The fuel gauge consists of a precision-calibrated two-bulb pipette and control valves. It mounts on the instrumentation frame of the test set and connects between the fuel tank and the engine under test. All connections are made using self-sealing couplings. The couplings ensure the fuel gauge can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel.

Fuel enters the pipette from the tank. The fuel supply from the tank is then cut off via a valve so that the engine draws fuel from the pipette only. Students record the time taken to consume a set volume of fuel, from which they can accurately calculate the flow rate.

Suitable for use with petrol or diesel.

Ancillary for:	Page
• Small Engine Test Set (TD200)	279
• Regenerative Engine Test Set (TD300)	285

Essential Ancillary:	Page
• Stopwatch (SW1)	30

Equipment training

We offer a comprehensive equipment training programme that includes start-up, operation, shut-down, safety and maintenance procedures. Training programmes can be delivered at your premises or our manufacturing facility in the UK.

Automatic Volumetric Fuel Gauge with Digital Read-Out (DVF1)

Works with VDAS®

Automatic fuel gauge for use with TecQuipment's Engine Test Sets (TD200 and TD300 series)

- Accurately and automatically calculates fuel consumption
- Directly displays fuel consumption on digital read-out
- Can cycle continuously or run once only
- Self-sealing couplings enable quick and efficient connection and disconnection of fuel lines with minimum loss or spillage of fuel

An automatic volumetric fuel gauge for use with TecQuipment's Small Engine Test Set (TD200) and Regenerative Engine Test Set (TD300). The gauge accurately calculates fuel consumption and displays it directly on a digital read-out.

The Automatic Volumetric Fuel Gauge consists of a:

- precision fuel gauge with sensors;
- digital read-out (display) unit which shows fuel consumption and allows data to be transferred to a suitable PC (not supplied) via the TecQuipment data acquisition system (VDAS®).

The gauge mounts on the instrumentation frame of the test set and connects between the fuel tank and the engine under test. Fuel enters the fuel gauge from the fuel tank. A solenoid valve automatically shuts off the fuel supply from the tank so that the engine draws the fuel from the fuel gauge. Sensors on the fuel gauge record the time taken to consume a set volume of fuel, and the display unit automatically calculates the fuel consumption.

The solenoid valve then opens and the fuel gauge refills. The unit can be set to continuously cycle in this manner or cycle once only. All connections are made using self-sealing couplings. The couplings ensure the fuel gauge can be connected and disconnected quickly and efficiently with minimum loss or spillage of fuel.

Suitable for use with petrol or diesel.

Ancillary for:	Page
• Small Engine Test Set (TD200)	279
• Regenerative Engine Test Set (TD300)	285

Product development

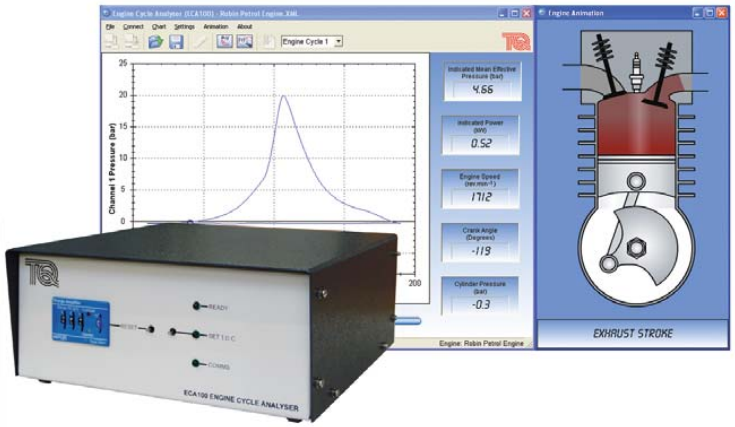
The information contained in this publication has been carefully prepared and is correct at the time of printing. TecQuipment, however, operates a continual product improvement process and therefore reserves the right to modify and update equipment to ensure it continues to meet your needs.

For the latest information on all our products please visit our website at:

www.tecquipment.com

Engine Cycle Analyser (ECA100)

Hardware and software to measure internal combustion engine cylinder pressure and crank angle



- For use with TecQuipment's Small Engine Test Set (TD200) and Regenerative Engine Test Set (TD300) and engines
- Includes powerful Windows®-based software specially designed for educational use
- Automatic calculation and real-time display of p-θ plots and p-V plots and other important parameters
- Snap-shot, replay and animation functions
- Accurate, clear animations of crank, piston, inlet and exhaust valve positions help students visualise the engine cycle

EXPERIMENTS:

When used with suitable test engines, the analyser allows investigations into a variety of internal combustion engine characteristics, including:

- **The thermodynamic cycle of an internal combustion engine.**
- **Calculation of indicated mean effective pressure and indicated power.**
- **Comparison of indicated mean effective pressure and brake mean effective pressure.**
- **Mechanical efficiency of the test engine.**
- **Further work using exported data such as combustion analysis.**

Ideal for student experiments, laboratory demonstrations or project work,TecQuipment's Engine Cycle Analyser enables students to investigate a variety of engine performance characteristics.

The versatile equipment consists of both hardware and software specially designed for educational use. It enables students to investigate the relationship between crank angle or volume and the cylinder pressure in an internal combustion engine. The equipment is primarily for use with TecQuipment engine test sets and engines (TD200 and TD300 series) but it can also be used with other engines fitted with compatible cylinder head transducers and crank angle encoders.

The equipment consists of a hardware unit with connectors and leads, plus Windows®-based data acquisition and analysis software. The hardware consists of a microprocessor-based signal conditioning unit with high-speed PC interface, housed in a rugged, protective enclosure. It accepts and conditions signals from the Cylinder Head Pressure Transducer (ECA101) and Crank Angle Encoder (ECA102), available separately. The cylinder pressure input includes a precision charge amplifier with a digital thumb-wheel for calibration. As well as crank angle position, the signal from the Crank Angle Encoder is also used to determine engine speed.

Note: Although interchangeable between engines, TecQuipment recommends that you buy and fit one ECA101 and one ECA102 to each of your test engines. This will reduce setting up time and any chance of damage.

The output from the hardware unit connects to a computer (computer not included) running the Engine Cycle Analyser software. The hardware unit includes LED indicators to show the processor readiness, encoder top dead-centre position and PC communication status.

The software provides real-time display of pressure versus crank angle (p-θ)and pressure versus volume (p-V) plots. It performs calculations on the data to accurately display indicated mean effective pressure (IMEP) and indicated power for comparison with brake mean effective pressure (BMEP), and brake power to determine the mechanical efficiency of the test engine.

The software has useful snap-shot, replay and animation functions to help students visualise and better understand the engine cycle. The snap-shot and replay allow students to capture several engine cycles and study them using an animation showing the relative position of the crank, piston, inlet and exhaust valves. The software also allows students to create and recall engine configuration files for convenient entry of test engine data needed for calculations such as crank radius and engine swept volume. Data can also be exported to other software for further analysis.

Essential Ancillaries:

- Cylinder Head Pressure Transducer (ECA101)*
- Crank Angle Encoder (ECA102)*
- Suitable Computer

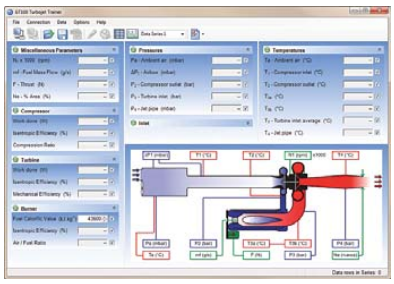
*** TecQuipment also offers a complete package (the ECA100S). This includes the ECA100, one ECA101 and one ECA102.**

Ancillary for:

	Page
• Modified Four-Stroke Petrol Engine (TD211)	283
• Modified Four-Stroke Diesel Engine (TD212)	284
• Four-Stroke Petrol Engine (TD301)	287
• Four-Stroke Diesel Engine (TD302)	288

Turbojet Trainer (GT100) ADA

Allows detailed experiments that show how a single-shaft gas turbojet works, and tests its performance



Screenshot of the GT100 software

- Uses industrial parts, powered by kerosene for realistic tests and results
- Fully interlocked starting procedure and automatic shut-down
- Automatic data acquisition (ADA) included (supplied with software)
- Well-proven design – versions installed in universities, technical colleges and military training establishments in 30 countries worldwide

EXPERIMENTS:

Various investigations into single-shaft turbine thrust jet performance, including:

- **Effect on thrust generation by variation in rotational speed and propelling nozzle area**
- **Isentropic, polytropic and mechanical efficiencies of compressor, combustion chamber and turbine**
- **Pressure ratios of turbine, compressor and non-dimensional characteristics**
- **Combustion chamber pressure losses and combustion efficiencies**
- **Specific fuel consumption, thermal efficiency, air standard cycle, work ratio and heat balance**

A self-contained, fully instrumented, educational single-shaft gas turbine. Powered by kerosene, the experimental abilities of this high-quality apparatus enable comprehensive, practical investigations into the principles and performance of single-shaft gas turbines.

It consists of a steel frame that holds a gas generator, combustion chamber, oil and fuel tanks, pumps, ancillaries and guards. Above these is an instrumentation and control panel with schematic diagram. The clearly labelled front panel with mimic diagram includes the instrument displays, controls and warning lights.

Air passes into an air box, into a compressor, then into the combustion chamber. A pump transfers fuel from the fuel tank to spray through a special nozzle into the combustion chamber. A high-energy spark ignites the air and fuel mixture which flows to a radial flow turbine, then a variable area propelling nozzle. The exhaust gases then discharge to a suitable exhaust system.

The combustion chamber gives excellent combustion, low pressure loss and good flame stability over a wide range of conditions. A fuel flow-control valve on the instrumentation and control panel regulates the speed. This design reduces the possibility of over-speed. The equipment has an oiling system including filters and water-cooled oil.

Starting is semi-automatic and fully interlocked, controlled by a start-up and shut-down logic system. For protection of the equipment and user, it shuts down the turbine if the user makes an error. Digital indicators show shaft speed, pressures, temperatures and fuel flow. Analogue indicators show fuel level, fuel pressure, oil temperature, oil pressure and hours run.

This equipment connects to a suitable computer (computer not included) and includes dedicated, user-friendly data acquisition software. This allows students to display, graph and analyse all relevant variables, and save their results for later analysis. The data acquisition system includes adaptors and leads, and the software is supplied on CD-ROM.

Supplied with the equipment is a detailed textbook that covers the theory and use of gas turbines.

Recommended Ancillary:

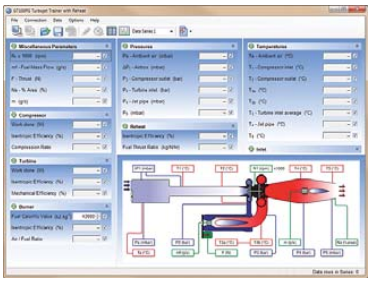
- Suitable computer

Alternative Products:

	Page
• Turbojet Trainer with Reheat (GT100RS)	294
• Two-Shaft Gas Turbine (GT185)	296

Turbojet Trainer with Reheat (GT100RS) ADA

Allows detailed experiments that show how a single-shaft gas turbojet with reheat (afterburner) works, and tests its performance



Screenshot of the GT100RS software

- Uses industrial parts, powered by kerosene for realistic tests and results
- Fully interlocked starting procedure and automatic shut-down
- Automatic Data Acquisition (ADA) included (supplied with software)
- Well proven design – versions installed in universities, technical colleges and military training establishments in 30 countries worldwide

EXPERIMENTS:

Turbine, reheat and nozzle tests to find key performance information such as:

- **Specific thrust and fuel consumption**
- **Pressure losses and ratios**
- **Thermal, propulsive, isentropic and mechanical efficiencies**
- **Work and power**
- **Thrust with and without reheat**
- **How the variable area nozzle affects thrust**

A self-contained, fully instrumented, educational single-shaft gas turbine with reheat. Powered by kerosene, the experimental abilities of this high-quality apparatus enable comprehensive practical investigations into the principles, and performance of single-shaft gas turbines with reheat.

This product helps students to understand the use of this 'engine' with additional exhaust nozzle control, on practical applications such as jet aircraft.

A steel frame holds a gas generator, combustion chamber, oil and fuel tanks, pumps, ancillaries and guards. Above these is an instrumentation and control panel with schematic diagram. The clearly labelled control panel with mimic diagram includes the instrument displays, controls and warning lights.

Air passes into an air box, through a calibrated nozzle into a compressor, then into the combustion chamber. A pump transfers fuel from the fuel tank to spray through a special nozzle into the combustion chamber. A high-energy spark ignites the air and fuel mixture, that flows to a radial flow turbine, then to the reheat section. This increases the temperature and velocity of the gas. It then passes through a variable area propelling nozzle. The exhaust gases then discharge to a suitable exhaust system. The combustion chamber gives excellent combustion, low pressure loss and good flame stability over a wide range of conditions. A fuel flow control valve on the instrumentation and control panel regulates the turbine speed. This design reduces the possibility of overspeed. A separate control adjusts the fuel flow to the reheat section. A second high-energy spark in the reheat section ignites the reheat fuel. This creates a

secondary burn (or afterburn), using some of the remaining oxygen in the hot exhaust gases leaving the turbine.

The equipment has an oiling system including filters and water-cooled oil.

A PLC (programmable logic controller) controls the turbine start up and shut down. For protection of the equipment and user, it shuts down the turbines if the user makes an error. It also switches on cooling fans after running.

Digital and analogue indicators show all the important readings from the sensors around the equipment, such as pressures, temperatures, fuel flow and level.

This equipment connects to your computer (computer not supplied) and includes dedicated, user-friendly data acquisition software. This allows students to display, graph and analyse all relevant variables, and save their results for later analysis. The data acquisition system includes adaptors and leads, and the software is supplied on CD-ROM.

Supplied with the equipment is a detailed textbook that covers the theory and use of gas turbines.

Recommended Ancillary:

- Suitable computer

Alternative Products:	Page
• Turbojet Trainer (GT100)	293
• Two-Shaft Gas Turbine (GT185)	296

Two-Shaft Gas Turbine (GT185) ADA

Allows detailed experiments that show how a two-shaft gas turbine works, and tests its performance

- Uses industrial parts, powered by kerosene for realistic tests and results
- Fully interlocked starting procedure and automatic shut-down
- Automatic Data Acquisition (ADA) included (supplied with software)
- Direct-coupled (no belts) eddy current dynamometer for accurate loading, speed control and true shaft power measurement
- Well proven design – versions installed in universities, technical colleges and military training establishments in 30 countries worldwide

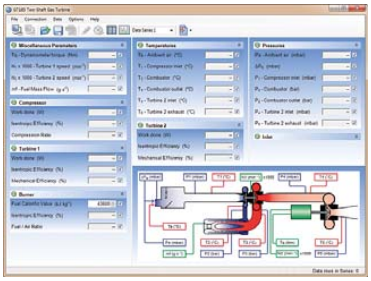
EXPERIMENTS:

Turbine tests to find key performance information such as:

- **Specific fuel consumption**
- **Pressure losses and ratios**
- **Thermal, isentropic and mechanical efficiencies**
- **Work and power**

Combustion chamber:

- **Pressure loss**
- **Combustion efficiency**
- **Air and fuel ratio**



Screenshot of the GT185 software

A self-contained, fully instrumented, educational two-shaft gas turbine. Powered by kerosene, the experimental abilities of this high-quality apparatus enable comprehensive practical investigations into the principles, and performance of two-shaft gas turbines.

This product helps students to understand the use of this 'engine' with a secondary power turbine, on practical applications such as helicopters or electrical power generators.

A steel frame holds a gas generator, power turbine, combustion chamber, oil and fuel tanks, pumps, ancillaries and guards. Above these is an instrumentation and control panel with schematic diagram. The clearly labelled control panel with mimic diagram includes the instrument displays, controls and warning lights.

Air passes through a calibrated nozzle and air box, into a compressor, then into the combustion chamber. A pump transfers fuel from the fuel tank to spray through a special nozzle into the combustion chamber. A high-energy spark ignites the air and fuel mixture, that flows to a gas generator turbine. The combustion chamber gives excellent combustion, low pressure loss and good flame stability over a wide range of conditions. A fuel flow control valve on the instrumentation and control panel regulates the turbine speed. This design reduces the possibility of overspeed.

Hot gas from the gas generator turbine passes through a short duct to the power turbine. The short duct reduces heat losses to atmosphere. The exhaust gases then discharge to a suitable exhaust system.

The power turbine couples direct to an eddy current dynamometer, so there are no belts to adjust. A load cell on the dynamometer measures torque and a sensor measures the dynamometer speed, to allow calculation of true shaft

power. A control on the instrumentation and control panel adjusts the load of the dynamometer (and therefore speed of the power turbine).

The equipment has an oiling system including filters and water-cooled oil.

A PLC (programmable logic controller) controls the turbine start up and shut down. For protection of the equipment and user, it shuts down the turbines if the user makes an error. It also switches on cooling fans after running.

Digital and analogue indicators show all the important readings from the sensors around the equipment, such as pressures, temperatures, fuel flow and level.

This equipment connects to your computer (computer not supplied) and includes specialist, user-friendly data acquisition software. This allows students to display, graph and analyse all relevant variables, and save their results for later analysis. Supplied on a CD-ROM, the data acquisition system includes a connection cable.

TecQuipment supply a detailed textbook with the equipment. The textbook covers the theory and use of gas turbines.

Recommended Ancillary:

- Suitable computer

Alternative Products:	Page
• Turbojet Trainer (GT100)	293
• Turbojet Trainer with Reheat (GT100RS)	294

Have you seen the following?

These products also cross over into the subject of thermodynamics – please turn to the Fluid Mechanics section for full details.

Works with VDAS®

Reciprocating Compressor Module (MFP104) – Page 147

Allows students to study and perform tests on a reciprocating compressor, to understand how it works and calculate its performance

Screenshot of the optional VDAS® software

Centrifugal Compressor Module (MFP105) – Page 148

Allows students to study and perform tests on a centrifugal compressor, to understand how it works and calculate its performance

Screenshot of the optional VDAS® software

Two-Stage Compressor Test Set (GT103)

Shows how single and two-stage compressors work, and their thermodynamic properties

- Works as single-stage, two-stage or two-stage intercooled compressor
- Independently controlled compressor units, both with variable-speed dynamometer drives
- Clear, fully-instrumented control panel with mimic diagram
- Completely fail-safe operation – interlocks and pressure-relief valves prevent misuse

EXPERIMENTS:

A range of experiments and tests based on:

- **Volumetric, mechanical and isothermal efficiency**
- **Indicated work done**
- **Motor output power (compressor shaft power)**
- **Pressure ratio**
- **Temperature ratio**
- **Inlet dryness calculations**
- **P-V indicator diagram (needs optional pressure indicator)**
- **Effect of inter-stage cooling on compressor total power requirements and effect on cycle temperatures**
- **Effect of two-stage compression and inter-stage pressure on power requirements**

This test set has two independently-controlled, motor-driven compressors, intercooler and air receiver. It works as a single-stage, two-stage or two-stage compressor with intercooler. All controls and instrumentation are on an easy-to-operate mimic panel.

Electric motors and low-maintenance toothed belts drive two twin-cylinder, air-cooled reciprocating compressors.

Electronic drive units independently control both motors. Meters show motor electrical power consumption of each motor. A close-coupled load cell on each motor measures torque. A sensor on each motor measures speed, shown by a digital indicator. The product of the torque and speed gives true shaft power.

To allow students to study different types of air compressor systems, diverter valves allow air to move in different directions. These include:

- From the first stage to the receiver
- Directly to the second stage
- To the second stage, by means of the integral water-cooled intercooler

Independent control of the two compressor speeds allows flexibility to match the two compressors under different conditions. Interlocks allow safe changes from one method of operation to another while the equipment works, and prevent misuse. For safety, all pressurised lines have relief valves.

To help produce pressure and volume diagrams, TecQuipment offers the optional Pressure Indicator (GT103a). It fits to an adaptor on each of the two compressors to measure the pressure changes during a compression cycle. One pressure indicator is enough to test each compressor, one at a time. However, you may choose to use two for convenience.

Recommended Ancillary:

- Pressure Indicator (GT103a)

Note: You need a modern computer with a spare USB 2.0 socket to setup and analyse the pressure indicator results.

Alternative Product:

Page

- Reciprocating Compressor Module (MFP104) 147